Individual Structures
Assessment Report

Spook Hill FRS
Signal Butte FRS
Apache Junction FRS

Structures Assessment Program - Phase 1

Prepared for
Flood Control District of Maricopa County
April 2001
FCD No. 98-41/PCN PLAN.01.00

Prepared by
Kimley-Horn and Associates, Inc.

APACHE JUNCTION FRS

Potential Failure Mode:

Adverse Factors	**Positive Factors**	**Facts**

Notes:

APACHE JUNCTION FRS

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STRUCTURES ASSESSMENT PROGRAM – PHASE I

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

Spook Hill FRS
Signal Butte FRS
Apache Junction FRS

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY
FCD 98-41
PCN PLAN.01.00

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April 2001

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

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INDIVIDUAL STRUCTURES ASSESSMENT REPORT

ACKNOWLEDGEMENTS

ACKNOWLEDGMENTS

Kimley-Horn and Associates, Inc. (KHA) on behalf of the Flood Control District of Maricopa County, extends our collected gratitude and appreciation to all the dam safety agency representatives, staff, individuals, and subconsultants for their review, knowledge, and experience into assisting in making this Individual Structures Assessment Report and the Structures Assessment Program a highly successful endeavor.

Kimley-Horn particularly wishes to thank the Steering Committee and Technical Committee for their valued input and guidance to the Structures Assessment Program.

The Steering Committee for the Structures Assessment Program consisted of Federal dam safety agency representatives, Arizona Department of Water Resources- Dam Safety Section, and District division chiefs from Engineering, Planning & Project Management, and Operations and Maintenance. The Steering Committee served in an advisory capacity to the District's project manager and Kimley-Horn and Associates concerning the major findings and recommendations of Phase I of the program. The Steering Committee members are as follows:

- Natural Resources Conservation Service – Mr. Noller Herbert, P.E., State Conservation Engineer, Phoenix, Arizona.
- U.S. Army Corps of Engineers, Los Angeles District – Mr. George Beams, P.E., Director of Engineering and Dam Safety Officer, Los Angeles, California
- Bureau of Reclamation – Mr. Dean Hagstrom, Phoenix, Arizona
- Arizona Department of Water Resources, Dam Safety Section – Mr. Jon Benoist, P.E., Chief of Dam Safety, Phoenix, Arizona
- Flood Control District of Maricopa County
    - Chief of Engineering Division – Mr. Ed Raleigh, P.E.
    - Chief of Planning and Project Management – Mr. Tom Johnson, P.E.
    - Chief of Operations and Maintenance – George Lindop

The Technical Committee served in a technical capacity to the District's project manager and Kimley-Horn and Associates concerning the major findings and recommendations of Phase I of the program. The Technical Committee members are as follows:

- Natural Resources Conservation Service – Mr. Noller Herbert, P.E., State Conservation Engineer, Phoenix, Arizona.
- U.S. Army Corps of Engineers, Los Angeles District – Mr. Ted Ingersoll, P.E.
- Bureau of Reclamation – Mr. Dean Hagstrom, Phoenix, Arizona
- Arizona Department of Water Resources, Dam Safety Section – Mr. Mike Greenslade, P.E., Phoenix, Arizona.
- Flood Control District of Maricopa County
    - Planning and Project Management – Mr. Tom Renckly, P.E., Project Manager for the Structures Assessment Program
    - Engineering – Mr. Joe Tram, P.E., Special Projects Branch Manager

- Operations and Maintenance – Chuck Smith

Kimley-Horn and Associates acknowledges the important contribution of our subconsultant for this report. URS-Greiner/Woodward Clyde and Associates (Mr. John Sikora, Denver, Colorado) provided technical review and assistance in regards to dam engineering and dam technologies. . Geological Consultants (Mr. Ken Euge, Phoenix, Arizona) provided local geological and geotechnical expertise in regards to subsidence, earth fissures, and seismic issues. Both subconsultants provided valuable input into state-of-the-art dam safety programs, policies, and procedures.

Kimley-Horn and Associates, Inc. (Phoenix, Arizona) project team members are as follows:

- Principal/Senior Project Manager (QA/QC) – Doug Plasencia, P.E.
- Project Manager and principal technical writer – Robert Eichinger, P.E.
- Senior Engineer – Daniel Sagramoso, P.E.
- Project Engineers and research– Mr. Brian Brennan, EIT and Diana Davisson, EIT

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

EXECUTIVE SUMMARY

STRUCTURES ASSESSMENT PROGRAM – PHASE I FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

EXECUTIVE SUMMARY

1.0 Introduction

This Individual Structures Assessment (ISA) Report documents the results of technical evaluations and field examinations for three of the twenty-two Flood Control District of Maricopa County (District) flood control dams. The three dams investigated as part of this project were the Spook Hill, Signal Butte, and Apache Junction Flood Retarding Structures. The ISA Report is part of Phase I of the Structures Assessment Program, as outlined below. The technical evaluation of the three dams consisted of engineering, geological and geotechnical reviews of structure historical reports and documents. The types of documents reviewed included original and subsequent design and analyses such as hydrology and hydraulic studies of the dams, foundation reports, boring logs, seismic studies, subsidence and earth fissure evaluations, construction plans (design and as-builts) and construction specifications, and any documents pertaining to repairs, modifications, or upgrades to the structures. Detailed visual field examinations were conducted for each of the three structures and associated features. The purpose of the field examinations was to assist in the systematic technical evaluation of the structure and operational adequacy of the dam project features and to determine if signs of distress exist at the dam and appurtenant features. The ISA report provides recommendations for each structure regarding work plans and actions for future engineering studies and dam safety repairs or modifications.

2.0 Structures Assessment Program

In recognition and realization of the changes occurring and associated with flood control dams both on the national and local level, the Flood Control District of Maricopa County (District) has embarked on the **Structures Assessment Program**, the purpose of which is to minimize the risk and liability associated with the District's flood control dams. Since many of the District dams were built, there have been a number of changes, which now need to be addressed. These changes are:

- District dams have aged and some are showing signs of distress,
- Significant urbanization within Maricopa County and adjacent to District dams has occurred and continues at a rapid pace,
- Changes in dam technology and design practices,
- Changes in methodology for determining inflow design flood,

- Significant increase in permit requests for utility and roadway crossings of dams,
- Rule changes by the Arizona Department of Water Resources, and,
- Subsidence impacts on District dams due to groundwater pumping.

The Structures Assessment Program will address and assess the District's dam safety program on several fronts including:

- Dam safety inspections/evaluations,
- Emergency Action plans,
- Impoundment areas and spillway channels,
- Improvements to the overall dam safety program,
- Impacts of future dam safety rules and regulation changes,
- Planning studies to evaluate project options, and
- Flood Control District policy evaluation.

The Structures Assessment Program will be conducted in three phases. Phase I will primarily involve:

- Collection of data and inspection of dams,
- Develop dam safety recommendations and priorities, considering changes listed above,
- Perform preliminary alternative analysis studies to modify existing projects to address urbanization related issues, and,
- Evaluate newly enacted ADWR rule changes and District policy issues.

Phase II will primarily involve:

- Perform detailed investigations and analyses as identified by need and priority in Phase I,
- Initiate project planning and authorization activities to correct identified distress issues,
- Implement changes to overall dam safety program and policies, and,
- Perform conceptual design studies and alternative analyses for modification of projects to address urbanization and distress issues.

Phase III will primarily involve:

- Implement projects to correct any identified dam safety concerns. These could include things like structural modifications, land acquisitions below spillways, and alternative, lower risk solutions,
- Implement approved projects and land acquisitions to address urbanization issues, and,
- Continue long-term dam safety program.

Phase I of the Structures Assessment Program will primarily be an evaluation and study phase. The District has retained Kimley-Horn and Associates to provide services to conduct Phase I evaluations and studies. This second work assignment will focus on three District dams. Evaluations and studies performed for these dams will initiate the Phase I process for these dams. The dams evaluated in the second work assignment were the Spook Hill Flood Retarding Structure (FRS), the Signal Butte Flood Retarding Structure, and the Apache Junction Flood Retarding Structure. This separate ISA report documents the evaluation and assessment of these three dams.

A Technical Committee was formed at the inception of Phase I and served in a technical advisory capacity to the District's project manager concerning the major findings and recommendations of Phase I of the program. The technical committee consists of representatives of the District's planning, engineering, and operations functions, Arizona Department of Water Resources Dam Safety Section, Natural Resources Conservation Service, Corps of Engineers, and Bureau of Reclamation. The technical committee will review the full ISA report and provide their input, technical comments, guidance, and experience.

This Executive Summary of the ISA Report provides a summary of the project features for each of the three District dams examined in this report, summarizes the results of the technical evaluation and field examinations for each dam, and provides the recommendations for further/future District actions to upgrade, enhance, modify, or repair signs of distress at the dams.

The purpose of the Individual Structures Assessment Report is twofold: (1) to assess the present condition of the three structures and, (2) to recommend actions for further investigations/monitoring of the structures and develop work plans to repair signs of distress in the structures.

3.0 Spook Hill Flood Retarding Structure (NATDAM ID AZ00175; STATE ID 07.5)

The Spook Hill Flood Retarding Structure (FRS) is a structural plan element of the Watershed Work Plan for the Buckhorn-Mesa Watershed, Maricopa and Pinal Counties, Arizona. The Watershed Work Plan was prepared by the Natural Resources Conservation Service (NRCS; formerly the Soil Conservation Service, SCS) in January 1963. The watershed heads in the southwest-facing slopes of the Superstition Mountains and drains onto a wide alluvial fan on which valuable agricultural, urban and commercial developments have been constructed. The watershed is one of three for which concurrent planning efforts were conducted by the NRCS at the request of the District. The northernmost watershed is the "Buckhorn-Mesa", the central watershed is the "Apache Junction – Gilbert", and the southern watershed is the "Williams-Chandler".

Spook Hill FRS is located within the City of Mesa. The FRS parallels the Central Arizona Project canal and begins 1/2 mile north of McDowell Road (at Power Road) and ends at 1/4 mile south of Brown Road and 1/4 mile east of Hawes Road. The FRS is about 22 miles east of downtown Phoenix and approximately eight miles west of the City of Apache Junction. The project consists of the FRS structure, principal spillway, and an emergency spillway.

Spook Hill FRS is a rolled zoned earthfill structure. The length of the FRS is 21,712 feet with a maximum height of 23 feet and a crest width of 14 feet. The reservoir capacity is

900 acre-feet at the emergency spillway crest elevation of 1582.0. The reservoir capacity is approximately 4,000 acre-feet at a maximum water surface elevation of 1591.0 feet. The FRS was designed with 6.3 feet of freeboard (top of dam minus maximum water surface) and 317 acre-feet of sediment storage (100-year). Spook Hill FRS is accessible off Brown Road by a padlocked gate. The maximum recorded impoundment for Spook Hill reservoir is 80 acre-feet with a stage of 6.74 feet at the FRS (January 11, 1993).

The principal spillway, approximately 60 feet long, consists of a gated 7-ft 6-in by 7-ft 0-in concrete box with an uncontrolled overflow at elevation 1577.5 feet. The design outflow is approximately 808 cfs from the principal spillway. The trash rack is located on the upstream inlet gatewell assembly. The gatewell assembly has a 24-in by 24-in slide gate. The outlet of the principal spillway discharges into a tapered sloped-bottomed energy dissipator. The outlet discharges to the Spook Hill Floodway (another structural element of the Buckhorn-Mesa Watershed Project). The Floodway eventually discharges through a sediment basin near the Salt River and then into the Salt River.

The emergency spillway is a reinforced concrete drop structure and is located near the principal spillway and 925-ft from the north (right) abutment of the FRS. The spillway is 260-ft wide with a discharge capacity of 4,800 cfs at maximum water surface elevation of 1584.7 feet. The emergency spillway crest elevation is 1582.0-feet.

Technical Review - Spook Hill FRS was originally analyzed and designed by the NRCS in the early to mid-1960's. The hydrology for the structure has been updated several times in the late 1970's and mid-1980's by the NRCS to account for planning considerations for the Buckhorn-Mesa structures (flood retarding structures and floodways). The basis of design for the FRS was originally founded in the NRCS publication "Engineering Memorandum EM-27" which is the precursor manual to "Technical Release TR-60: Earth Dams and Reservoirs" the present NRCS design guideline for earth dams. The FRS has been analyzed and designed according to TR-60.

Spook Hill FRS was designed to control the 100-year event using NRCS criteria. This design event was used to size the principal spillway and reservoir volume. The hydrology for the emergency spillway design and freeboard design flood is discussed below in the Hydrology section following NRCS criteria.

According to ADWR criteria, the Spook Hill FRS Inflow Design Flood (IDF) for emergency spillway capacity is the ½ probable maximum flood (PMF). Current (June 2000) ADWR regulations could change the size classification of the dam. The new size classification combined with the hazard classification could require that the IDF be changed. The IDF could be changed to be between the ½ PMF and the full PMF, or to the full PMF. The NRCS, in their hydrologic study of Spook Hill FRS, have designed the dam not to overtop during the passage of the freeboard hydrograph, which was based on the full PMP/PMF.

The NRCS classifies Spook Hill FRS as a Class C structure. Class C structure are structures located where failure may cause loss of life, serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads. The Arizona Department of Water Resources rules and regulations for jurisdictional dams classifies Spook Hill FRS as a high hazard, small size dam.

A review of the NRCS documentation revealed that the apparent design precipitation for the Spook Hill FRS for the 100-year, 24-hr storm is 3.81-in; for the Emergency Spillway Hydrograph (ESH) - a depth of 5.6-in; and for the Freeboard Hydrograph (FBH) - a depth (PMP) of 13.0-in (for a drainage area of 13.56 square miles and an emergency spillway width of 260-ft). The NRCS peak inflow for the full PMP into Spook Hill FRS is approximately 21,000 cfs with an outflow discharge of 18,340 cfs. The PMF will not overtop the structure according to the NRCS studies.

The District has conducted several hydrologic and hydraulic studies as part of emergency management for the dam and downstream areas. These studies include dambreak analyses of the dam and spillway inundation studies that examines the downstream flooding limits due to emergency spillway releases.

Due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment, subsidence due to groundwater withdrawal is not expected to be an issue at the Spook Hill FRS. It appears that the Spook Hill FRS is located on the Usery Mountain granitic pediment with bedrock ranging in depth from the surface to a relatively shallow depth of 23 feet beneath the FRS structure.

Due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment on which the Spook Hill FRS is founded, earth fissuring should not be a issue. The nearest ground subsidence-related earth fissure is about two and one-half miles south of the south end of the FRS.

The Spook Hill FRS is located near an area of active ground subsidence and earth fissures. However, due to the presence of shallow granite pediment in the FRS area, earth fissuring is not expected to impact the Spook Hill FRS. Likewise, ground subsidence at the FRS is expected to be negligible. The Spook Hill FRS should be included in an area-wide monitoring program because of its proximity to the ground subsidence area and associated earth fissures.

Post-construction level surveys have been conducted at the Spook Hill FRS in 1979, 1984, 1987, and 1998. The records indicated, when compared to the design crest elevation, negligible settlement has occurred at the Spook Hill FRS. A comparison of crest elevation data with the level survey conducted in 1998 show the possible settlement to range from 0.047 feet to 0.43 feet below design crest elevation while Stations 170+00 and 190+00 show the embankment has heaved from 0.14 to 0.317 feet (Gilbertson & Associates, 1998).

Construction of the Spook Hill FRS was accomplished under contract to Mardian Construction Company. The completion date of the construction of the dam and landscape treatment is April 10, 1980. Construction observation reports are available for this dam and include observation reports by ADWR. A review of the project as-built plans indicated no significant changes were made to the dam design during construction. Typical dam cross sections show the embankment was constructed symmetrically with respect to the dam centerline. The cutoff trench centerline was placed on the upstream side of the dam offset at a distance of 10 ft from the dam centerline.

Field Examination - Spook Hill FRS is inspected on an annual basis jointly by the Flood Control District and the Arizona Department of Water Resources. The next joint District/ADWR inspection is scheduled for December 2001.

Longitudinal cracks were observed on the crest of the dam during the July 2000 inspection. All cracks were less than 1/4-inch in width but varied in length from several feet to 30-ft. During the inspection, 10 longitudinal cracks were located. The location of these cracks were at the following stations: Sta. 97+05 (thin hairline cracks 30 ft. long); Sta. 102+00 (hairline crack, brushed to expose crack 1/8-inch wide); Sta. 116+00 (small crack, 10 inches long, 1/8-inch wide); Sta. 117+00 (4-inch long hole, 2-inch deep – possibly associated with crack); Sta. 128+50 (hairline crack 2 ft. long); Sta. 139+00 (small hole and 1/16-inch wide crack, found from previous ADWR – Nov. 1999 inspection); Sta. 186+56 (crack from Sta. 186+56 to 188+26); Sta. 188+26 (centerline crack ¼-inch wide, 20 ft. long); Sta. 201+65 (centerline hairline crack, 25 ft. long, probed 2.5 ft.); Sta. 284+10 (centerline crack with holes); Sta. 233+56 (hole 3' x 6" at surface, probed to 22" on downstream side of crest above erosion gully, suspect transverse crack). No obvious transverse cracks were observed. This is most likely due to the severity of the slope erosion, which make transverse crack detection difficult.

The upstream and downstream slopes of the embankment are currently undergoing erosion in the form of gullies and rills. Review of previous inspection reports has noted the severity of the gullies and rills. The depth of the gullies appears to extend below the 1-foot landscape soil layer that was constructed to establish vegetation on the slopes of the dam.

The following is a list of recommended corrective actions resulting from the field examination:

a. Continuing observation should be made of the above mentioned items (erosion of slopes, longitudinal and transverse cracking),
b. Evaluate erosion protection of upstream and downstream slopes (rock mulch).
c. Removal of large diameter abandoned PVC irrigation lines.
d. Station posts need to have signs on both sides of post facing both directions of travel.
e. Repair slope erosion gullies on downstream and upstream slopes. Remove landscaping terraces.
f. Video and photograph log the interior of the principal spillway conduit.
g. Develop a plan for the repair of transverse and longitudinal cracks.

h. Prepare a monitoring plan for tracking the locations of longitudinal and transverse cracks on as-built plans or similar method.

Recommendations for Further Actions/Investigations – Spook Hill FRS and it's sister dams (Signal Butte FRS and Apache Junction FRS) have been and mostly likely will be subject to continued transverse and longitudinal cracking. The cracking could be attributable to several factors including embankment desiccation, differential settlement, ground subsidence, or foundation conditions. A general crack repair plan has been prepared, however, for Spook Hill FRS, monitoring of the longitudinal cracks on the crest of the dam is recommended at this time as opposed to any repairs.

It is recommended that the slopes of the embankment for the Spook Hill FRS be repaired to correct severe erosion. A conceptual slope erosion work plan has been prepared and is included in the full ISA Report. The work plan summarizes the engineering and construction phases for repair of the slopes. Basically, plans would be prepared that provide a typical embankment section that includes embankment slopes of 2:1 upstream and 2:1 downstream. Protected flora would be containerized and replaced after the repair project.

It is recommended that a risk assessment be conducted for Spook Hill FRS. The risk assessment would examine failure modes and the effects/consequences of the failure. Failure modes that potentially could occur at Spook Hill FRS include breach failure by piping, or piping along a transverse crack.

It is recommended that an evaluation be conducted to examine the need for a transition filter (and finger drains) along the longitudinal centerline embankment and key the filter into the foundation. This recommendation is based on the design and construction of transition filters for other NRCS earth embankment dams in Maricopa County. Based on the review of records, embankment cracking was not factored into nor considered in the original embankment design.

Although limited slope stability analyses were conducted by the NRCS (SCS), KHA recommends that a slope stability analysis of the exiting dam embankment under various loading conditions be conducted. The stability analysis can be used with a computer model such as UTEXAS3. The results of the study will provide factors of safety for the embankment given the loading conditions anticipated and can be compared against ADWR rules and ADWR recommended factors of safety for embankment dams.

A hydrologic/hydraulic analysis of Spook Hill FRS should be conducted to confirm that the dam provides greater than 100-year flood protection. The District completed a capacity analysis of the reservoir and found that the dam and reservoir could have a greater capacity than originally designed. It is also recommended that a restudy of the 100-year sediment yield to the impoundment be conducted. A potential reduction in the sediment yield to the dam from the contributing watershed could provide increased flood storage capacity. A recommendation is to conduct a site specific PMP for this watershed prior to reevaluating the hydrology and hydraulics of the dam. A site specific PMP will evaluate storm centering on the watershed and storm distribution.

An Incremental Damage Analysis (IDA) could also be performed on this structure. The purpose of an IDA analysis is to estimate if there would be additional damage to downstream structures if the dam were to fail during a large storm event over no structure in place and a large flood event occurring within the watershed.

A detailed inspection procedure, settlement monitoring procedure, earth fissure and subsidence monitoring procedure, and recommended operation and maintenance improvements for all District dams were provided in the previous report titled "Policy and Program Report".

It is recommended that a utility database be prepared for Spook Hill FRS. The structure has several utility crossings through, under, or over the embankment. The database should include at a minimum the type of utility, location of utility crossing, owner of utility, cross-reference to utility crossing construction plans, and measures to control piping and seepage.

Conclusions - The overall conclusion of the field examination is that the FRS and appurtenant structures are in satisfactory operational condition.

4.0 Signal Butte Flood Retarding Structure (NATDAM ID AZ00205; STATE ID 07.6)

The Signal Butte FRS is a structural plan element of the Watershed Work Plan for the Buckhorn-Mesa Watershed, Maricopa and Pinal Counties, Arizona. The Watershed Work Plan was prepared by the Natural Resources Conservation Service (NRCS; formerly the Soil Conservation Service, SCS) in January 1963. The watershed heads in the southwest-facing slopes of the Superstition Mountains and drains onto a wide alluvial fan on which valuable agricultural, urban and commercial developments have been constructed. The watershed is one of three for which concurrent planning efforts were conducted by the NRCS at the request of the District. The northernmost watershed is the "Buckhorn-Mesa", the central watershed is the "Apache Junction – Gilbert", and the southern watershed is the "Williams-Chandler".

Signal Butte FRS is located within the City of Mesa. The FRS begins west of Meridian Road and north of Brown Road. The FRS is about 28 miles east of downtown Phoenix and approximately 3 miles west of the town of Apache Junction. The project consists of the FRS structure, principal spillway and an emergency spillway.

Signal Butte FRS is a rolled earthfill structure. The length of the FRS is 7,022 feet with a maximum height of 38.5 feet and a crest width of 18 feet. The reservoir capacity is 1,365 acre-feet at the emergency spillway crest of 1712.4 ft. The reservoir total capacity is approximately 2,750 acre-feet at the dam crest elevation of 1721.0 ft. The FRS was designed with 4.8 feet of freeboard and 175 acre-feet of sediment storage (100-year).

Signal Butte FRS is accessible off Meridian Road by a padlocked gate. The maximum recorded impoundment for Signal Butte reservoir is 166 acre-feet with a stage of 13.7 feet at the FRS (January 11, 1993).

The principal spillway is an ungated 36-inch diameter concrete pipe approximately 147 feet long. The design outflow is 160 cfs from the principal spillway. The trash rack is located on the upstream inlet. The outlet of the principal spillway discharges into a constructed channel through an outlet structure. A standard impact basin (energy dissipator) is located on the downstream end of the concrete outlet structure.

The emergency spillway is a reinforced concrete baffle block structure and is located adjacent to the left abutment of the FRS and 1000-ft from Meridian Road. The spillway is approximately 140 feet wide with a capacity of 2,450 cfs. The spillway crest elevation is 1712.4 feet.

Technical Review - Signal Butte FRS was analyzed and designed by the NRCS in the early to mid-1960's. The basis of design for the FRS was founded in the NRCS publication "Technical Release TR-60: Earth Dams and Reservoirs".

Signal Butte FRS was designed to control the 100-year event using NRCS criteria. This design storm was used to size the principal spillway, set the emergency spillway crest elevation, and reservoir volume.

According to ADWR criteria, the Signal Butte FRS Inflow Design Flood (IDF) for emergency spillway capacity is the ½ PMF. Current (June 2000) ADWR regulations could change the size classification of the dam. The new size classification combined with the hazard classification could require that the IDF be changed. This IDF could be changed to between the ½ PMF and the full PMF. The NRCS, in their hydrologic study of Signal Butte FRS, has designed the dam not to overtop during the passage of the freeboard hydrograph, which was based on the full PMP/PMF.

The Arizona Department of Water Resources rules and regulations for jurisdictional dams classifies Signal Butte FRS as a high hazard, small size dam. NRCS classifies Signal Butte FRS as a Class C structure.

The original construction of the embankment was completed in July 1987 by Pulice Construction. The left abutment or east end of the Signal Butte FRS was extended in December 1988 to tie the end of the dam to the left dike of the Bulldog Floodway. The purpose of the extension was to provide containment of flood flows from Bulldog Floodway into the impoundment area for the Signal Butte FRS.

Note that Signal Butte FRS was not constructed with a central longitudinal filter as was done on several other NRCS structures in the vicinity of Signal Butte (e.g., Apache Junction FRS, Powerline FRS, Vineyard Road FRS, and Rittenhouse FRS). An HDPE curtain was constructed in-lieu of the central transition filter.

There have been no reports of observations of embankment cracking at Signal Butte FRS. The reason significant cracking has not been observed at the Signal Butte FRS embankment is thought to be because the external forces, that have initiated cracks in the other embankments, have not been realized by the Signal Butte embankment. The main reasons that this embankment does not exhibit major cracking such as Vineyard Road, Rittenhouse, and Powerline structures is two fold: (1) the dam foundation and, (2) the cutoff trench has been centered within the dam. Probably the largest factors in not observing the significant embankment cracking in this structure are the proximity to the dam foundation to the hard caliche layer, the shallow underlying granite pediment, and the absence of compressible soil layers along the entire length of the embankment. This results in less differential regional subsidence and minimizes the potential for settlement of the native materials between the dam foundation and the caliche layer.

Desiccation cracking still may be an issue for this embankment and the HDPE liner was installed to minimize loss of water (seepage) and/or piping of embankment material through transverse cracks, should cracks develop. Desiccation cracking will tend to be more "superficial" cracking than settlement cracking. Settlement cracks from differential movement could potentially tear the HDPE liner and lead to distress in the embankment.

A review of the NRCS documentation revealed that the apparent design precipitation for the Signal Butte FRS for the 100-year, 24-hr storm is 4.05-in; for the ESH - a depth of 7.07-in; and for the FBH - a depth (PMP) of 15.8-in (for a drainage area of 10.27 square miles and an emergency spillway width of 140-ft). The emergency spillway crest elevation used in the DAMS2 model is 1712.4-ft, which is the same elevation depicted on the as-built construction plans and the elevation-discharge rating curve for Signal Butte. The maximum water surface elevation for the ESH and FBH in the DAMS2 model was 1715.7-ft and 1720.0-ft, respectively. The peak discharges from the emergency spillway for the ESH and FBH are 2,450-cfs and 11,300-cfs, respectively.

The District has conducted several hydrologic and hydraulic studies as part of emergency management for the dam and downstream areas. These studies include dambreak analyses of the dam and spillway inundation studies that examines the downstream flooding limits due to emergency spillway releases.

Due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment, subsidence due to ground-water withdrawal is not expected to be an issue at the Signal Butte FRS. It appears that, like the Spook Hill FRS, the Signal Butte FRS is located on the Usery Mountain granitic pediment with bedrock at a relatively shallow depth (probably less than 200 feet) beneath the FRS structure.

Due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment on which the Signal Butte FRS is founded, earth fissuring should not be an issue. The nearest ground subsidence-related earth fissure is about two and one-half miles southwest of the Signal Butte FRS on the east site of Double Knoll Hill near the intersection of the Apache Trail at 85th Street.

The Signal Butte FRS is located near an area of active ground subsidence and earth fissures. However, due to the presence of shallow granite pediment in the FRS area and the FRS's proximity to the pediment edge, earth fissuring should have minimal impacts on the Signal Butte FRS. Ground subsidence at the FRS is expected to be negligible. However, the Signal Butte FRS should be included in an area-wide monitoring program because of its proximity to the ground subsidence area and known earth fissures.

Two post-construction level surveys have been conducted at the Signal Butte FRS. According to the records indicated, when compared to the design crest elevation, negligible settlement has occurred at the Signal Butte FRS. The maximum settlement was plus 0.07 feet with minimum elevation change of 0.15 feet below the design crest elevation.

Field Examination - Signal Butte FRS is inspected on an annual basis by Flood Control District personnel. The Arizona Department of Water Resources conducts annual inspections of Signal Butte FRS. The latest ADWR and District inspection was conducted in December 2000. The next annual inspection is scheduled for December 2001. Kimley-Horn inspected the structure in July, 2000.

No longitudinal or transverse cracks were observed during the field inspection conducted in July 2000. The embankment slopes showed only minor erosion rills.

The following is a list of recommended corrective actions resulting from this field examination:

i. Continuing observation should be made of erosion of slopes.
j. Station posts need to have signs on both sides of post facing both directions of travel.
k. Monitor and repair when necessary erosion rills on the upstream and downstream face.
l. Video and photograph log the interior of the principal spillway conduit.
m. Monitor for transverse and longitudinal cracks. Establish crack monitoring program.

Recommendations for Further Actions/Investigations - Signal Butte FRS and it's sister dams (Spook Hill FRS and Apache Junction FRS) have been and most likely will be subject to transverse and longitudinal cracking. The cracking could be attributable to several factors including embankment desiccation, differential settlement, ground subsidence, or foundation conditions. A general crack repair plan has been prepared, however, for Signal Butte FRS, monitoring of the longitudinal and transverse cracks is recommended at this time as opposed to repair.

It is recommended that a risk assessment be conducted for Signal Butte FRS. The risk assessment would examine failure modes and the effects/consequences of the failure. Failure modes that potentially could occur at Signal Butte FRS include breach failure by piping, or piping along a transverse crack. The risk assessment could evaluate the failure mode and effects of the HDPE liner to prevent seepage or piping through the embankment.

A hydrologic/hydraulic analysis of Signal Butte FRS should be conducted based on District methods to confirm that the dam provides greater than 100-year flood protection. The District completed a capacity analysis of the reservoir and found that the dam and reservoir could have a greater capacity than originally planned. It is also recommended that a restudy of the 100-year sediment yield to the impoundment be conducted. A potential reduction in the sediment yield to the dam from the contributing watershed could provide increased flood storage capacity. A recommendation is to conduct a site specific PMP for this watershed prior to reevaluating the hydrology and hydraulics of the dam. A site specific PMP will evaluate storm centering on the watershed and storm distribution.

An Incremental Damage Analysis (IDA) could also be performed on this structure. The purpose of an IDA analysis is to estimate if there would be additional damage to downstream structures if the dam were to fail during a large storm event over no structure in place and a large flood event occurring within the watershed.

It is recommended that a slope stability analysis be conducted for Signal Butte, Spook Hill, and Apache Junction flood retarding structures. The stability analysis will evaluate the embankments (upstream and downstream fills). The results of the analysis can provide factors of safety of the structures under various hydraulic loading conditions and compare the results of the analysis with the original design and the current ADWR recommended factors of safety for embankment dams. Computer programs, such as UTEXAS3, are suitable for such an analysis.

A detailed inspection procedure, settlement monitoring procedure, earth fissure and subsidence monitoring procedure, and recommended operation and maintenance improvements for all District dams were provided in the previous report titled "Policy and Program Report".

It is recommended that a utility database be prepared for Signal Butte FRS. The structure has several utility crossings through, under, or over the embankment. The database should include as a minimum the type of utility, location of utility crossing, owner of utility, cross-reference to utility crossing construction plans, and measures to control piping and seepage.

Conclusions - The overall conclusion of the field examination is that the Signal Butte FRS and appurtenant structures are in satisfactory operational condition.

5.0 Apache Junction Flood Retarding Structure (NATDAM ID AZ00211; STATE ID 11.15)

The Apache Junction FRS is a structural plan element of the Watershed Work Plan for the Buckhorn-Mesa Watershed, Maricopa and Pinal Counties, Arizona. The Watershed Work Plan was prepared by the Natural Resources Conservation Service (NRCS; formerly the Soil Conservation Service, SCS) in January 1963. The watershed heads in the southwest-facing slopes of the Superstition Mountains and drains onto a wide alluvial fan on which valuable agricultural, urban and commercial developments have been constructed. The watershed is one of three for which concurrent planning efforts were conducted by the NRCS at the request of the District. The northernmost watershed is the "Buckhorn-Mesa", the central watershed is the "Apache Junction – Gilbert", and the southern watershed is the "Williams-Chandler".

Apache Junction FRS is located within the City of Apache Junction. The FRS begins 1,200 ft west of Apache Trail and ends at 1/4 mile south of McKellips Road and 1/4 mile west of Idaho Road. The FRS is about 30 miles east of downtown Phoenix and approximately one mile north of the City of Apache Junction. The project consists of the FRS structure and an emergency spillway.

Apache Junction FRS is a rolled earthfill structure. The length of the FRS is 8,764 feet with a maximum height of 22 feet and a crest width of 14 feet. The reservoir capacity is 540 acre-feet at a water surface elevation of 1799.77(emergency spillway crest elevation). The total capacity is approximately 2,000 acre-feet at a dam crest elevation of 1810.0 ft. The FRS was designed with 10 feet of freeboard and 95 acre-feet of sediment storage (100-year). Apache Junction FRS is accessible off Apache Trail by a padlocked gate. The maximum recorded impoundment for Apache Junction reservoir is 15 acre-feet with a stage of 4.76 feet at the FRS (July 23, 1993).

The principal spillway is an ungated 30-inch diameter concrete pipe approximately 137 feet long. The design outflow is 97 cfs from the principal spillway. The trash rack is located on the upstream inlet. The principal spillway discharges into a constructed channel (Bulldog floodway) through an outlet structure and then discharges into the Signal Butter FRS.

The emergency spillway is a reinforced concrete baffle block structure and is located adjacent to the north (left) abutment of the FRS. The spillway is approximately 100 feet wide with a capacity of 1875 cfs. The spillway crest elevation is 1799.77 feet.

Technical Review - Apache Junction FRS was analyzed and designed by the NRCS in the early to mid-1960's. The basis of design for the FRS was founded in the NRCS publication "Technical Release TR-60: Earth Dams and Reservoirs".

Apache Junction FRS was designed to control the 100-year event using NRCS criteria. This design event was used to size the principal spillway and reservoir volume. The hydrology for the emergency spillway design and freeboard design flood is discussed below in the Hydrology section following NRCS criteria. According to ADWR criteria, the Apache Junction FRS Inflow Design Flood (IDF) for emergency spillway capacity is the ½ PMF. Current (June 2000) ADWR regulations could change the size classification of the dam. The new size classification combined with the hazard classification could require that the IDF be changed. This IDF could be changed from between the ½ PMF and the full PMF. The NRCS, in their hydrologic study of Apache Junction FRS, has designed the dam not to overtop during the passage of the freeboard hydrograph, which was based on the full PMP/PMF.

The Arizona Department of Water Resources rules and regulations for jurisdictional dams classifies Apache Junction FRS as a high hazard, small size dam. The NRCS classifies the Apache Junction FRS as a Class C structure.

The Ashton Company completed the original construction of the embankment in December 1988. The original construction of the embankment included the construction of a longitudinal centerline transition filter. The filter trench is 3.0-ft wide and extends from the bottom of the cut-off trench to 1.0-ft below the crest of the dam. The "as-built" filter trench was constructed deeper, approximately 2 to 4-ft deeper, from Stations 33+00 to 45+00, 55+00 to 60+00, and from 97+00 to 100+00. The transition filter was extended below the cut-off trench to the elevation of a communications conduit at Station 76+50. The filter was designed in response to embankment cracking at other NRCS structures located near the Apache Junction FRS. The NRCS and EBASCO, consultant to the NRCS, assumed that embankment cracking was going to occur and would be handled by the transition filter. The transition zone would be made of granular cohesionless material which will maintain a filter zone capable of preventing the migration of embankment materials. The NRCS has estimated that the embankment transition zone can accommodate as much as approximately two feet of settlement in the twenty-foot high embankment. This, combined with the limited depth of the soil layer between the underlying caliche and the embankment, had led the NRCS to decide to make no provisions other than to apply extra compaction effort to the foundation materials under the embankment. No provision of embankment camber to allow for settlement has been made or considered necessary by the NRCS.

Previous inspection reports have documented observations of longitudinal cracks on the dam crest along the dam centerline. The first reports of longitudinal cracks on the dam crest appear in the District's November 1996 inspection report. The cracks appear to be formed in association with the central transition filter. Recent longitudinal cracks were observed and noted in ADWR's November 1999 inspection of Apache Junction. These cracks were located at Stations 81+88, 84+85, 86+00, and 98+60. ADWR probed the cracks with a steel probe to try to get an indication of the depth of cracking. ADWR also photographed the cracks and provided the photos as part of their inspection report.

Kimley-Horn conducted an inspection of the dam in July 2000. The inspection included looking for past reported longitudinal cracks. Longitudinal cracks were located on the crest at centerline at Stations 81+00 to 82+50, 86+00, and 95+50. One old transverse crack was observed at Station 36+00 on the downstream and upstream slope. The transverse crack was probed but to no depth.

A review of the EBASCO documentation revealed that the design precipitation for the Apache Junction FRS for the 100-year, 24-hr storm is 4.1-in; for the Emergency Spillway Hydrograph (ESH) - a depth of 7.1-in; and for the Freeboard Hydrograph (FBH)(6-hr PMP) of 13.7-in and a depth (24-hr PMP) of 15.8-in (for a drainage area of 5.79 square miles and an emergency baffle block spillway width of 100-ft).

The District recently completed a restudy of the downstream inundation flooding limits from discharges from the emergency spillway. The study was completed in July 2000 and was conducted on behalf of the District by Michael Baker Jr. Inc. (FCD Contract No. 98-33). The study limits from upstream to downstream were from the emergency spillway to the Central Arizona Project canal (a distance of approximately 4.7 miles). The study examined the inundation limits for spillway discharges for the full PMF, the 2/3 PMF, and the 1/3 PMF. The full PMF emergency spillway discharge used in the study was 10,500 cfs which is relatively the same freeboard hydrograph emergency spillway discharge determined by EBASCO in 1986 (10,600 cfs).

Based on the sediment storage investigation, the NRCS estimated that sediment accumulation in the Apache Junction FRS would be at the rate of 0.21 acre-feet per square mile per year. The 100-year period sediment volume required was calculated to be 95 acre-feet based on a (1974) drainage basin area for Apache Junction FRS of 6.30 square miles.

Subsidence due to groundwater withdrawal is not expected to be an issue at the Apache Junction FRS due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment. Apache Junction FRS is located on the Usery Mountain granitic pediment with bedrock at a relatively shallow depth (probably less than 50 feet) beneath the FRS structure.

Earth fissuring at the Apache Junction FRS site and local vicinity should have a low degree of concern due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment on which the Apache Junction FRS is founded. The nearest ground subsidence-related earth fissure is about two and one-half miles south of the south end of the FRS.

The Apache Junction FRS is located near an area of active ground subsidence and earth fissures. However, due to the presence of shallow granite pediment in the FRS area and the FRS's proximity to the pediment edge, earth fissuring should have minimal impacts on the Apache Junction FRS. Ground subsidence at the FRS is expected to be negligible. However, the Apache Junction FRS should be included in an area-wide monitoring program because of its proximity to the ground subsidence area and known earth fissures.

KHA has plotted the existing available settlement surveys. It should be noted that the maximum water surface elevation for the PMF was determined by EBASCO Services to be 1809.4-ft. The minimum top of dam settlement monument was surveyed in 1998 at Station 44+77 to be 1809.447-ft. The PMF water surface elevation is essentially at the top of the dam at this location. A PMF flood could potentially overtop the dam.

Field Examination - Apache Junction FRS is inspected on an annual basis by Flood Control District personnel. The Arizona Department of Water Resources conducts annual inspections of Apache Junction FRS. The last ADWR and District inspection was conducted in December 2000. The next annual inspection is scheduled for December,

2001. Kimley-Horn conducted an inspection of Apache Junction FRS in July 2000. The following discussion is from the results of that inspection.

Centerline crest longitudinal cracks were observed at Stations 81+00 to 82+50, 86+00, 95+50, and 98+68. Minor erosion rills are forming on the embankment slopes.

The following is a list of recommended corrective actions resulting from this field examination:

a. Continuing observation should be made of the above mentioned items (erosion of slopes, monitoring of longitudinal cracks).
b. Station posts need to have signs on both sides of post facing both directions of travel.
c. Monitor and repair when necessary erosion gullies on slope faces.
d. Video and photograph log the interior of the principal spillway conduit.
e. Develop a plan for the repair of transverse and longitudinal cracks.
f. Locate, uncover and expose all settlement monuments prior to settlement surveys.
g. Evaluate the need for finger drains to tie to the central transition filter.

Recommendations for Further Actions/Investigations - Apache Junction FRS and it's sister dams (Spook Hill FRS and Signal Butte FRS) have been and most likely will continue to be subject to transverse and longitudinal cracking. The cracking could be attributable to several factors including embankment desiccation, differential settlement, ground subsidence, or foundation conditions. A general crack repair plan has been prepared, however, for Apache Junction FRS, monitoring of the longitudinal and transverse cracks is recommended at this time as opposed to any repairs.

It is recommended that a risk assessment be conducted for Apache Junction FRS. The risk assessment could examine failure modes and the effects/consequences of the failure. Failure modes that potentially could occur at Apache Junction FRS include breach failure by piping, or piping along a transverse crack. The risk assessment could evaluate the failure mode and effects of the transition filter as a crack stopper.

A hydrologic/hydraulic analysis of Apache Junction FRS should be conducted based on District methods to confirm that the dam provides greater than 100-year flood protection. The District completed a capacity analysis of the reservoir and found that the dam and reservoir could have a greater capacity than originally designed. It is also recommended that a restudy of the 100-year sediment yield to the impoundment be conducted. A potential reduction in the sediment yield to the dam from the contributing watershed could provide increased flood storage capacity. A recommendation is to conduct a site specific PMP for this watershed prior to reevaluating the hydrology and hydraulics of the dam. A site specific PMP will evaluate storm centering on the watershed and storm distribution. The hydrologic/hydraulic analysis could confirm that the PMF potentially could overtop the dam (based on 1998 crest survey data).

An Incremental Damage Analysis (IDA) could also be performed on this structure. The purpose of an IDA analysis is to estimate if there would be additional damage to downstream structures if the dam were to fail during a large storm event over no structure in place and a large flood event occurring within the watershed.

It is recommended that a slope stability analysis be conducted for Apache Junction, Spook Hill, and Apache Junction flood retarding structures. The stability analysis will evaluate the embankments (upstream and downstream fills). The results of the analysis can provide factors of safety of the structures under various hydraulic loading conditions and compare the results of the analysis with the original design and the current ADWR recommended factors of safety for embankment dams. Computer programs, such as UTEXAS3, are suitable for such an analysis.

A detailed inspection procedure, settlement monitoring procedure, earth fissure and subsidence monitoring procedure, and recommended operation and maintenance improvements for all District dams were provided in the previous report titled "Policy and Program Report".

It is recommended that a utility database be prepared for Apache Junction FRS. The structure has several utility crossings through, under, or over the embankment. The database should include at a minimum the type of utility, location of utility crossing, owner of utility, cross-reference to utility crossing construction plans, and measures to control piping and seepage.

Conclusions - The overall conclusion is that the Apache Junction FRS and appurtenant structures are in satisfactory operational condition.

6.0 Closing

A technical review and field examination was conducted for the Spook Hill, Signal Butte, and Apache Junction flood retarding structures. The technical review consisted of engineering, geological, and geotechnical reviews of design documents including reports, studies, and construction plans for each of the four structures. Field examinations of the dams were conducted in order to assist in the systematic technical evaluations and to identify and report signs of distress. Recommendations for further District action/investigations are provided for each dam.

At the present time, all three structures examined as part of the Individual Structures Assessment Report appear to be in satisfactory operational condition for the design conditions, criteria, and assumptions under which the dams were constructed. The District will be faced with ongoing monitoring and potential future repair of transverse and longitudinal cracks at the Spook Hill, Signal Butte, and Apache Junction flood retarding structures. Future considerations for District actions include slope stability analyses for the Spook Hill, Signal Butte, and Apache Junction flood retarding structures as well as a PMF evaluation of these dam's hydrologic/hydraulic performance and downstream hazard conditions.

The following table provides a summary of the recommendations for further investigations and studies for Spook Hill, Signal Butte, and Apache Junction FRS.

Recommendation	Spook Hill	Signal Butte	Apache Junction
Dam Safety Inspections	X	X	X
Develop Utility Database	X	X	X
Update Operations and Maintenance Plan	X	X	X
Prepare Emergency Action Plan to meet Minimum requirements of FEMA 64	X	X	X
Continue Settlement Surveys	X	X	X
Prepare Subsidence and Earth Fissure Monitoring Plan	X	X	X
Conduct Risk Assessment	X	X	X
Conduct Slope Stability Analyses	X	X	X
Update Hydrologic Models (100-yr, PMF)	X	X	X
Evaluate upstream/downstream land use and watershed conditions	X	X	X
Prepare Future Conditions hydrologic model	X	X	X
Conduct Incremental Damage Analysis	X	X	X
Conduct updated Sediment Yield Analysis	X	X	X
Conduct updated Reservoir Capacity Analysis	X	X	X
Examine need for transition filter along longitudinal centerline of embankment	X		
Prepare Slope Erosion Repair Plan	X	X	X
Prepare Work Plan for Repair of Transverse Cracks	X	X	X
Install settlement monitoring monuments (total of 4 at each cross section)		X	
Conduct Soil Dispersion Tests			X

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART I INTRODUCTION

Section 1.0 Introduction

Section 1.0 Introduction

1.1 Authorization

The Individual Structures Assessment Report was prepared by Kimley-Horn and Associates, Inc. (KHA) under authorization by the Flood Control District of Maricopa County (District) through the scope of work for the Structures Assessment Program-Phase I, Work Assignment No. 3 (Contract FCD 98-41). Kimley-Horn and Associates retained URS Corporation, and Geological Consultants to assist with the preparation of the elements of Work Assignment No. 3.

1.2 Purpose

The purpose of the Individual Structures Assessment Report is twofold: (1) to assess the existing condition of Spook Hill, Signal Butte, and Apache Junction Flood Retarding Structures; and (2) to recommend actions for further investigations/monitoring of the structures and develop work plans to repair signs of distress in the structures.

The Individual Structures Assessment Report is a companion report to one other major report under FCD 98-41, Work Assignment No. 3. This other report is the Alternatives Analysis Report.

The Alternatives Analysis Report documents an alternatives study for each of the Work Assignment No. 3 structures. The Alternatives Analysis Report is being prepared subsequent to the Individual Structures Assessment Report.

1.3 Scope

The Individual Structures Assessment Report is the culmination of an investigation, evaluation, and assessment of the present condition of the three District structures - Spook Hill FRS, Signal Butte FRS, and Apache Junction FRS. The investigation was founded in the scope of work for Work Assignment No. 3, Task 3.0 – Individual Structures Assessment. Under Task 3.0, Kimley-Horn and Associates reviewed current dam safety criteria as related to the existing structure and the original dam safety design criteria. KHA also reviewed the historic dam safety records for each dam to identify and assess any modifications to the dams related to dam safety. The records review also included identification of modifications not related to dam safety. The historic records review included reviewing documents, for example previous inspection reports, to identify documented potential dam safety signs of distress such as transverse and/or longitudinal cracking. KHA will recommend methods to reduce, eliminate, or counteract evidence of distress.

Part of Task 3.0 includes a review of the available technical documentation for each structure. The purpose of the technical review is to review the historic records related to the dam and through this review familiarize the project team with the structure, familiarize the team with the history of the structure, and acquaint the team with the basis of analysis and design, with the original design criteria and design guidelines, and to compare versus current state of practice.

Finally, a field examination was conducted for each structure. The examination was visual in manner and included the dam embankment and associated features. An inspection log was prepared summarizing the results of the field examinations. The purpose of the field examinations was to familiarize the project team with the existing field conditions at each structure, to note past signs of distress, and to document any new signs of distress.

The assessment of each structure will be based upon the technical review and field examinations. Recommendations are prepared for each structure for further investigations and analysis and work plans prepared to counteract, repair, or reduce distress signs found at each dam.

1.4 Report Organization

The Individual Structures Assessment report is organized into five Parts.

Part I, Section 1.0 - Introduction, provides the project authorization, purpose, Work Assignment No. 3 scope, and report organization. Section 2.0 – Structures Assessment Program Background, provides a general discussion of the Structures Assessment Program and the three phases of the program. Section 3.0 provides a brief discussion of the Buckhorn-Mesa Watershed Project.

Part II – Spook Hill Flood Retarding Structure: Section 1 is a description of the dam and associated features; Section 2 is the technical review conducted of historic dam safety records; Section 3 describes the results of the field examination and recommendations for corrective actions, and, Section 4 provides recommendations for further actions and investigations. Part II includes an appendix that compares NRCS and ADWR design criteria and an appendix for the settlement monitoring data.

Part III – Signal Butte Flood Retarding Structure: Section 1 is a description of the dam and associated features; Section 2 is the technical review conducted of historic dam safety records; Section 3 describes the results of the field examination and recommendations for corrective actions, and, Section 4 provides recommendations for further actions and investigations. Part III includes an appendix that compares NRCS and ADWR design criteria and an appendix for the settlement monitoring data.

Part IV- Apache Junction Flood Retarding Structure: Section 1 is a description of the dam and associated features; Section 2 is the technical review conducted of historic dam safety records; Section 3 describes the results of the field examination and recommendations for corrective actions, and, Section 4 provides recommendations for further actions and investigations. Part IV includes an appendix that compares NRCS and ADWR design criteria and an appendix for the settlement monitoring data.

Part V – Closing: is a summary of the conclusions from the Individual Assessment Report and includes a list of references to technical documents used in the preparation of this study.

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART I INTRODUCTION

Section 2.0 Structures Assessment Program

Section 2.0 Structures Assessment Program

2.1 General

The Flood Control District of Maricopa County (District) recently celebrated their fortieth anniversary by renewing their mission and commitment to continued excellence in reducing flood risks for the people of Maricopa County by providing comprehensive flood and stormwater management services. As part of their continued mission, the District has embarked on a Structures Assessment Program, the primary objective of which is to minimize the risk and liability associated with the District's flood control dams.

The District owns, operates and maintains twenty-two dry flood control dams and is mandated by state and federal law to assure the safety of these structures. The District has initiated a program called the Structures Assessment Program to assess and evaluate these structures (or dams – used interchangeably) and related features due to an ever-increasing urbanized environment and to assure continued compliance with current standards, guidelines, and regulatory requirements. The situation faced by the District is that the same population protected by the dams can be at risk in the unlikely event of dam failure or spillway discharge. The District is seeking measures that provide flood control and that properly manage long term risk. The Structures Assessment Program is intended to address issues related to urbanization and dam safety as well as to enhance and improve the District's ongoing Dam Safety Program.

The purpose of the Structures Assessment Program is to minimize the risk and liability associated with the District's flood control dams. Since many of the District dams were built, there have been a number of changes, which now need to be addressed. These changes are:

- Structures have aged and some are showing signs of distress,
- Significant urbanization upstream and downstream has occurred and continues at a rapid pace,
- Changes in dam technology and design practices,
- Changes in methodology for determining inflow design flood,
- Significant increase in permit requests for utility and roadway crossings of dams,
- Proposed rule changes by the Arizona Department of Water Resources (ADWR), and,
- Subsidence impacts due to groundwater pumping.

The Structures Assessment Program will address and assess the District's dam safety program on several fronts including:

- Dam safety inspections/evaluations,
- Emergency Action plans,
- Impoundment areas and spillway channels,
- Improvements to the overall dam safety program,

- Future rules and regulatory changes,
- Planning studies to evaluate project options, and
- Flood Control District policy evaluation.

The Structures Assessment Program will be conducted in three phases. Phase I will primarily involve:

- Collection of data and inspection of dams,
- Develop dam safety recommendations and priorities, considering changes listed above,
- Perform preliminary alternative analysis studies to modify existing projects to address urbanization related issues, and,
- Evaluate newly enacted ADWR rule changes and District policy issues.

Phase II will primarily involve:

- Perform detailed investigations and analyses as identified by need and priority in Phase I,
- Initiate project planning and authorization activities to correct identified distress issues,
- Implement changes to overall dam safety program and policies, and,
- Perform conceptual design studies and alternative analyses for modification of projects to address urbanization and distress issues.

Phase III will primarily involve:

- Implement projects to correct any identified dam safety concerns. These could include structural modifications, land acquisitions for spillway discharges, and alternative, lower risk solutions,
- Implement approved projects and land acquisitions to address urbanization issues, and,
- Continue long-term dam safety program.

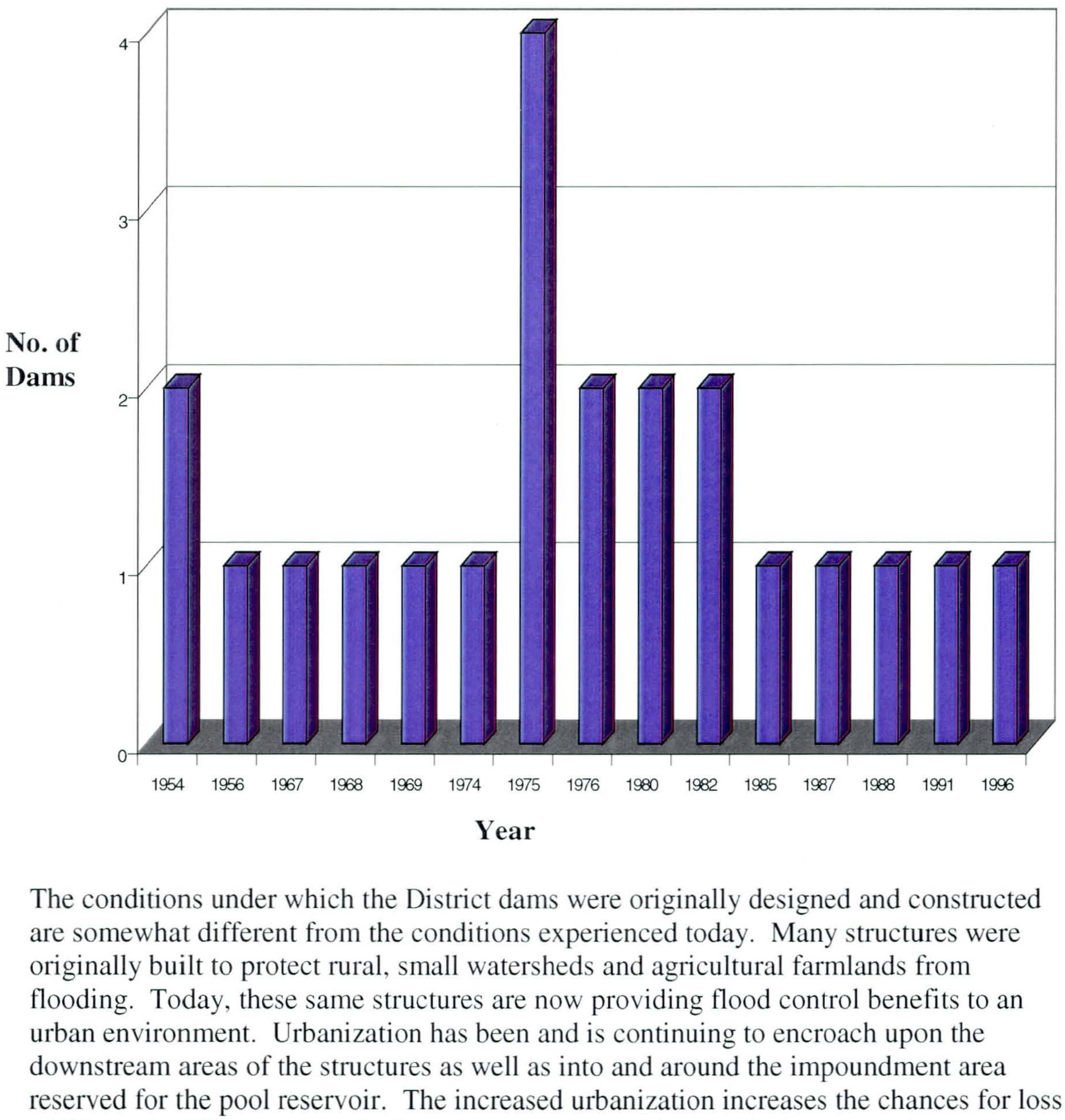
Phase I of the Structures Assessment Program is primarily an evaluation and study phase. The District has retained Kimley-Horn and Associates to provide services to conduct Phase I evaluations and studies. The first work assignment focussed on four District dams. Evaluations and studies performed for these dams will initiate the Phase I process. It is intended that the first work assignment will be a pilot study from which to establish initial District dam safety policy and programs, and from which to refine engineering and planning methods for the Structures Assessment Program. The dams evaluated in the first work assignment were the Powerline Flood Retarding Structure (FRS), the Vineyard Road Flood Retarding Structure, the Rittenhouse Flood Retarding Structure, and Cave Buttes Dam.

A steering committee serves in an advisory capacity to the District's project manager concerning the major findings and recommendations of Phase I of the program. The committee consists of representatives of the District's planning, engineering, and operations functions, Arizona Department of Water Resources Dam Safety Section, Natural Resources Conservation Service (NRCS), Corps of Engineers, and Bureau of Reclamation (USBR).

2.2 Structures Opportunities and Challenges

The Flood Control District owns, operates, and maintains twenty-two flood control dams. The dam impoundments are normally dry and only experience reservoir ponding in response to rainfall/runoff within their respective watersheds. Figure 2-1 illustrates the number of District flood control dams constructed year by year.

Figure 2-1. District Dams Constructed by Year.



The conditions under which the District dams were originally designed and constructed are somewhat different from the conditions experienced today. Many structures were originally built to protect rural, small watersheds and agricultural farmlands from flooding. Today, these same structures are now providing flood control benefits to an urban environment. Urbanization has been and is continuing to encroach upon the downstream areas of the structures as well as into and around the impoundment area reserved for the pool reservoir. The increased urbanization increases the chances for loss of life or significant economic damages in the event of a dam failure or spillway discharge. An example of encroachment of urbanization is provided in Figures 2-2 and 2-3 for Spook Hill Flood Retarding Structure.

In addition to the aging of dams and urbanization challenges, the dam safety regulatory environment has undergone changes as well. Dam safety rules, regulations, and design criteria and requirements, through changes in dam technology/operation, maintenance knowledge, and dam safety practices and experience, have been strengthened since the time the structures were originally planned and constructed. Some of the changes in dam safety regulations are retroactive and may conflict with the original design of the dam. Changes in dam safety regulations may change the hazard classifications of some dams from their original classification.

The existing small watershed dams were planned and constructed originally to provide, as the primary purpose, flood control benefits. In today's environmentally sensitive awareness, the structures, reservoir areas, and downstream conveyance corridors are being looked upon for further and expanded multi-use opportunities. These opportunities include recreation corridors, riparian and wildlife habitat enhancement, groundwater recharge, and educational opportunities. These changes in downstream use, as well as within the reservoir and upstream, have changed the risks associated with the dams.

The local situation and conditions appear to mirror national trends, however there are some local challenges as well. The District is faced with the same challenges experienced at the national level, but on a localized level. These include aging of dams, urbanization, subsidence, desiccation, and, changing dam safety regulations.

Some of the District dams within the next 10 to 15 years will be reaching the end of their original design life. This does not necessarily mean that the dams have reached the end of their useful life, but it does point to the need for increased major maintenance activities and the need to initiate planning for the potential replacement of function. Many of these structures are showing the effects of aging and changes from the environment such as subsidence due to groundwater withdrawal. Typical effects included increased sedimentation, deterioration of concrete structures, and settlement and cracking of earthen embankments.

Recent inspections of several District dams have revealed transverse and/or longitudinal cracks on the dams slopes or crests. Examination of dam safety records indicate that these same structures have had a history of cracking, crack investigations, and crack repairs. Earth fissures associated with ground subsidence have been documented in the vicinity of several District dams.

Figure 2-2. Aerial photograph of Spook Hill FRS showing urbanization encroachment downstream of the dam and emergency spillway.

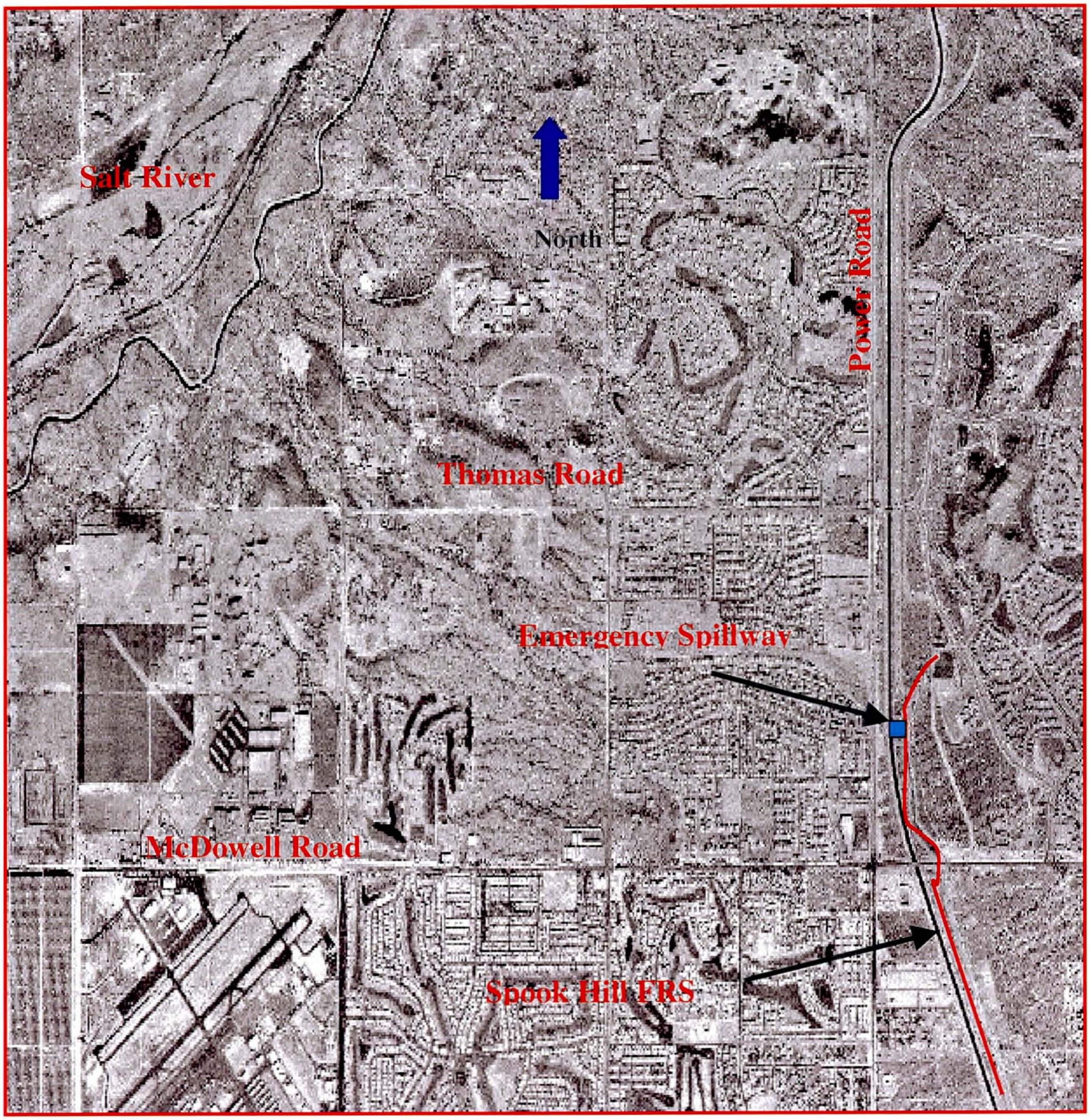


Figure 2-3. Ground level photograph downstream of Spook Hill FRS showing homes built adjacent to downstream toe of dam and the Central Arizona Project.

Opportunities facing the District now and in the near future will be the development of a strong dam safety program and a commitment of District resources to the goals of the Structures Assessment Program, commitment of qualified personnel with the capabilities to carry out the Structures Assessment Program and enhanced dam safety program, application of new dam technologies including incorporating the results of research and development from the Corps, Bureau of Reclamation, FEMA, and NRCS, and application of risk-based methodologies to dam safety.

One of the more important opportunities for the District, as part of their Structures Assessment Program, is the evaluation and assessment of each of their twenty-two flood control dams and associated features. The assessment of each structure will be conducted based upon a technical review of each structure's dam safety documentation and upon an extensive examination of the existing field conditions found at each dam. Ultimately, recommendations will be developed for further actions and investigations in regards to dam safety for each of the District's dams.

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART I INTRODUCTION

Section 3.0 Buckhorn-Mesa Watershed Plan Summary

Section 3.0 Buckhorn-Mesa Watershed Plan Summary

The following section presents a summary of the original plan formulation for the Buckhorn-Mesa Watershed. The plan formulation is provided in detail in the Soil Conservation Service (NRCS) watershed workplan (January 1963) prepared under the authority of the Watershed Protection & Flood Prevention Act (Public Law 566, 83rd Congress, 68 Stat. 666) as amended. The purpose of this summary is to provide the background information and concepts for the watershed master planning of the Buckhorn-Mesa watershed. The following discussion is derived from the original watershed workplan document and is predominately unchanged from the original version. Minimal effort has been made to update project characteristics or features in this section with Parts II, III, and IV of this report (refer to Parts II, III, and IV for updated project features). The purpose of this section is to provide a short background of the development of the Buckhorn-Mesa Watershed workplan as presented by the NRCS. Section 3.7 marks the last section taken from the NRCS watershed workplan. Section 3.8 was derived from the District's Internet website for the Buckhorn-Mesa project description.

3.1 Size and Location

The Buckhorn-Mesa watershed is located in eastern Maricopa and northwestern Pinal Counties, Arizona. Heading in the "rough" Usery, Goldfield and western Flanks of the Superstition Mountains, the watershed drains onto a wide alluvial fan on which valuable improvements have been established. It contains portions of the most highly productive irrigated farm land in the state and is a part of the Salt River Project and the Roosevelt Water Conservation District. This region, which lies east of Phoenix and Mesa, has undergone a tremendous rate of population and development growth during the past years. This growth consists of the rapidly expanding urban and commercial developments along U.S. Highway 60-70-80-89 (Apache Trail) from the City of Mesa east to the Town of Apache Junction. This highway forms the southern boundary of the watershed.

The total (original) plan formulation watershed area contains 69,172 acres of which 19 percent is cultivated farm land, eight percent is urban and commercial, and the remaining 73 percent is range land. Sixty-eight percent of the watershed is in private ownership, 30 percent is Federal (15 percent is the Tonto National Forest, and 15 percent is National Land Reserve), and two percent is state owned.

This watershed is one of three for which the sponsoring local organizations have requested concurrent planning because part of the flood problem area is affected by all three watersheds. The northern-most watershed is "Buckhorn-Mesa", the central watershed is "Apache Junction-Gilbert", and the southern watershed is "Williams-Chandler".

3.2 Sponsoring Organizations

The work plan was prepared by the Flood Control District of Maricopa County, the Board of Supervisors of Pinal County, the East Maricopa Soil Conservation District, and the Mesa-Tempe Soil Conservation District, with technical assistance furnished by the United States Soil Conservation Service (NRCS) and the United States Forest Service.

3.3 Watershed Problems Prior to Buckhorn-Mesa Structures

From 1910 to 1960, 33 floods, an average of one every two and one-half years, have inundated agricultural and non-agricultural lands of the watershed. High intensity "cloudburst" type of storms during July, August, and September and local gentle rains in winter months result in destructive floods. Flood waters resulting from these storms inundate the rich irrigated farm land above the Roosevelt Water Conservation District Canal. These floodwaters backed up behind the Roosevelt Water Conservation District Canal and overflow into the canal in such volume to cause breaks in the canal banks. Floodwater then poured over high value farm land in the Salt River Project's canal system where further damage occurs. These floodwaters also inundate the rapidly developing residential and commercial area along the Apache Trail and in Apache Junction.

Past attempts to use flood flows for irrigation purposes on the cultivated acreages have met with limited success. Under present conditions it is impossible to get the maximum use from the silt and debris laden waters. They scour and gully existing canals upon their entrance in the canals and by their uncontrolled nature are of an undependable source of supply to augment other surface and pump supplies. A dependable silt-debris free supply of water to help preserve present groundwater levels and maintain present pumping costs is the desire of the local sponsors. This is an area short of water. Manageable flows of floodwaters have been used to some extent in the past. This supply of water is needed to augment the needs of irrigation. Flood flows from storms greater than the 20 percent frequency of occurrence cause damage to the irrigation facilities and cannot be used.

3.4 Physical Data of the Buckhorn-Mesa Watershed

Location - The watershed is located in eastern Maricopa and northwestern Pinal Counties, Arizona, about 25 - 30 miles east of Phoenix. Heading in the "rough" Usery, Goldfield and western flanks of the Superstition Mountains, it drains onto a wide alluvial fan on which valuable improvements have been established. Portions of the most highly productive irrigated farm land in the state are found in the flood plain and are served by the Salt River Project and Roosevelt Water Conservation District. It covers a portion of the rapidly-expanding urban and commercial development along the Apache Trail from Mesa east to Apache Junction. U.S. Highway 60-70-80-89 (Apache Trail) forms the southern boundary of the watershed.

Land Use and Status - The total (original) watershed area contains 69,172 acres of which 13,232 acres are cultivated farm land, 5,798 acres are urban and commercial, and the remaining 50,142 acres are range land. 47,073 acres of the watershed are in private ownership, 20,819 acres are Federal (10,637 acres are Tonto National Forest and 10,182 acres are National Land Reserve), and 1,280 acres are state owned.

Land Resource Units - Land resource units have been used to describe the soil, cover, topography, geology, and erosion. Resource units delineated in the watershed include the following:

Resource Unit	Acres	% of Area
Mountains	22,746	33
Valley Slopes	22,131	32
Valley	24,295	35
TOTAL:	**69,172**	**100**

Topography - The elevation ranges from 1,200 feet at the Salt River to 5,100 feet in the Superstition Mountains. The general slope is to the south and west.

The following is a tabulation of average slope variations in the resource units:

Resource Unit	Percent Slope
Mountains	5 – vertical
Valley Slopes	3 – 10
Valley	less than 1

Geology - Physiographically, the area is part of the Sonoran Desert section of the Basin and Range province. The mountains are of granite and comprise the only consolidated material within the watershed with the exception of beds of caliche and siltstone at lower elevations. Gentle alluvial slopes extend basinward from the mountains. In places the upper slopes are underlain at shallow depths by rock surfaces. The lower alluvial slopes are underlain by caliche and siltstone at depths from two to 20 feet.

Soils - Soil conditions differ considerably in the watershed. A general description of the soils by land resource units follows:

Mountains — Soils are shallow, stony, and the texture ranges from loam to sandy loam. In this area, up to 75 percent is bare rock or boulders.

Valley Slopes — Surface soils are non-calcareous gravelly loams or sandy loams underlain by either sandy loam, loam, or sandy clay loam. The soils with the sandy clay loam subsoils generally are underlain at 14 to 30 inches by a strongly cemented lime layer which extends to undetermined depth.

Valley — These soils are deep loam to clay loams moderately to highly calcareous. Small areas of soils have a strongly cemented lime layer at depths of 14 to 30 inches.

Vegetation and Range Condition

Mountains — The dominant species are cacti, paloverde, algerita, scrub oak, and mesquite. Range condition is poor.

Valley Slopes — Vegetation is desert shrub with scattered grasses. Shrub species are creosote bush, paloverde, mesquite, ironwood, burr sage, and cacti. Perennial grasses are generally lacking. Annual grass species are six-week fescue and three-awn. Range condition is poor.

Valley — Most of this area is cultivated cropland. Crops grown are citrus, vegetables, alfalfa, cotton, and grain sorghums. Vegetation on the uncultivated area is mainly shrubs with a light overstory of trees. In wet years there is a heavy cover of annual grasses. Perennial grasses are not present. The shrub species are creosote bush and burr sage with an overstory of mesquite. The annual species are six-week fescue and mustard. The condition of this uncultivated area is poor.

Stream Channels - There are no perennial streams in the watershed. Channels in the mountains are well defined but meander and disappear when they reach the valley slopes and valley.

Climate - The climate in the watershed area varies from semi-arid to dry. The mean annual precipitation varies from eight inches in the irrigated lands in the western portion of the watershed to 13 inches in the rugged mountain country to the east. Precipitation during July, August, and September averages three inches in the western portion of the watershed, and five inches during the same period in the eastern portion. Climatic data from the Weather Bureau station at Mesa is typical of the western portion of the watershed and climatic data from the Mormon Flat station is typical of the eastern portion.

During July, August, and September, late afternoon or early evening thunderstorms may occur in a very brief period. These storms are associated with moist tropical air that flows in the state from the Gulf of Mexico. The maximum daily precipitation recorded at Mormon Flat occurred in August 1930, and amounted to 4.49 inches. These rare storms often make the difference between a wet and dry summer.

3.5 Watershed Problems

The following is excerpted from the NRCS watershed work plan. The quantities and dollar figures are based upon original plan formulation (in 1963 dollars).

Floodwater Damages - Floodwaters have over the past years seriously affected the economy of the watershed. From 1910 to 1960, 33 floods, an average of one every two and one-half years, of varying magnitude have occurred damaging agricultural lands, residences, retail-commercial establishments, roads, highways, and other physical appurtenances. During this period, 21 floods occurred in the summer months and 12 during the winter months. Runoff from heavy rains in the years 1926, 1930, 1941, 1943, 1946, 1954, and 1959 caused particularly serious damage in the watershed.

Floodwaters from the watershed's drainage area flow in a south-southwest direction, not only inundating lands within the watershed, but lands to the south in the Apache Junction-Gilbert Watershed.

Runoff from the watershed during the storm of 1954 inundated 5,750 acres of highly productive cultivated land. This storm was of a magnitude which would recur once every 17 years. Damage to this land was extensive. Loss of cotton yields on the 1,840 acres of cotton land amounted to 1,290 bales. This loss spread out over a ten-year period amounts to two percent of gross receipts or six percent of net receipts each year. In addition to the actual cotton lost, 417,680 pounds of cotton seed were rendered useless for further processing. The floodwaters of this storm damaged 690 acres of vegetable land. Some 640 acres of alfalfa hay and seed land were inundated. The tonnage of alfalfa lost from this one storm alone would support 525 head of cattle for one year. The total evaluated damages to crops and pastures from this 1954 storm amounted to an estimated $300,000.

The effects of a storm to be expected once every 100 years (one percent event) would seriously affect the economy of the area for a number of years. Some 9,700 acres of cultivated land would receive flood damage. Loss of cotton yield alone would amount to 2,200 bales. Cotton seed rendered unusable would amount to 715,000 pounds. This one percent event would deposit water on the first floor of some 400 residential and commercial units. Total damages from a storm of this magnitude in the area would approximate two and one-half times that of the 1954 event.

In addition to these direct damages there are considerable indirect losses as a result of flood inundations. Flood flows over U.S. Highway 60-70-80-89 disrupt traffic some three to four hours. Traffic flow on this interstate highway is estimated at 7,430 vehicles per day at the present time. Loss of income to businessmen and other enterprises within the watershed is substantial. A flood during the height of the tourist season, for which this area is noted, can seriously affect income of individual owners of motels, trailer courts, and others depending on this trade. The cotton gins in and around the area report delays in processing and loss of income due to reduced yields because of flood flows. Delays in harvesting the citrus crops affect transportation schedules as well as profits to citrus growers.

Flood damages to the type of agricultural and non-agricultural economy of the area are difficult to measure in terms of adverse effects to the state and nation. They are nonetheless present. They reduce the need for on-farm labor over the short and long term. Floods reduce the potential earning power of the watershed's population and thereby reduce investments in capital goods and services.

The agricultural lands east of the Roosevelt Water Conservation District Canal served for the most part by private wells, suffer the heaviest flood damages in the watershed. The Roosevelt Water Conservation District Canal offers some degree of protection to cultivated lands west of the canal. Of the 5,750 acres inundated in the 1954 storm, 3,960 acres are located east of the canal where flood flows are unabated. The remaining 1,790 acres of cultivated land damaged by this flood are located in the flood plain of the Apache Junction-Gilbert Watershed.

Flood flows during this 1954 storm varied from four inches to three feet in depth throughout the residential and commercial areas east of the Roosevelt Water Conservation District Canal. This residential and retail-commercial area has in the past five to ten years undergone a tremendous growth. If a storm the magnitude of the 1954 event were to recur, it is estimated that 1,080 units or 3,600 people would be directly affected. The extent of damages to these properties varies from extensive first floor damage down to small washouts in driveways and on lawns. Of the 1,080 units, it is estimated that 140 would suffer heavy damage from floodwater on first floors.

This type of damage results in losses to wall to wall carpeting. Tile floors are warped and ruined from the floodwaters. The dry wall construction found in most of these homes has to be reworked and repainted. Extensive damages to yards and outside features are sustained. The 1954 flood washed away the majority of yards containing fine, brightly colored gravel used in many yards. The estimated total damage includes the damages sustained to 35 miles of county and state roads. A number of these roads were eroded some three to four feet as a result of this flood inundation.

Of deep concern to local residents are the effects of floods or threat to future residential and commercial development in the watershed. On the basis of the flood characteristics of the 1954 storm, an analysis was made as to the magnitude of damages to these future developments. It is estimated that within a ten-year period an additional 4,050 homes and stores will be susceptible to damage.

Sediment Damages - Deposition of sediment on alfalfa fields has a smothering effect on the plant. This smothering effect can cause losses up to two cuttings, depending upon the severity of such action. On-farm irrigation ditches and laterals are filled with sediment when breached by flood flows. This causes additional loss of crop yields due to the inability of providing proper amounts of irrigation water through reduced ditch capacity. Sediment deposition on fields prevents proper distribution of irrigation water and causes additional crop damage. Farmers are also faced with the problem of releveling fields after heavy sediment deposition.

Fine silts and other material carried by the flood flows entering homes ruin wall to wall carpeting. Sediment deposition in privately owned wells not only necessitates the removal of sediment and cleaning of wells, but presents an unsatisfactory health condition for the community by contaminating drinking water. This condition is further aggravated by overflow of septic tanks and sewage disposals into homes and wells. This problem, if not alleviated, will seriously deter the areas' potential for development.

Deposition of sediment on county roads and U.S. Highway 60-70-80-89 during the 1954 flood presented a formidable cleanup problem to county and state highway crews. Deposition occurred on 35 miles of county and state roads during this storm. As the area develops, this type of damage will increase in magnitude.

Erosion Damages - Scouring of cultivated fields necessitating fill and releveling occurred during the 1954 storm. Since 400 acres suffered this type of damage from the 1954 storm, immediate remedial action was necessary by farmers to maintain proper irrigation grades.

3.6 Projects Of Other Agencies

The Bureau of Reclamation has constructed the Central Arizona Project. The Salt-Gila Aqueduct of the Central Arizona Project crosses the watershed in a southeasterly direction approximately three miles east of the Roosevelt Water Conservation District Canal, and is complimented by the structural works of improvement as proposed by this plan. Considerable savings were afforded the aqueduct in providing flood protection and drainage. The local office of the Bureau of Reclamation has concurred in the formulation of structural measures outlined in this work plan.

3.7 Basis For Project Formulation

The project objectives of the local people are to: (1) alleviate damage to highly productive irrigated lands within the watershed, (2) alleviate inundations of residences, retail-commercial properties, roads and highways, (3) protect the existing Salt River Project and Roosevelt Water Conservation District's canals and on-farm irrigation facilities, (4) reduce flood plain scour and erosion, (5) afford protection to lands now undergoing rapid urbanization, and (6) make better use of floodwater for agricultural purposes.

The final site selections for the three (originally four) floodwater retarding structures were based on providing maximum protection for the existing flood plain developments and still permit the expected expansion of these developments into protected areas. This involved a determination of the approximate size of area needed for future expansion, topographic and geologic conditions of the sites, comparative costs and benefits and other related factors.

3.8 Works Of Improvements Installed

The following discussion regarding the works of improvements installed is a summary of the watershed workplan project structural features. The description was obtained from the District's Internet website for the Buckhorn-Mesa project.

Structural Measures - Three floodwater retarding structures (Spook Hill, Signal Butte, and Apache Junction FRSs) and four floodways (Spook Hill, Signal Butte, Bulldog, and Apache Junction floodways) were constructed as part of the Buckhorn-Mesa watershed project. The dams were constructed in series with interconnecting floodways with one common outlet to a safe disposal point (Salt River). A debris basin and division box were constructed in the common outlet floodway so as to safely utilize the floodwater originating in the watershed for irrigation purposes. These flood retarding structures and associated floodways are as follows:

Spook Hill FRS and Floodway with Debris Basin

The Spook Hill floodwater retarding structure was constructed above the Apache Trail and the New Bush Highway. This structure provides floodwater protection from the one percent event. It has a total storage capacity of 1,217 acre-feet, with 900 acre-feet allocated to floodwater storage and 317 acre-feet allocated to a 100-year accumulated sediment storage. The FRS is approximately 4.11 miles long and has a maximum height of 23 feet. An emergency spillway with a width of 260 feet and capacity of 4,800 cubic feet per second (cfs) is located on the north end of the embankment. The maximum release rate from the 7.5-ft x 7.0-ft reinforced concrete box principal spillway is approximately 808 cfs.

The Spook Hill floodway, 2.0 miles long, conveys floodwater from the Spook Hill FRS to the Southern Canal and the Salt River. Floodwaters from the floodway and a wash will be conveyed into a debris basin immediately above the Southern Canal. Floodwaters may be released into the canal through a division box with gates or continue through the Spook Hill floodway to the Salt River.

The debris basin has a total capacity of 48 acre-feet of which 40 acre-feet are allocated to floodwater storage and 8 acre-feet are for sediment. Its purpose is to remove sediment from water used for irrigation. There will also be a division box in conjunction with the debris basin so as to accomplish the diversion of floodwater releases from the structures into the Southern canal.

Signal Butte FRS and Floodway

The Signal Butte floodwater retarding structure was constructed above the Apache Trail near the Maricopa-Pinal County line. This structure will provide floodwater protection from the one percent event. It will have a total storage capacity of 1,540 acre-feet, with 1,365 acre-feet allocated to floodwater storage and 175 acre-feet allocated to a 100-year accumulated sediment storage. The FRS is approximately 1.33 miles long and has a maximum height of 38.0 feet. An emergency spillway with a width of 140 feet and a capacity of 2,450 cfs was located on the east end of the embankment. The maximum release rate from the 36-inch diameter reinforced concrete pipe principal spillway will be 160 cfs.

A floodway 1.6 miles long will convey floodwater from the 36-inch diameter reinforced concrete pipe principal spillway to the Spook Hill FRS. This floodway is lined with reinforced concrete with a stilling basin at the lower end and has a capacity of 1,200 cfs.

Apache Junction FRS and Floodway

The Apache Junction floodwater retarding structure was constructed north of the Town of Apache Junction. This structure will provide floodwater protection from the one- percent event. It has a total storage capacity of 635 acre-feet with 540 acre-feet allocated to floodwater storage and 95 acre-feet allocated to a 100-year accumulated sediment storage. The FRS is 1.66 miles long and has a maximum height of 22 feet. An emergency spillway with a width of 100 feet and a capacity of 1,875 cfs is located on the southeast end of the embankment. The maximum release from the 30-inch reinforced concrete pipe principal spillway is approximately 97 cfs.

The Bulldog floodway, 1.4 miles long, conveys floodwaters from the 30-inch reinforced concrete pipe principal spillway west to the Signal Butte FRS. This floodway is lined with reinforced concrete with a stilling basin at the lower end and has a capacity of 4,700 cfs.

Pass Mountain Diversion and Outlet consists of a 1.2 mile long earth embankment and a 2,800-foot outlet that drains floodwaters from a four square mile area downstream to the Signal Butte FRS.

The original Buckhorn-Mesa project proposal included construction of a FRS on Weekes Wash with an adjoining floodway that would outfall into the reservoir behind Apache Junction FRS. This has not been constructed.

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART II SPOOKHILL FRS

<u>Section 1.0 Description of Dam</u>

Section 1.0 Description of Dam

The Spook Hill Flood Retarding Structure (FRS) is a structural plan element of the Watershed Work Plan for the Buckhorn-Mesa Watershed, Maricopa and Pinal Counties, Arizona. The Watershed Work Plan was prepared by the Natural Resources Conservation Service (NRCS; formerly the Soil Conservation Service, SCS) in January 1963. The watershed heads in the southwest-facing slopes of the Superstition Mountains and drains onto a wide alluvial fan on which valuable agricultural, urban and commercial developments have been constructed. The total original watershed area of Buckhorn-Mesa is 89,983 acres. The watershed is one of three for which concurrent planning efforts were conducted by the NRCS at the request of the District. The northernmost watershed is the "Buckhorn-Mesa", the central watershed is the "Apache Junction – Gilbert", and the southern watershed is the "Williams-Chandler".

1.1 Purpose of Dam

The Spook Hill FRS is one of three flood retarding structural measures designed and constructed under the watershed work plan. The other flood retarding structures are the Signal Butte FRS and the Apache Junction FRS. The purpose of the Spook Hill FRS is to provide flood and erosion control benefits for downstream developments (agriculture, commercial and urban areas). The Spook Hill FRS was designed to control runoff from the 100-year event and the full PMF.

1.2 Dam Location and Features

Spook Hill FRS is located within the City of Mesa. The FRS parallels the Central Arizona Project canal and begins 1/2 mile north of McDowell Road (at Power Road) and ends at 1/4 mile south of Brown Road and 1/4 mile east of Hawes Road. The FRS is about 22 miles east of downtown Phoenix and approximately eight miles west of the City of Apache Junction. Figure 1-1 provides a location map of Spook Hill FRS. The project consists of the FRS structure, principal spillway, and an emergency spillway. The project is part of the Buckhorn Mesa Watershed Protection and Flood Prevention Project, which includes the Signal Butte and Apache Junction flood retarding structures. The Flood Prevention Project was prepared, designed, and constructed by the U.S. Department of Agriculture, Natural Resources Conservation Service.

The reservoir behind the FRS is 232 acres with a capacity of 900 acre-feet. A permanent pool will not be retained in the reservoir, instead, the FRS and reservoir are designed to trap floodwater and store it only for as long as it takes to release it slowly and safely downstream. Reservoir capacity is then restored to handle a future flood.

The emergency spillway is located near the north (right) abutment of the FRS. Construction of the FRS and appurtenant structures was completed in April 1980.

1.3 Physical Features

Spook Hill FRS is a rolled zoned earthfill structure. The length of the FRS is 21,712 feet with a maximum height of 23 feet and a crest width of 14 feet. The reservoir capacity is 900 acre-feet at the emergency spillway crest elevation of 1582.0. The reservoir capacity is approximately 4,000 acre-feet at a maximum water surface elevation of 1591.0 feet. The FRS was designed with 6.3 feet of freeboard (top of dam minus maximum water surface) and 317 acre-feet of sediment storage (100-year). Spook Hill FRS is accessible off Brown Road by a padlocked gate. The maximum recorded impoundment for Spook Hill reservoir is 80 acre-feet with a stage of 6.74 feet at the FRS (January 11, 1993).

The principal spillway, approximately 60 feet long, consists of a gated 7-ft 6-in by 7-ft 0-in concrete box with an uncontrolled overflow at elevation 1577.5 feet. The design outflow is approximately 808 cfs from the principal spillway. The trash rack is located on the upstream inlet gatewell assembly. The gatewell assembly has a 24-in by 24-in slide gate. The outlet of the principal spillway discharges into a tapered sloped-bottomed energy dissipator. The outlet discharges to the Spook Hill Floodway (another structural element of the Buckhorn-Mesa Watershed Project). The Floodway eventually discharges through a sediment basin near the Salt River and then into the Salt River.

The emergency spillway is a reinforced concrete drop structure and is located near the principal spillway and 925-ft from the north (right) abutment of the FRS. The spillway is 260-ft wide with a discharge capacity of 4,800 cfs at maximum water surface elevation of 1584.7 feet. The emergency spillway crest elevation is 1582.0-feet.

The inflow design flood under the current ADWR licensing is the ½ PMF.

Station markers are located every 500-ft along the downstream crest of the FRS. A series of staff gages is located on the upstream slope adjacent to the principal spillway. Settlement monuments are located along the crest and downstream toe of the FRS.

Table 1-1 provides a summary of the physical structure data for Spook Hill FRS.

Table 1-1. Spook Hill Flood Retarding Structure Physical Data.

ITEM (NATDAM ID AZ00175 STATE ID 07.50)	PHYSICAL DATA
Drainage Area	11.4 sq mi
Storage Capacity Sediment Floodwater (100-yr) Total	 317 af 900 af 1,217af
Surface Area Floodwater Pool	 232 ac
Volume of Fill	1,500,000 cy
Elevation Top of Dam	1591.0 ft
Maximum Height of Dam Length of Dam	23.0 ft 4.11 mi
Freeboard	6.3 ft
Emergency Spillway Inflow Design Flood (Design FBH) Crest Elevation Bottom Width Type Percent Chance of Use Emergency Spillway Hydrograph Storm Rainfall (6 hr) Spillway Capacity Freeboard Hydrograph Storm Rainfall (6 hr)	 PMF (NRCS) 1582.0 ft 260 ft RC Drop 1 5.8 in 4,800cfs 13.0 in
Principal Spillway Conduit (reinforce concrete box) Length of Conduit Gated Outlet Elevation Ungated Crest Elevation Capacity at Elev Emergency Spillway Time to release	 7-ft 6-in by 7-ft box 60 ft 1574.5 ft 1577.5 ft 808 cfs less than 10 days
Class of Structure (NRCS)	**C**
Hazard Classification (ADWR)	**High**
Size of Dam (ADWR)	**Small**

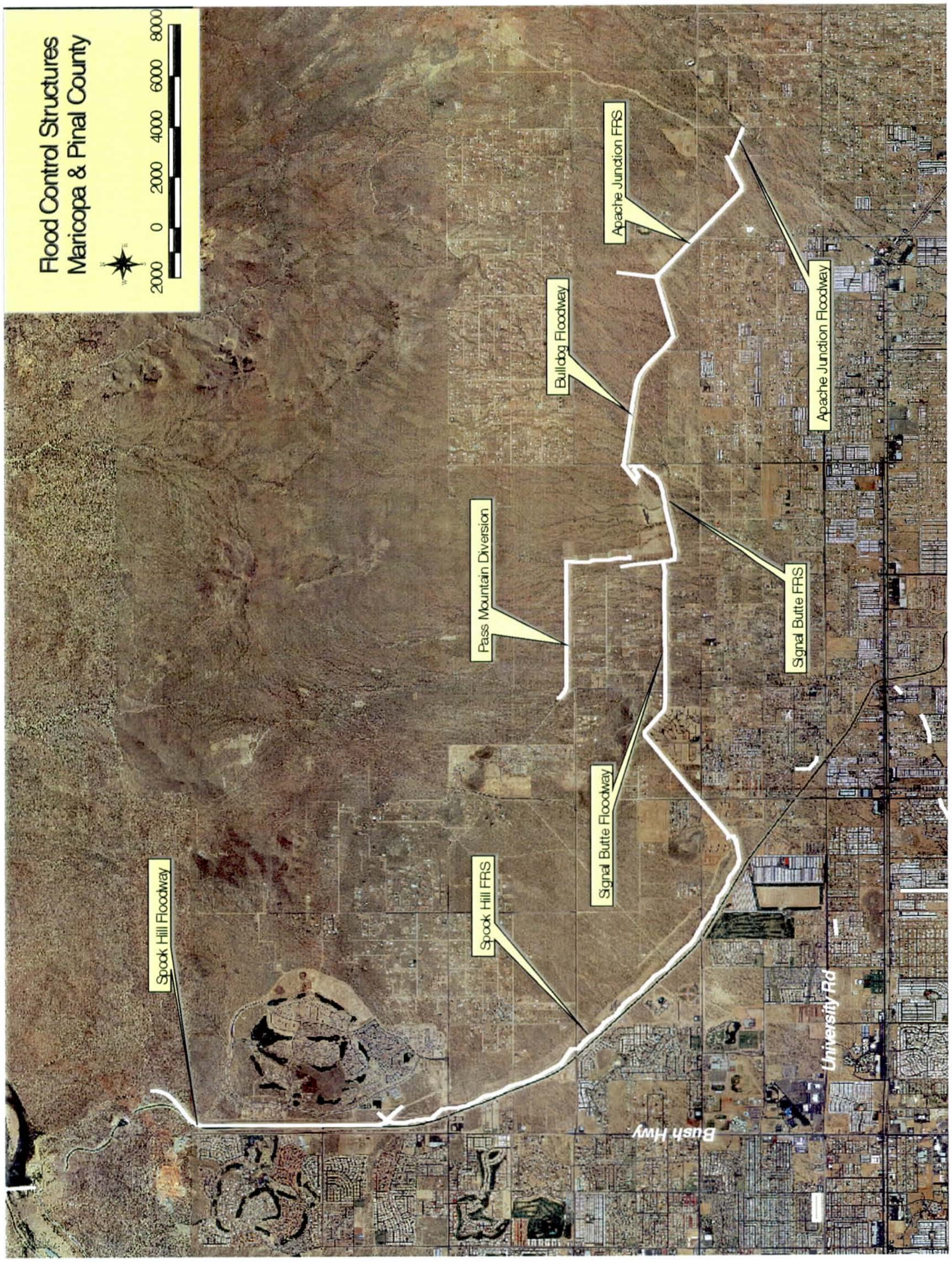


Figure 1-1. Buckhorn-Mesa Watershed Flood Retarding Structures.

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART II SPOOKHILL FRS

<u>**Section 2.0 Technical Review**</u>

Section 2.0 Technical Review

The purpose of the technical review is to review the engineering records related to the dam, it's construction, and through this review familiarize the project team with the structure, familiarize the team with the history of the structure, and acquaint the team with the basis of analysis and design. The review also provides for a review of original design criteria and design guidelines. The final design was compared, to the extent practical from review of existing and available records, to the original design and design guidelines.

This section of the report presents a discussion of the dam design criteria under which the dam was originally constructed versus the ADWR dam safety rules and regulations for jurisdictional dams. This section also includes a discussion of the record modifications to the dam that were constructed as related to dam safety issues and modifications to the dam that are not directly dam safety related . A discussion is presented that focuses on past dam safety signs of distress.

This section of the report also presents a review of the technical documentation for the structure. The review of the technical documentation was limited to the available reports, studies, investigations, construction plans and as-builts, specifications, and office correspondence collected as part of this study. The purpose of the review of the technical documents is to assist in the engineering assessment of the structure. The technical document review, along with the field examinations, provided a basis to evaluate the structure regarding operational adequacy, structural stability, and dam safety rules and regulations.

2.1 Dam Design Criteria

Spook Hill FRS was originally analyzed and designed by the NRCS in the early to mid-1960's. The hydrology for the structure has been updated several times in the late 1970's and mid-1980's by the NRCS to account for planning considerations for the Buckhorn-Mesa structures (flood retarding structures and floodways). The basis of design for the FRS was originally founded in the NRCS publication "Engineering Memorandum EM-27" which is the precursor manual to "Technical Release TR-60: Earth Dams and Reservoirs" the present NRCS design guideline for earth dams. The FRS has been analyzed and designed according to TR-60.

Appendix A (of this Part II) provides a summary of the original NRCS design criteria (based on TR-60) for the dam and compares the criteria against ADWR dam safety rules and regulations for jurisdictional dams. Spook Hill FRS was designed to detain the 100-year event using NRCS criteria. This design event was used to size the principal spillway and reservoir volume. The hydrology for the emergency spillway design and freeboard design flood is discussed below in the Hydrology section following NRCS criteria. According to ADWR criteria, the Spook Hill FRS Inflow Design Flood (IDF) for emergency spillway capacity is the ½ probable maximum flood (PMF). Current (June

2000) ADWR regulations could change the size classification of the dam. The new size classification combined with the hazard classification could require that the IDF be changed. The IDF could be changed to be between the ½ PMF and the full PMF, or to the full PMF. The NRCS, in their hydrologic study of Spook Hill FRS, have designed the dam not to overtop during the passage of the freeboard hydrograph, which was based on the full PMP/PMF (see below – Hydrology).

2.2 Dam Classification

The NRCS in their TR-60 guidelines uses a three-category "hazard" classification system. The three categories or classes are established to permit the association of criteria with the damage that might result from a sudden major breach of the earth dam embankment.

The NRCS classifies the Spook Hill FRS as a Class C structure. Class C structures are structures located where failure may cause loss of life, serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads.

The Arizona Department of Water Resources rules and regulations for jurisdictional dams classifies Spook Hill FRS as a high hazard, small size dam. Current ADWR Regulations could change the size classification of the dam.

2.3 Structure Modifications Related to Dam Safety

The original construction of the embankment dam was completed in April 1980. Construction was completed at the same time for installation of landscaping treatments and underground irrigation for the Spook Hill FRS. The landscaping treatment included providing seed mixes on the embankment slopes and borrow areas as well as planting of native trees and cacti (both off-slope). The purpose of the landscaping treatment and irrigation system was to reduce or minimize embankment slope erosion that has been experienced at other NRCS embankment dams in the vicinity as well as to attempt to reduce the rate of embankment desiccation and therefore, embankment cracking. The irrigation system installed as part of the landscaping treatment has since been turned off and is no longer in use. The system basically has been abandoned in-place. Remnants of the irrigation system were visible during the recent field inspection of the dam (September 2000). A review of the office correspondence and construction reports (from the District and ADWR) indicates that the irrigation system has a history of breakage and failure. Failures and breakage of the irrigation system have caused severe slope erosion of the embankment. The NRCS office correspondence includes discussions in which the NRCS agreed to turn off the irrgation system at Spook Hill FRS as the effect of the system of minimize embankment desiccation was not confirmed and whether the approach was actually effective in reducing or minimizing embankment cracking.

2.4 Structure Modifications Non-Dam Safety Related

The "as-built" record drawings for Spook Hill indicate two City of Mesa waterlines were relocated as part of the original construction of the embankment. The waterlines are 12-inch (in) cast iron water pipes and are located in Usery Pass Road and Hermosa Vista Drive. The waterlines pass under the dam and do not extend into the foundation or embankment. The waterlines have been encased in reinforce concrete with 20-ft on center 5-ft 6-in by 7-ft 6-in anti-seep collars. The Usery Pass waterline also has a 2-in gas pipe encased adjacent the waterline. Plans were reviewed for a 15-in sanitary sewer that cross under Spook Hill FRS at Hermosa Drive. The sewer becomes a 16-in ductile iron pipe encased in reinforced concrete as it passes under the dam.

Various utilities have been constructed in the Brown Road crossing of the Spook Hill FRS. These utilities include a Mountain States telephone 1/3-in direct buried cable, three City of Mesa waterlines (one 20-in and two 36-in diameter waterlines), and two Salt River Project 5-in diameter conduits. The as-built plans for the 20-in waterline indicates that the waterline crossing of the dam included three cutoff collars. None of the utility plans indicated if the waterlines were encased either by an outer pipe or by reinforced concrete.

Other utility crossings of Spook Hill FRS occur at Lost Dutchman Road (Brown Road in Maricopa County) and McDowell Road. Indications of these crossings are documented in ADWR Office of Dam Safety files and District files. It is recommended that an extended research be conducted of all District dams for documented utility crossings. The database should include at a minimum the type of utility, utility owner, size of utility, depth of utility, encasement types, cross reference to dam, construction plans and specifications, and permits.

Other modifications or repairs to the structure included ongoing slope erosion repairs and hydroseeding. District records of these types of maintenance activities are not detailed sufficiently to indicate the limits and extent of hydroseeding and slope erosion repair.

2.5 Dam Safety Signs of Distress

Previous inspection reports for Spook Hill FRS indicates that the structure has been and continues to be subject to minor transverse and longitudinal cracking. Inspection reports for Spook Hill FRS were reviewed from the latest report (including ADWR and District) of November 1999 back to October 1987. KHA also conducted an inspection of Spook Hill FRS in September 2000 and found several longitudinal cracks on the crest of the dam along the structure longitudinal centerline. These cracks have a very small crack width (on the order of 2-mm or less). The September 2000 inspection, however, did not locate all previously reported transverse and longitudinal cracks. The noted previous cracks may have been covered with soil and therefor have not manifested themselves for visual observation. District inspection reports are available at the District. ADWR has provided the District with recent ADWR dam safety inspection reports for Spook Hill

FRS. The inspection log from the September 2000 inspection conducted by KHA is provided as part of Section 3.0 of this Part II. Note that Spook Hill FRS was not constructed with a central longitudinal filter as was done on several other NRCS structures in the vicinity of Spook Hill (e.g., Apache Junction FRS, Powerline FRS, Vineyard Road FRS, and Rittenhouse FRS). The extent of longitudinal cracking observed in the September 2000 inspection was not severe. This statement is based on local observations of other NRCS structures such as Rittenhouse FRS and Vineyard Road FRS were cracking, both transverse and longitudinal, are relatively more frequent, deeper, and wider in size.

Previous inspection reports have also noted severe erosion rills and gullies that have formed on both the downstream and upstream embankment slopes. The erosion is extensive and makes discovery of transverse cracks on the embankments difficult. The erosion has extended below the 1-foot topsoil terracing that was constructed as part of the original landscaping treatment for the dam. The inspection report for the September 2000 inspection is included in Section 3.0 of this Part II and includes inspection photographs that illustrate the slope erosion.

The September 2000 inspection and previous ADWR inspection reports have noted transverse cracking in the concrete control sill of the emergency spillway structure. These cracks extend the full height of the face of the sill and appear to be spaced equidistantly. Observed cracks widths are very small (on the order of 1mm or less).

2.6 Review of Technical Documentation

Hydrology- The Buckhorn-Mesa Watershed Project was outlined in Part I, Section 3.0. The structural elements of the watershed project include three flood retarding structures and several interconnecting floodways. The three flood retarding structures capture and impound stormwater from their respective upstream watersheds. The floodways (Bulldog, Signal Butte, and Spook Hill) convey the discharges from the principal spillways of the dams and also serve to intercept stormwater from their respective upstream drainage areas. The interception of stormwater is accomplished through the use of side inlets into the floodways. Discharges from the principal spillway of Apache Junction FRS are conveyed into the Bulldog Floodway which then discharges into the impoundment for the Signal Butte FRS. Discharges from the principal spillway of Signal Butte FRS are conveyed into the Signal Butte Floodway which then discharges into the impoundment for the Spook Hill FRS. Discharges from the principal spillway of Spook Hill FRS are conveyed into the Spook Hill Floodway, which then ultimately discharges into the Salt River. Figure 1-1 located in Section 1.0 of this Part provides the layout of the Buckhorn-Mesa structures and floodways.

The NRCS designed the Spook Hill FRS to control the 100-year storm event. NRCS's determination of the 100-year precipitation and runoff was based on the procedures in the NRCS "National Engineering Manual – Section 4 – Hydrology" and the requirements of TR-60 for a Class C hazard structure. The NRCS used three design hydrographs to size the dam. The principal spillway hydrograph (PSH) is the hydrograph used to determine the minimum crest elevation of the emergency spillway. It is used to establish the principal spillway capacity and determine the associated minimum floodwater retarding storage. For a Class C structure, the PSH is based on the one hundred-year precipitation (P_{100}). The emergency spillway hydrograph (ESH) is the hydrograph used to establish the dimensions of the emergency spillway. For a Class C hazard structure, the ESH is based on a watershed precipitation depth according to the following formula: $\{P_{100} + 0.26(PMP - P_{100})\}$. The freeboard hydrograph (FBH) is the hydrograph used to establish the minimum settled elevation of the top of the dam. It is also used to evaluate the structural integrity of the spillway system. For a Class C hazard structure, the FBH is based on a watershed precipitation depth for the probable maximum precipitation (PMP).

The original hydrologic analysis for Spook Hill FRS is summarized in NCRS's 1963 Watershed Work Plan report titled "Buckhorn-Mesa Watershed – Maricopa and Pinal Counties, Arizona". The hydrographs for the 1963 emergency spillway hydrograph (ESH) and freeboard hydrograph (FBH) were based on precipitation depths of 4.0-in and 10.0-in, respectively (6-hr) (NRCS, 1963: Table 3 - Structures Data). The hydrology for Spook Hill FRS was revised by the NRCS from the original hydrology during the time period from approximately the mid-1970's to the late 1970's. NRCS used the TR-20 hydrograph computer program to develop the inflow to the dam from the contributing upstream watershed. The hydrology was revised due to changes in project structure elements and revised drainage subbasin limits. A review of the NRCS documentation revealed that the apparent design precipitation for the Spook Hill FRS for the 100-year, 24-hr storm is 3.81-in; for the ESH - a depth of 5.6-in; and for the FBH - a depth (PMP) of 13.0-in (for a drainage area of 13.56 square miles and an emergency spillway width of 260-ft). A TR-20 model was located in the NRCS documentation that provides both the input and output from the model for the ESH and FBH design storms. The emergency spillway crest elevation used in the model is 1582.0-ft which is the same elevation depicted on the as-built construction plans and the elevation-discharge rating curve for Spook Hill. The maximum water surface elevation for the FBH in the TR-20 model matched the maximum water surface elevation depicted on the as-built plan rating curve (1584.7-ft) (NRCS, Spook Hill Design Vol. 3 - Final Design).

The NRCS documentation regarding the hydrologic analysis conducted for Spook Hill FRS contains what appears to be a number of preliminary TR-20 input and output printouts. It could not be determined specifically from the documents if a complete final design TR-20 was included in the documentation that includes full input and output for the PSH, ESH, and FBH design hydrographs. Specific final analysis of watershed parameters such as subbasin delineations, curve number development, rainfall depth and rainfall distribution, and routing parameters were not readily apparent in the NRCS documents.

The emergency spillway was designed by routing the emergency spillway hydrograph through the spillway. The starting water surface for routing the emergency spillway hydrograph through the reservoir is at the elevation of the sediment pool or at the water surface elevation after 10 days of drawdown, whichever is higher. According to TR-60, the emergency spillway for Class C structures is not to be used during the 100-year event.

The freeboard hydrograph for Class C structures are routed through the reservoir starting at the same water surface elevation as for the emergency spillway hydrograph.

The NRCS peak inflow for the full PMP into Spook Hill FRS is approximately 21,000 cfs with an outflow discharge of 18,340 cfs. The PMF will not overtop the structure according to the NRCS studies (NRCS, Spook Hill Design Vol. 3 - Final Design).

Spillway Inundation Studies – The Flood Control District completed several spillway inundation studies of Spook Hill FRS. Lowry & Associates completed the first study in August 1985. The Lowry study was based on a 100-year storm inflow. Outflow hydrographs were developed using the modified Puls method to route flow through a reservoir assumed full before the 100-year event. Spillway overflows into the downstream floodplain were simulated with a two-dimensional model to determine maximum expected flooding depths, maximum expected runoff velocities, and maximum expected Froude numbers. The Lowry study used flood retarding basin inflow hydrographs developed by the NRCS for the 100-year inflow hydrograph. The Lowry study provides (Lowry, 1985: Figure II-I) the inflow hydrograph for the 100-year event into the dam. The peak inflow is approximately 12,000 cubic feet per second (cfs). The Lowry report does not provide, however, the documentation of the 100-year hydrology, reservoir stage/storage/discharge curves, or other hydrologic parameters for the 100-year event.

The Lowry study and report includes mapping of the downstream inundation area for the 100-year spill in the emergency spillway. The maps depict depths of inundation based on depth ranges (6-in to 12-in; 12-in to 24-in; and over 24-in), flow velocities (based on velocities of 4 feet per second and over 10 feet per second), and areas having Froude numbers greater than one.

McLauglin-Kmetty Engineers (MKE) conducted a second study in October 1990. The analysis presented the results of a study to determine the magnitude and extent of flooding downslope of the Spook Hill FRS (into the City of Mesa) that would occur from either the passage of the Probable Maximum Flood (PMF) through the emergency spillway or a breach of the earthen embankment due to piping failure. The flood inundation analysis was part of technical documentation that was furnished to the Maricopa Department of Civil Defense and Emergency Services to prepare an emergency preparedness plan for the dam.

MKE reviewed the NRCS design hydrology for Spook Hill FRS, which resulted in reevaluation of the inflow flood for the purposes of the inundation study. The PMF was selected as the most critical inflow flood, and the PMP was determined by the procedures in Hydrometerological Report No. 49 (HMR No. 49). The alignment of the as-built Signal Butte Floodway changed from the alignment that was assumed during the design of the Spook Hill FRS and that change resulted in a reduction of drainage area from 13.57 square miles to 11.42 square miles. For the PMF, the MKE study assumed that the Signal Butte Floodway would be contributing 2,100 cubic feet per second into the Spook Hill FRS impoundment prior to the onset of the PMP. For that condition, the water level in the impoundment is at elevation 1583.4 ft at the start of the PMF. The contribution from the Signal Butte Floodway is a more severe PMF condition than was assumed by the NRCS.

MKE used the HEC-1 computer program to develop the PMF and to route the flood through the principal and emergency spillways. The PMF peak inflow was estimated as 52,150 cfs with a maximum water surface elevation of 1590.86 ft. The MKE report states that the PMF does not result in an overtopping of the earthen embankment and therefor failure by overtopping was not deemed to be a critical flood inundation condition.

A two-dimensional computer program was used to model the PMF emergency spillway release. The Diffusion Hydrodynamic Model (DHM) was able to model unsteady backwater effects, ponding, and channel-floodplain interfaces.

The MKE report provides a summary of their review of the NRCS design hydrology. In their summary, MKE states that the NRCS used the TR-20 model to compute flood hydrographs. In the TR-20 model, the watershed was divided into nine subbasin (No. 14 through 22). In that watershed delineation it was assumed that all runoff from subbasins 14 through 17 was diverted to the Spook Hill FRS by the Signal Butte Floodway. That assumption may have been based on a preliminary design concept for the Signal Butte Floodway in regard to discharge capacity, channel freeboard, or berms along the floodway. A second analysis by NRCS was preformed with a separate NRCS program (DAMS2) that was used for spillway sizing, and in that analysis the watershed was modeled as a single basin. The TR-20 subbasin model of the watershed resulted in a peak inflow estimate of 47,315 cfs while the other, single basin model resulted in a peak inflow of 38,045 cfs. The NRCS subsequently used the results of the single basin model analysis to size the emergency spillway and to set the dam crest elevation. Some of the NRCS model input was not accepted by the MKE study for a PMF analysis because the existing conditions of the watershed were different from those that were assumed by the NRCS at the time of design, or because current flood hydrology standards have changed since the NRCS design hydrology was performed.

The MKE review of the NRCS hydrology resulted in the recommendation that the following deviations from the NRCS hydrology be used for estimating the PMF:

1. The rainfall time distribution should be from HMR No. 49.
2. PMF discharges from subbasins 14 through 16 cannot be conveyed to the Spook Hill FRS by the Signal Butte Floodway with the floodway as constructed. This results in a reduction of the effective area for the PMF that can drain directly to the Spook Hill FRS impoundment.
3. The initial condition for the PMF should include a discharge of 2,100 cfs (maximum capacity) from the Signal Butte Floodway to the Spook Hill FRS.

MKE stated that documentation could not be obtained on the development of the NRCS design rainfall. However, copies of TR-20 output indicate that 13.0 inches of rainfall was applied according to the NRCS 6-hour emergency spillway and freeboard volume adjustments and storm distributions. MKE computed the 6-hour local storm PMP to be 12.8 inches. The HMR-49 rainfall distribution is much more intense that the NRCS rainfall and this resulted in a larger peak discharge at the dam than the NRCS inflow design flood. MKE modeled with HEC-1, the NRCS and HMR-49 distribution to verify the NRCS design hydrology and HMR-49 distribution to develop the full PMF for the MKE study. MKE provided a summary of the results of their hydrologic investigation which are reproduced in Table 2-1 and 2-2 below.

Table 2-1. Flood Hydrology Conditions*.

Case (HEC-1)	Rainfall Depth (In)	Rainfall Distribution	Watershed Area (Sq Mi)	Initial Conditions Of Impoundment
A	13.0	NRCS	13.57	Dry
B	12.8	HMR-49	13.57	Dry
C	12.8	HMR-49	11.42	2,100 cfs inflow

* Table II-5 from MKE report

Table 2-2. Results of Flood Hydrology Review Using HEC-1 and Comparison with the TR-20 Results*.

Hydrologic Parameter	NRCS Flood Hydrology Analyses		MKE Hec-1 Results		
	Single Basin	NRCS TR-20	Case A	Case B	Case C
Area (sq mi)	13.57	13.57	13.57	13.57	11.42
Rainfall (in)	13.0	13.0	13.0	12.8	12.8
Runoff (in)	10.28	9.84	9.67	9.58	9.68
Inflow volume (af)	7,438	7,122	7,001	6,935	6,987
Peak Discharge (cfs)	38,045	47,315	45,440	61,010	52,150
Time to Peak (hrs)	3.00	3.26	2.75	2.67	2.75
Peak Spill (cfs)					
Em Spillway	B	C	15,280	18,130	19,560
Prin Spillway	B	C	1,070	1,090	1,100
Embank Overtop	B	C	0	0	0
Combined	18,340	C	16,350	19,220	20,660
Time to Peak Spill (hrs)	4.25	C	4.00	3.75	3.67
Max. Water Surface Elevation (ft)	1,589.69	C	1,589.5	1,589.37	1,590.86

*Table II-6 from MKE report (B: spillway rating deviates from Table II-3 in MKE report; C: Routing was for a different spillway configuration than was finally used)

The MKE study produced flood inundation maps prepared from the DHM model output. The maps prepared provide the time of arrival of the peak discharge downstream from the emergency spillway, provide personal hazard zones which are areas where the flow depth is two-feet or greater, or where the product of the flow depth times the velocity is seven or greater, provide maximum depth contours, and maximum velocity contours.

Dambreak Analysis - MKE also conducted, as part of their Flood Inundation Study, a dam breach analysis for Spook Hill FRS. Due to the length of the dam, three locations for embankment breach were selected to be representative of different downgradient flood inundation scenarios that could be expected. These scenarios are:

1. (Location A) is near the embankment's northern end where the principal spillway conduit passes through the dam embankment;
2. (Location B) is near the embankment mid-length with a maximum embankment section and having extensive urbanization downslope of the dam;
3. (Location C) is near the embankment's southern end.

The piping breach hydrographs were estimated by application of the BOSS Breach program. Geotechnical information from the NRCS dam design documentation was analyzed, and sensitivity analyses of the breach parameters were conducted.

Since one of the objectives of the dam breach analysis study was to estimate the downslope flood potential from a breach in the dam, the location of piping breaches was selected by considering both the location of likely piping breaches and also the downslope consequences of such breaches. The centerline profile of the dam was surveyed in order to evaluate if any settlement had occurred, which could affect the maximum hydraulic head on the embankment. The maximum measured variance from the design dam crest (elevation 1591.50 ft) is about 0.5 ft at Station 110+00 (elevation 1,591.03 ft) which was considered to be insignificant.

The MKE study assumed that the Spook Hill FRS is impounded to the elevation of the emergency spillway crest (1,582.0 ft) in order to develop a piping breach. This is because in order for a piping breach to occur, impounded water must be maintained at a sufficient elevation for a duration long enough to initiate a flow path through a structural deficiency in the embankment, resulting in the formation of a flow path and piping breach.

For Locations A and B, a breach peak discharge of 9,730 cfs and 1.0 hour failure time was estimated by MKE with the use of the Breach program. For Location C, a breach peak discharge of 6,670 cfs was estimated. The lower peak discharge at Location C is attributed to a lower hydraulic head on the breach at Location C (12 ft) as opposed to 15 ft at Locations A and B. MKE provided breach outflow hydrographs for the three breach locations.

MKE accounted for and evaluated the effect of the Central Arizona Project canal on breach hydrographs. The CAP canal is parallel with the embankment and is just downslope from the dam. MKE assumed for the piping breach analysis that the embankment breach dumps a large quantity of earthen embankment into the CAP canal resulting in the instantaneous plugging of the canal. The effect will cause the canal discharge (2,750 cfs) to break out of the canal and to join with the breach release. MKE had superimposed the CAP canal breakout hydrograph on the piping breach hydrographs. The combined breach and CAP breakout hydrographs for Locations A and B and for Location C was input to the appropriate DHM models for the flood inundation analyses.

MKE provides in their report, breach personal hazard zones (breach flood inundation maps) for each breach location from the results of the DHM modeling. Location A contains five personal hazard zones. The maximum calculated velocity is 11.5 ft per second and the maximum depth is 5.4-ft. Location B has a small area within a personal hazard zone. The maximum depth for Location B is 1.8-ft and the maximum velocity is 7.4 ft. There is a long narrow personal hazard zone immediately downstream of the breach at Location C, which encompasses a mobile home community and residential dwellings. The maximum flow depth is 2.1 ft and the maximum velocity is 8.8 ft per second.

Sedimentation - The sediment storage requirements for the FRS is based on local stock pond surveys, studies of sediment sources, and factors that influence sediment yields. The major sources of sediment is from all areas above the dam site. Based on the sediment storage investigation, the NRCS estimated that the sediment storage requirements for the 100-year period was estimated at 317 acre-feet for the Spook Hill FRS.

Capacity Analysis - In March 1997, the District reanalyzed the capacity for the Spook Hill FRS based on new aerial topographic mapping provided as part of FCD Contract 93-51. The District developed new stage-storage-area curves and computed the time to evacuate a full impoundment pool. The District study found the crest of the emergency spillway elevation to be 1583.86 ft (NAVD 1988) which is a gage height of 16 ft for a storage capacity of 1391 ac-ft. The time to drawdown this volume of water was estimated at 5.5 days assuming no inflow into the impoundment or clogging of the principal spillway.

A District analysis conducted in July 1997 compared the design capacity versus the March 1997 computed capacity. The design emergency crest elevation is 1582.2 ft while the FCD 93-51 study determined the crest elevation to be 1583.86 ft or a difference of 1.66 ft. The design capacity of Spook Hill FRS at the emergency spillway crest is 846 ac-ft while the District study estimated the capacity to be 1,391 ac-ft or an increase of 64 percent. The October 1990 Flood Inundation Study discussed above provided a capacity rating table in the HEC-1 model for Spook Hill FRS. The rating table provides for elevation 1582 ft a reservoir capacity of 902 ac-ft.

Section 4.0 of the Part II provides recommendations for further investigations and analyses for Spook Hill FRS. A discussion is presented recommending a new 100-year HEC-1 hydrologic model for Spook Hill be prepared based on the revised rating curves developed by the District as a result of the aerial mapping provided under Contract FCD 93-51.

Geotechnical/Geological - Regional Geology

Regional Geology

The Spook Hill FRS is located within the Sonoran Desert section of the Basin & Range Physiographic Province near the boundary with the Mexican Highlands Section. The latitude and longitude of the center part of the structure is approximately 33°27'27"N and 111°40'27"W based on NAD 83 datum. This portion of the Basin and Range Province is characterized by northwest, north, and northeast trending mountains that rise abruptly to form broad, elongated, deep, sediment-filled valleys produced by block faulting and folding (Geological Consultants Inc., 1999) during past episodes of mountain/basin bounding fault movements (Cooley, 1977). The section boundary is defined on the north and northeast by the McDowell, Usery, Goldfield and Superstition Mountains and on the south by the Phoenix Basin.

The McDowell and Usery Mountains are composed of pre-Cambrian granitic and metamorphic rocks including granite and schist that is often overlain by early to middle Tertiary sedimentary and volcanic rocks. The Goldfield and Superstition Mountains are composed primarily of Tertiary volcanic rocks consisting of andesite, rhyolite, latite and dacite flows and tuffs. The bedrock is also locally overlain by Quaternary age (younger than 1.6 million years ago (mya)) alluvium. The Phoenix Basins, formed by the down faulted blocks, have been partially filled with material eroded from the higher surrounding mountain ranges. With incision of the Salt River and tectonic disturbances in Tertiary time, subsequent stream rejuvenation, combined with climatic changes in early Quaternary time, terraces were developed along the Salt River. These terraces are reportedly buried under valley fill deposits downstream in the Phoenix Basin (Pewe, 1978; Ertec-Western, 1981).

Alluvial materials deposited in the basins consist of heterogeneous unconsolidated mixtures of clay, silt, sand, and gravel which locally contain cobbles and boulders (See Figure 2-1). Near the mountain fronts the older alluvial deposits are commonly well cemented with caliche to a rock-like consistency.

This alluvial material grades from coarser to finer grained with increasing distances from their sources in the surrounding mountains and are variably cemented by calcium carbonate. Rock hills and knobs protrude through the alluvial materials (USBR, 1982 & 1986) as evidenced by Double Knolls, located south of Spook Hill FRS. During the Pleistocene Epoch when climatic conditions were much wetter than current conditions, the alluvial basins were charged through the percolation of excess water flows. This initial charging created large groundwater basins with abundant groundwater resources that in turn have influenced greatly recent development in south central Arizona.

Regional Seismicity

No discussion of seismicity and faulting was presented in the original geotechnical report prepared by the NRCS (formerly the Soil Conservation Service), (1975). A discussion of regional seismicity and faulting was presented in the Phase I Inspection Report prepared for ADWR by Ertec-Western Inc. (1981). A comprehensive evaluation of Arizona seismicity for the development of seismic maps for the State of Arizona was conducted for the Arizona Department of Transportation (ADOT, 1992). The ADOT data base was used to prepare the following description of seismicity and faulting that might potentially impact the Spook Hill FRS.

Historic seismicity within a 100-mile radius of Spook Hill FRS is documented for the period from 1776 through May 2000 (Dubois et al, 1982; U.S.G.S., 2000). Earthquake epicenter locations are depicted on Figure 2.2. Fault structures identified from recent work by ADOT (1992) are depicted on Figure 2.3 for faults within a 100-mile radius from the FRS and on Figure 2-4 for structures within a 25-mile radius. Tables summarizing the seismic source zones or faults, along with their length, estimated displacement, and associated maximum credible earthquake are provided in Table 2-3 and Table 2-4.

Spook Hill FRS is located in the Basin and Range Province in the southwestern portion of Arizona, including Maricopa County and portions of Pinal County, and is astride the seismotectonic zone boundary separating the Sonoran Seismotectonic Zone and the Arizona Mountain Zone (ADOT, 1992) (Figure 2-2 & 2-3). These zones represent distinct coherent crustal blocks with varying degrees of seismic activity and their own characteristic earthquake potential. The following paragraphs, excerpted from ADOT (1992), describe the zones' seismotectonic characteristics:

Sonoran Seismic Source Zone: The Sonoran seismic source zone encompasses approximately 58,900 square miles in southwestern Arizona, southeastern California, and Mexico. The Sonoran zone is characterized by small, scattered mountain ranges [Harquahala Mountains, Big Horn Mountains, Gila Bend Mountains, Maricopa Mountains, South Mountain, Phoenix Mountains, White Mountains, Sierra Estrella Mountains, Sand Tank Mountains and San Tan Mountains] and large flat plains and valleys [Harquahala Plains, Hassayampa Plain, Rainbow Valley, Salt River Valley, Paradise Valley, and Chandler Basin]. Some of these ranges and valleys are locally aligned but overall the province has no preferred directional trends. Mountains constitute approximately 20 percent of the total province area and are generally surrounded by broad pediments indicating relative geomorphic maturity. Elevations range from approximately 500 feet to 1,500 feet in the valleys to about 3,000 to 4,000 feet in the mountainous areas. Generally, local relief rarely exceeds 2,500 feet and is generally about 1,000 to 2,000 feet.

Geodetic data suggests the Sonoran zone is tectonically stable compared to the tectonically active regions in California (Burford and Gilmore, 1982). The geomorphology of river terraces along the Colorado and Gila Rivers provides longer-term verification of this tectonic stability (Schell and Wilson, 1982; Arizona Public Service Company, 1974) indicating no substantial crustal warping during late Quaternary time.

Although the Sonoran zone exhibits basin-and-range-type geologic structure, it has not experienced extensive block-faulting typical of the tectonic regime since Pliocene and possibly late Miocene time (Schell and Wilson, 1982; Menges, 1983). Presently, the zone has very little tectonic activity. Earthquakes are rare and of small magnitude and the faults are very minor. The Sonoran zone is relatively aseismic compared to adjacent zones to the northeast and southwest. The largest historical earthquake within the Sonoran zone was the magnitude 5.0 event that occurred in the southern part of the zone in 1956. The maximum credible earthquake is estimated to be $M_w = 6.5$ although events this large should be exceedingly rare.

In this zone there are only a few young faults and these are very minor features. Except for the Sand Tank fault, most of these faults are in proximity to the Colorado River Trough near Blyth, Needles, and Topock. These faults are short (two to eight miles) and discontinuous with low, subtle scarps indicating low rates of activity and small-magnitude earthquakes. For determining the zone recurrence interval, earthquakes of magnitude 6 were assumed to have been associated with these surface ruptures. The age of these events are poorly constrained but they appear to have occurred over the latter part of the Quaternary. Assuming that they occurred within the past 10^5 years, the average recurrence for the zone as a whole would be about 25,000 years. In addition to such events associated with surface rupture, similar recurrences should be expected for random earthquake events.

In summary, the Sonoran zone represents a nearly stable block between tectonically active regions to the northeast and southwest. The zone can be distinguished by its paucity of earthquakes, few short Quaternary age faults, mature physiography, and thin crust.

Arizona Mountain Zone: Spook Hill FRS is less than 5 miles southwest from the boundary of the Arizona Mountain Zone. This zone has an area of about 38,000 square miles and forms an arcuate belt around the southern margin of the Colorado Plateau and the Plateau margins seismotectonic zones. The Arizona Mountain Zone encompasses a variety of mountain ranges, plateaus, and valleys between the relatively flat, high elevation Colorado Plateau to the north and the lower elevation Sonoran Zone to the southwest. Geomorphic features (mountains and valleys) were produced by erosional down cutting related to regional uplift and extensional block faulting (ADOT, 1992).

Rock units exposed within the mountainous areas are composed of nearly every rock type in the state. Predominant rock types are Precambrian igneous and metamorphic rocks and Mesozoic through Tertiary age volcanic and sedimentary rock. The wide variety of rocks is a direct result of uplift, extensional faulting, and erosion of the fault blocks exposing the deeper and older basement crystalline rocks that the overlying stratigraphic sequence.

Major neotectonic (post-Miocene age) faults, typical of the Basin and Range tectonic style, lie near the valley margins and separate down-dropped valley blocks. This zone has abundant hot spring activity and a high heat flow. The rate of faulting is slow. Major down faulted block structures are Aubry Valley, Chino Valley, Verde Valley, Tonto Basin, northern San Pedro Valley, northern San Simon Valley, Lordsburg Basin, and San Augustin Plain. In Arizona, major faults and their corresponding fault block structures generally trend north-northwesterly and northwesterly. Faulting is characterized by several young Quaternary age northwest-southeast trending normal faults such as those found in the Verde Valley and Chino Valley located north of Prescott, Arizona.

Seismicity in this zone includes small and moderate magnitude earthquakes. The largest recorded earthquake (magnitude 5.2) epicenter occurred near Prescott in February 1976. The maximum earthquake associated with this zone's characteristic fault, the Big Chino Fault, is expected to be about magnitude 7.25. The maximum random earthquake, not considering discrete fault zone seismic sources, is expected to be about magnitude 6.75. Recurrence intervals determined from field investigations are estimated to be 20,000 to 30,000 years (ADOT, 1992)

Two other seismotectonic zones are within a 100-mile radius of the Spook Hill FRS including:

- Southwestern Plateau Margin Zone
- Southeastern Plateau Margin Zone

Southwestern Plateau Margin Zone: Spook Hill FRS is approximately 73 miles southwest from the boundary of the Southwestern Plateau Margin Zone. The southern margin of the zone is near the Mogollon Rim, a prominent escarpment marking the edge of the Colorado Plateau physiographic province (ADOT, 1992).

Rocks of the zone primarily comprise upper Paleozoic and lower Mesozoic sedimentary rock and volcanic rocks that are of predominantly Cenozoic age including those of the Pliocene and Pleistocene Epoch.

The Southwestern Plateau Margin Zone has numerous neotectonic faults. These faults comprise numerous minor features of short length to several major lengthy faults with relatively small displacement. The largest of these faults are the Sinyala-West Kaibab system and the Bright Angel system.

Seismicity of the zone is one of the more active in Arizona with about the same number of earthquakes as the Arizona Mountain Zone. The largest recorded event was the 1959 Fredonia earthquake of about magnitude 5.6. Reanalysis of the 1912 Grand Canyon/Marble Canyon earthquake resulted in an estimated magnitude of 6.2. There is no evidence of modern surface faulting in the zone. The maximum credible earthquake is estimated to be about $M_w = 6.5$.

The Southwestern Plateau Margin seismic source zone is characterized by low-activity Quaternary age faults and moderate seismicity. It is differentiated from the Arizona Mountain Zone by is physiography and lower rate of faulting activity, and from the Southeastern Plateau Margin zone by its higher seismicity and more numerous neotectonic faults.

Southeastern Plateau Margin Zone: At its closest point, the Spook Hill FRS is approximately 70 miles southwest from the boundary of the Southeastern Plateau Margin Zone. The southern margin of this zone extends from the central part of the Mogollon Rim eastward to the Rio Grande Rift zone in New Mexico. (ADOT, 1992).

Rocks of this zone are similar to those found in the Southwestern Plateau Margin zone. Cenozoic age volcanic rocks occur in three major fields: the Springerville, the Zuni-Bandara, and Mount Taylor volcanic fields.

Similar to the Southwestern Plateau Margin Zone, the Southeastern zone has several neotectonic faults that are expressed in the same northeast and northwesterly intersecting pattern. Very few Quaternary faults are known to exist in this zone. This may be partly due to some faults being covered by extensive late Quaternary age volcanic flow (ADOT, 1992). This seismic source zone is characterized by low to moderate historical seismicity. There has been no earthquake with a magnitude in excess of five. The maximum credible earthquake is estimated to be about $M_w = 6.5$.

In summary, the zone is characterized by young volcanic activity, a low to moderate level of seismicity, and few Quaternary faults (ADOT, 1992).

Table 2-3. Summary of Faults & Fault Zones Within 25 Miles of Spook Hill FRS.

Seismic Source Zone or Fault		Length (miles)		Displacement		Earthquake
Number	Name/Location	Zone	Longest Segment	Latest Age	Slip Rate	Maximum Credible
141	Sugarloaf Peak Fault: 20 miles West of Roosevelt Dam, AZ	6	3	H	-	6.75
142	Rolls Fault: 20 miles Southwest of Roosevelt Dam, AZ	6	3	L/M & E/P	-	6.5

* See Figures 2-3 and 2-4 for a listing of abbreviations and meanings.

Table 2-4. Summary of Faults & Fault Zones Within 100 Miles of Spook Hill FRS.

Seismic Source Zone or Fault		Length (miles)		Displacement		Earthquake
Number	**Name/Location**	**Zone**	**Longest Segment**	**Latest Age (1)**	**Slip Rate**	**Maximum Credible**
21	Railroad/Verde River: 9 miles North-Northwest of Cottonwood, AZ	12	-	?	-	6.75
22	Verde Fault: Southwest side of Verde Valley, Yavapai County, AZ	38	17	H/L	0.01 to 0.05 mm/year	7.25
25	Prescott Valley Grabens: 10 miles North-Northwest of Prescott, AZ	5	1	L/M	0.07 to 0.2 mm/year	6.5
36	Sand Tank Fault: 7 miles E-Southeast of Gila Bend, AZ	2	-	H	0.01 to 0.04 mm/year	6.5
91	Date Fault: Northwest of Wickenburg near town of Date, AZ	2	-	?	-	6.5
92	Wagoner: 20 miles northeast of Wickenburg, AZ	4	-	?	-	6.5
93	Lake Pleasant: North of Lake Pleasant, 36 miles N-Northwest of Phoenix, AZ	3	-	?	-	6.5
123	Munds Park Fault Zone-North Segment: 5 miles West of Flagstaff, AZ	15	7.5	M/E	-	7.0
129	Chavez Mountain Faults: 40 mi. SE of Flagstaff, AZ; SE Side of Chavez Mts.	25	10	?	-	6.75
130	Turret Peak Fault: 22 miles South of Camp Verde, AZ	7	-	Qy	-	6.75
131	East Verde River Fault: 14 miles West of Payson, AZ	4	-	?	-	6.75
132	Deadman Creek Fault Zone: 30 miles Northeast of Carefree, AZ	11	-	?	-	6.75
133	Horsehoe Dam Fault Zone (Tangle Peak Fault): 18 miles Northeast of Carefree, AZ	13	7-8	L/M	0.007 mm/year	6.75
134	Seven Springs Fault: 13 miles North of Carefree, AZ	3	-	?	-	6.5
135	Carefree Fault: 5 miles East of Carefree, AZ	8	4	?	-	6.5
136	Alder Creek Fault Zone: 26 miles Northwest of Roosevelt Dam, AZ	7	4	Qy	-	6.5

Seismic Source Zone or Fault		Length (miles)		Displacement		Earthquake
Number	Name/Location	Zone	Longest Segment	Latest Age (1)	Slip Rate	Maximum Credible
137	Tonto Basin-Northwest Fault: Southwest Side of Roosevelt Lake, AZ	9	3	?	-	6.5
138	Tonto Basin-Central Fault (Punkin Center Fault): 10 mi. NW of Roosevelt Dam, AZ	3	2	?	-	6.5
139	Two Bar Mountain (North & South): 2 miles Southeast of Roosevelt Dam, AZ	2	-	?	-	6.5
140	Gold Gulch Fault-West Branch: SW Side Roosevelt Lake, 11 to 24 mi. NW of Globe, AZ	6	-	?	-	6.5
141	Sugarloaf Peak Fault: 20 miles West of Roosevelt Dam, AZ	6	3	H	-	6.75
142	Rolls Fault: 20 miles Southwest of Roosevelt Dam, AZ	6	3	L/M & E/P	-	6.5
143	Miami Fault: West side of Miami, AZ	12	-	?	-	6.75
144	Picketpost Mountain Fault: 7 miles West of Superior, AZ	2	-	?	-	6.5
145	China Wash Scarp: 6 miles Northeast of Florence, AZ	3	-	?	-	6.5
146	Muscal Creek: Muscal Mountains, 16 miles Southeast of Globe, AZ	3	-	?	-	6.5
147	Antelope Flat Scarps: 28 miles East of Globe, AZ	3	-	?	-	6.5
148	Mammoth Fault: 22 miles Southeast of Hayden, AZ	9	-	?	-	6.5
149	San Manuel Fault: 8 miles East of San Manuel, AZ	4	2	?	-	6.5

* See Figures 2-3 and 2-4 for a listing of abbreviations and meanings.

Site Geology and Soils

The Spook Hill FRS is located in the Sonoran Desert Subprovince of the Basin and Range Physiographic Province near the boundary with the Mexican Highlands Section. The Spook Hill FRS is situated approximately twelve miles west of the Superstition Mountains and about five miles southwest of the Goldfield Mountains. Alluvial fans extending from the base of this mountain front coalesce to form the broad, gently sloping surface of the alluvial basin. The topography of the area consists of sparsely vegetated, flat desert interrupted by narrow, shallow washes where vegetation is concentrated. The ground surface slopes downward to the west-southwest. Depth to granite bedrock ranged from nil to about 50 feet below ground surface along the centerline of the dam (SCS, 1975).

The FRS is founded on Quaternary-Tertiary age shallow sedimentary units consisting of alluvial fan deposits derived from the nearby Usery Mountains and Quaternary age to recent stream channel deposits, which occupy the ephemeral washes. The sedimentary sequence overlies a near surface granitic pediment (Ertec, 1981).

The dam is underlain by relatively thin soils that are reportedly low density, dry, and non-cohesive fine to coarse-grained silty sands, sandy silts, and thin gravel lenses with thicknesses up to six (6) feet. Based on the SPT, the soil density increases from loose to very dense where a heavy caliche hardpan and weathered granitics are encountered at shallow depths (Ertec, 1981).

Groundwater in the immediate site area is poorly defined because the shallow alluvial sediments are barren and the granitic basement does not effectively transmit water. According to the Bureau of Reclamation (1976), regional water levels west of Spook Hill FRS were about 600 feet below ground surface (elevation 990 MSL). No decline in regional ground-water levels was recorded between 1964 and 1972. Because of the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment, subsidence due to groundwater withdrawal should not be a problem (Ertec, 1981).

Foundation soils of the principal spillway are reportedly uniform, shallow, gravelly caliche overlain by thin loosely consolidated, non-compressible silt. As built construction drawings indicate the emergency spillway is founded on soft, gravelly, poorly to moderately indurated caliche and compacted structural backfill (Ertec, 1981). According to the SCS (1975), only minor erosion of the emergency spillway was anticipated downstream from the outlet. However construction of the Central Arizona Project canal crosses the emergency spillway outlet. Modification to the emergency spillway has resulted in spillway outlet being lined with large stone ungrouted, grouted riprap, and reinforced concrete downstream from the drop structure.

Depth to weathered granitics found at the dam site ranged from surface exposures (outcrops) to 23 feet. No faulting was reported by the SCS (1975) nor identified during the Phase I dam safety investigation conducted by Ertec (1981).

The dam site design investigation was conducted by the U.S.D.A. Soil Conservation Service (now the NRCS) in October 1975. The stratigraphy of the site was defined on the basis of 73 exploratory borings drilled to depths ranging from 8 feet to 44 feet below ground surface. A summary of the SCS subsurface exploration program is presented in Table 2-5. No groundwater was observed in the borings drilled or backhoe test pits excavated along the dam centerline nor the principal or emergency spillways or in test pits excavated in borrow areas (Ertec, 1981).

Table 2-5. Subsurface Exploration Program Summary Spook Hill FRS.

Structure	Drill Holes	Depth Range (Ft)	Test Pits	Depth Range (Ft)
Dam Centerline	43	8-44	39	2-15
Emergency Spillway	24	8-30	2	(?)
Principal Spillway	6	15-20	--	--
Borrow	--	--	44	2-6

Open-end field permeability tests were conducted at 5 locations along the dam centerline. Three tests in the SC-CL material demonstrated permeability values of 3.3 ft^3/ft^2/day; six tests in SM, SP and GP materials exhibited permeabilities ranging from 62.2 to 100.6 ft^3/ft^2/day (Ertec, 1981). Results of these tests are summarized in Table 2-6.

According to the SCS (1975) soils consist primarily of a fine to coarse-grained, silty sand from Station 88+00 to about Station 200+00, and are sandy silt, with fine gravels from Station 200+00 to Station 304+00. These horizons average about three feet thick, but range up to six feet thick. The upper soil horizon tends to be thinner in the segment from Station 200+00 to Station 304+00. In the segment from 88+00 to 200+00, the upper horizon is underlain by a layer of fine to coarse-grained sand that is slightly cemented with minor amounts of clay. The SP-SC horizon averages about 2.5 feet thick. In the segment from 200+00 to 304+00, there is no intermediate soil horizon between the surface soil horizon and the consolidated, cemented caliche beds (SCS, 1975).

The density of the uppermost soil horizons increases rapidly from a very loose condition at the surface to a very dense consistency at relatively shallow depths. Standard penetration test data indicate an increase in density with depth in the upper soil horizon (SCS, 1975).

The surface soils are underlain by deposits which are relatively well consolidated by induration and cementation and consist of massively bedded, gravelly siltstone which grades into a gravelly caliche in the vicinity of Station 200+00 along the dam centerline (SCS, 1975). Standard penetration tests in these pre-consolidated sediments indicate a very low potential for further consolidation, and a relatively incompressible foundation (SCS, 1975).

In the vicinity of Station 223+00, there is a buried channel filled with silty-sand (SM) material. This condition could possible exist at any point along the dam centerline. Test data indicated the channel deposit has undergone considerable consolidation but it is highly permeable when compared to the foundation soils on both side of the buried channel. There was no surface expression of the buried channel identified by the SCS (1975).

Along portions of the dam centerline, granite was encountered at the surface and in 24 boring drilled along the centerline from Station 318+00 to 386+00. Depth to granite in the drill holes ranged from zero feet to about 23 feet below natural ground surface. The average depth to granite in the drill holes is about eight feet.

Table 2-6. Open-End Field Permeability Test Results Spook Hill FRS.

Station	Hole No.	Test Interval (Ft)	Permeability ($ft^3/ft^2/day$)	Material (USCS)
112+00	2	6.5	7.6	SP-SC
112+00	2	12.0	62.1	Siltstone
223+00	7	17.0	87.8	SM
280+00	14	8.0	9.3	ML
280+00	14	15.0	3.3	ML
333+00	24	6.5	97.7	SP
333+00	24	13.5	92.1	GP
338+00	27	8.5	94.5	SP
338+00	27	23.0	100.6	GP

Conditions in the vicinity of the proposed principal spillway found to consist of uniform, relatively shallow foundation of earthy, gravelly, cream to tan colored caliche. This well consolidated material is overlain by a thin mantle of sandy, tan-colored silt of a very loosely consolidated nature. This condition exists from Station 0+00 to Station 20+00. Standard penetration tests at selected locations along the principal spillway centerline indicate that the foundation is relatively noncompressible (SCS,1975).

Foundation soils of the emergency spillway, at about Station 294+50, are reportedly founded on poorly to moderately indurated caliche-cemented soils. As-built construction drawings indicate the emergency spillway is founded in loose to slightly dense silty sand (SM) that is poorly consolidated. The detailed geologic investigation report states the emergency spillway, in the opinion of the SCE investigator, "…the proposed crest section will be adequately stable but not incapable of sustaining damage during flow" (SCS, 1975). No other information concerning the erosion potential of the emergency spillway could be found in NRCS or District files. Granite underlies the caliche at depths of 15 to 20 feet below ground surface. In areas where the granite is shallower, (0-ft to 10-ft) the caliche layer is absent.

A time-drawdown slope stability analysis was performed by the SCS with a water surface elevation established with the phreatic line considered fully developed. It was determined that the phreatic surface could not develop at any level other that the crest of the principal spillway. The Swedish Circle analysis was use to assess the downstream slope for steady seepage conditions, with the water surface at the crest of the emergency spillway and assuming a slope of 2:1 (horizontal to vertical). The minimum factor of safety against failure was 1.24 (SCS, 1975).

The embankment design stability analysis, based on a review of the NRCS (SCS) records, used a time-drawdown analysis with a water surface elevation established with a phreatic line fully developed. The analysis for the downstream slope for steady seepage condition with the water surface at the crest resulted in a minimum factor of safety of 1.24. The results of the embankment stability analysis originally conducted for Spook Hill FRS does not satisfy the current ADWR criteria for minimum factors of safety for the end of construction, steady state no seepage or instantaneous drawdown-upstream slope (R12-15-1216, (B) (1) (c) (i) Table 5).

The NRCS (SCS) records reviewed for this investigation do not state that seismic design criteria were included in the embankment stability analysis.

Considering the high hazard classification for the Spookhill and because the original design analysis does not apparently meet current ADWR embankment stability criteria, it is recommended the embankment stability be re-evaluated based on the current conditions and design criteria.

A settlement analysis performed by the SCS (1975) indicated structural settlements would be minimal and the maximum settlement would occur near the upstream edge of the dam. The cumulative foundation and embankment settlements were calculated by the SCS to be about 0.40 feet in the vicinity of Station 222+35.

Ground Subsidence

Due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment, subsidence due to groundwater withdrawal is not expected to be an issue at the Spook Hill FRS. It appears that the Spook Hill FRS is located on the Usery Mountain granitic pediment with bedrock ranging in depth from the surface to a relatively shallow depth of 23 feet beneath the FRS structure.

Earth Fissures

Due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment on which the Spook Hill FRS is founded, earth fissuring should not be a issue. The nearest ground subsidence-related earth fissure is about two and one-half miles south of the south end of the FRS.

Subsidence and Earth Fissure Monitoring Program

The Spook Hill FRS is located near an area of active ground subsidence and earth fissures. However, due to the presence of shallow granite pediment in the FRS area, earth fissuring is not expected to impact the Spook Hill FRS. Likewise, ground subsidence at the FRS is expected to be negligible. The Spook Hill FRS should be included in an area-wide monitoring program because of its proximity to the ground subsidence area and associated earth fissures. This recommendation is repeated in Section 4.0.

Construction Plans/Specifications/Construction Methodology - Construction of the Spook Hill FRS was accomplished under contract to Mardian Construction Company.

The completion date of the construction of the dam and landscape treatment is April 10, 1980. Construction observation reports are available for this dam and include observation reports by ADWR. A review of the project as-built plans indicated no significant changes were made to the dam design during construction (see Sheets SH 1 - 9). Typical dam cross sections show the embankment was constructed symmetrically with respect to the dam centerline(see Sheet SH 8). The cutoff trench centerline was placed on the upstream side of the dam at a distance of 10-ft from the dam centerline. The foundation for the dam was prepared by excavating approximately 3 to 6 feet into existing ground to remove unsuitable materials and to expose the firmer siltstone and caliche layers. The embankment was constructed in compacted earthen lifts with proper moisture contents.

The primary earthfill embankment materials placed in the embankment according to NRCS documents is termed "Type 2" materials and is indicated on the as-built plans. Type 2, according to the Spook Hill FRS construction specifications, consists of silt, silty sand, gravelly silt, gravelly silty sand, sand, gravelly sand, clayey gravelly sand and clayey sand. The material was specified to contain a minimum of 15 percent passing the No. 200 sieve when determined on a dry weight basis in accordance with ASTM D 1140.

In general, it is a good practice to place less permeable material on the upstream slope of a dam. The specifications for Spook Hill show two types of material on the upstream half of the dam as Type 1 and Type 2. The major difference in these materials is Type 1 has a plasticity index (PI) of 5. A PI of 5 indicates more clay content. Both the Type 1 and Type 2 show a minimum fines content of 15 percent which can be either silts or clays. So both Type 1 and Type 2 has the same fines content but Type 1 has more clay than silts. Clay particles are more desirable for the construction of earth embankment dams. As a reference the State of Arizona allows a PI of 5 in base course material for highway construction. Base course is to be relatively free draining. The point for using this base course reference is a PI of 5 is not much clay content to make a difference in dam construction and Type 1 and Type 2 material is essentially the same material.

The sources of borrow material to construct the embankment for Spook Hill FRS came from the reservoir pool area and from excavation materials from the CAP canal. A materials investigation program was conducted by the NRCS to test the suitability of the native earthen materials found within the reservoir pool for embankment construction.

Settlement Monitoring – A summary of the District settlement monitoring program is provided in the District paper titled " Settlement Monitoring of Earthen Dams Operated by the Flood Control District of Maricopa County". The paper was prepared by Jan Staedicke in June 1995. The purpose of the report was to:

- Compile settlement monitoring data that has been acquired to date,
- Recommend refinements to the monitoring procedure,
- Recommend a schedule of continued monitoring,

- Recommend that the settlement monitoring procedure be supplemented with a) an earth fissure monitoring procedure, and b) periodic inspection using a team of specialists.

Appendix A of the District report contains a summary that lists each structure and shows the maximum settlement between the years surveyed, and the difference between the design crest and the minimum crest elevation. Appendix B of the District report contains detailed comments regarding each structure, while the last appendix of the District report, Appendix C, contains detailed information for each structure. This detailed information includes a data table showing survey elevations, incremental and total settlement, a plot of the crest settlement monuments, and a plot of the change in crest over the years surveyed.

Appendix B of the District report states that for Spook Hill FRS

"...Three surveys were performed over an eight year period. The maximum settlement was –0.03 feet. The minimum elevation is 0.48 feet below the design crest".

MKE (MKE, 1990) conducted a centerline crest survey as part of their dam breach analysis conducted for the District. MKE reported that the maximum measured variance from the design dam crest (elevation 1591.50 ft) is about 0.5 ft at Station 110+00 (elevation 1,591.03 ft) which was not considered significant for the purposes of the dam breach analysis.

The contents of the three District report appendices are included with this report (Part II) as Appendix B. Only those portions of the District appendices specific to Spook Hill FRS are included in Appendix B. Recommendations for continued settlement monitoring for Spook Hill FRS are provided in Section 4.0 of this Part II.

Post-construction level surveys have been conducted at the Spook Hill FRS in 1979, 1984, 1987, and 1998. The records indicated, when compared to the design crest elevation, negligible settlement has occurred at the Spook Hill FRS. A comparison of crest elevation data with the level survey conducted in 1998 show the possible settlement to range from 0.047 feet to 0.43 feet below design crest elevation while Stations 170+00 and 190+00 show the embankment has heaved from 0.14 to 0.317 feet (Gilbertson & Associates, 1998).

KHA plotted the existing settlement surveys and the results are provided in Appendix B. Not all monuments were surveyed in some years. This may be due to lost, destroyed, or monuments not uncovered in time for the survey.

2.7 Structures Inspection Checklist

A stie-specific inspection checklist for Spook Hill FRS was prepared and is based upon the inspection checklist developed by the Dam Safety Section at ADWR. The inspection checklist for Spook Hill FRS is provided in Section 3.0 of this Part II.

2.8 Maintenance Activities

The Operation and Maintenance Division has an established animal and vegetation control program for District structures, including dams and appurtenant features. The District animal and vegetation control program is documented in a recent District paper (November, 1999) that was presented at the workshop on "Plant and Animal Penetration Earthen Dams" held in Knoxville, Tennessee. A copy of the District's paper is included the Policy & Program Report. The following discussion summarizes these control programs. Further details are referenced in the District paper.

The purpose of the District's vegetation management program for District dams is twofold: (1) to minimize erosion of embankment slopes, and (2) eliminate undesired plant species from the dam crest and embankment slopes. The first purpose is actually part of the District's erosion control efforts to prevent or minimize loss of embankment material due to erosion. The District has a history of application of erosion control measures on their structures. These measures include hydroseeding slopes in attempt to establish a vegetation cover, placement of gravel or rock mulch on the embankment slopes to reduce rainfall impacts and flow velocities, and/or a combination of these two measures.

The District's methodology for establishment of vegetation covers on the embankment slopes presently consists of hydroseeding methods. The procedure is discussed in the District's paper. The paper presents the type of seed mix included in the hydroseeding program.

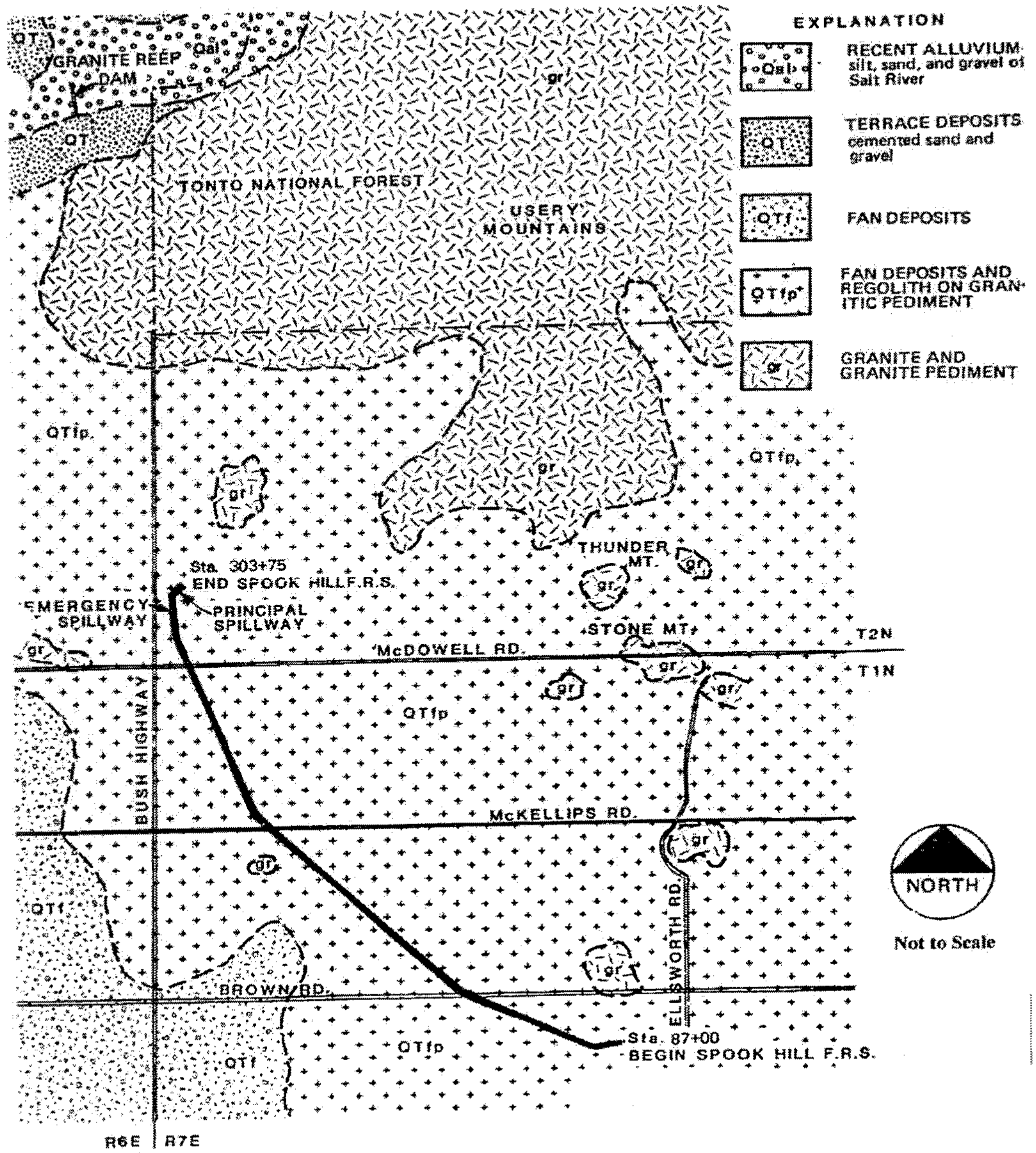
The second purpose of the vegetation management program is to control unwanted plant species, particularly on the embankment slopes. These undesired plant species include all deep-rooted plants typically found in Maricopa County such as desert broom, salt cedar, mesquites, and palo verdes. The method of vegetation control is explained in detail in the District's paper, but includes eradication by herbicides or manual pruning, and trimming by a boom-mower.

District O&M crews maintain low flow channels to principal spillway inlets. The maintenance conducted for the low flow channels consists of eradication of unwanted vegetation within the channel limits and removal of accumulated sediment in the channel bottom. Sediment removal is conducted with the use of a loader and dump truck and conducted on an as-needed basis.

A review of design and as-built plans for Spook Hill FRS indicates that no sediment monuments or markers were installed to monitor sediment accumulation in the impoundment area. Discussions with District staff indicate that very minor activity regarding the monitoring of sediment accumulation has ever been conducted for District impoundment areas. Hardly any sediment removal activities are conducted in the impoundment area. The design reports for the structures, however, do indicate that sediment pools were designed as part of the reservoir. The reports provide the volume of sediment storage available and the elevation of the top of the sediment pool.

District O&M crews conduct maintenance activities at Spook Hill FRS on a regularly scheduled basis. The District has conducted vegetation eradication within the low-flow channel located at the heel of the dam. The low-flow channel takes flows entering the FRS impoundment area and directs the flow towards the principal spillway. The eradication methods include physical removal of unwanted vegetation by clearing and grubbing methods using bulldozers, front-end loaders, and dump trucks. Very little vegetation eradication is conducted within the reservoir pool area outside the low-flow channel. Discussions with District O&M staff indicate that their crews may pick up dead and fallen trees and woody debris within the reservoir pool area, but the extent of the effort and frequency of removal is very limited.

The District performs very minor sediment removal from the inlet and outlet structures of the principal spillway and in the area just upstream of the inlet structure where sediment typically accumulates. Sediment removal from the inlet and outlets structures is typically conducted by hand-labor with shovels and buckets. The buckets are filled and then loaded into an awaiting dump truck. The sediment accumulated upstream of the inlet structure is removed by front-end loader and placed into the dump truck.



Modified from Ertec, 1981.

Figure 2-1. Spookhill FRS Regional Geology.

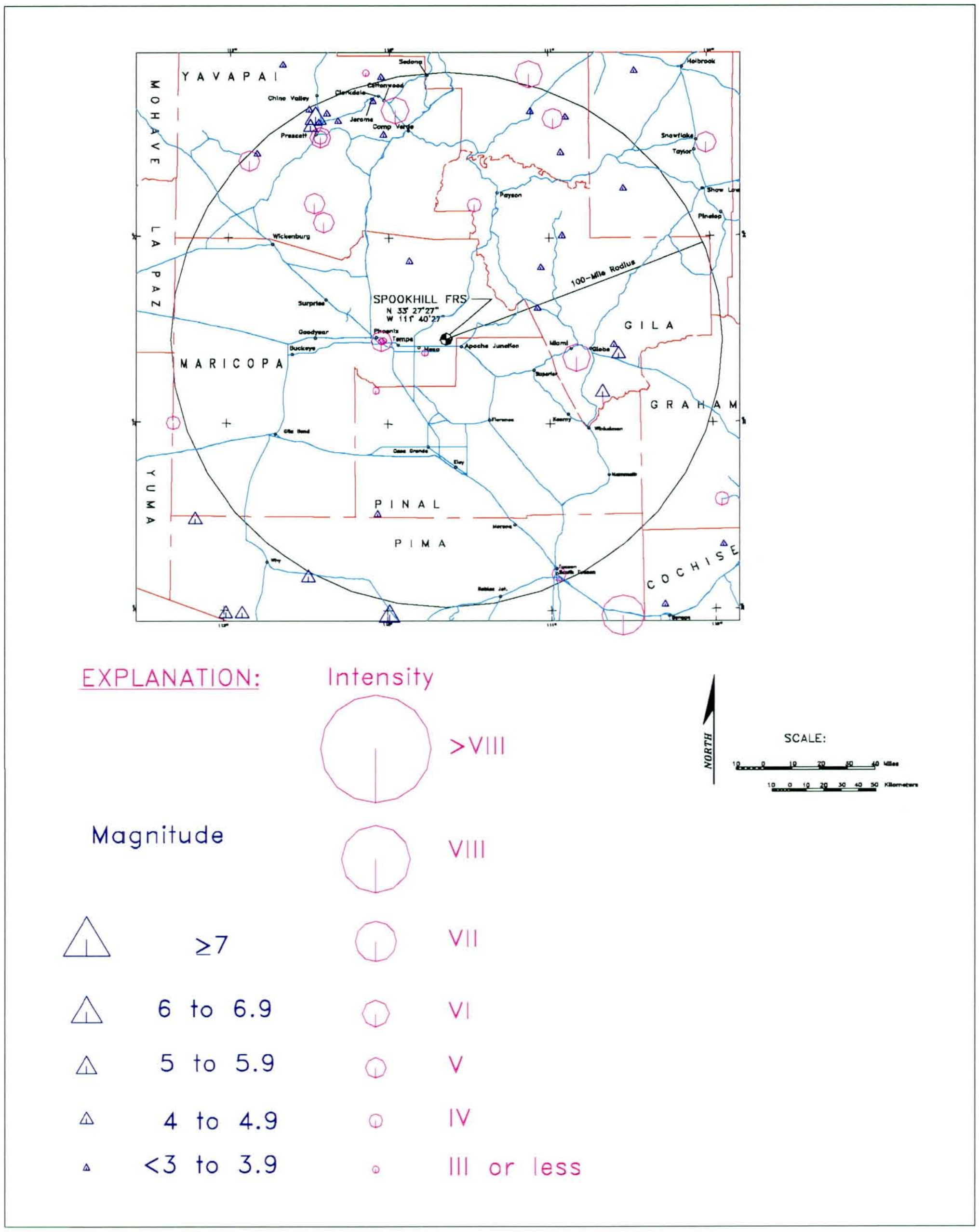


Figure 2-2. Earthquake Epicenter Map: Spookhill FRS and Vicinity

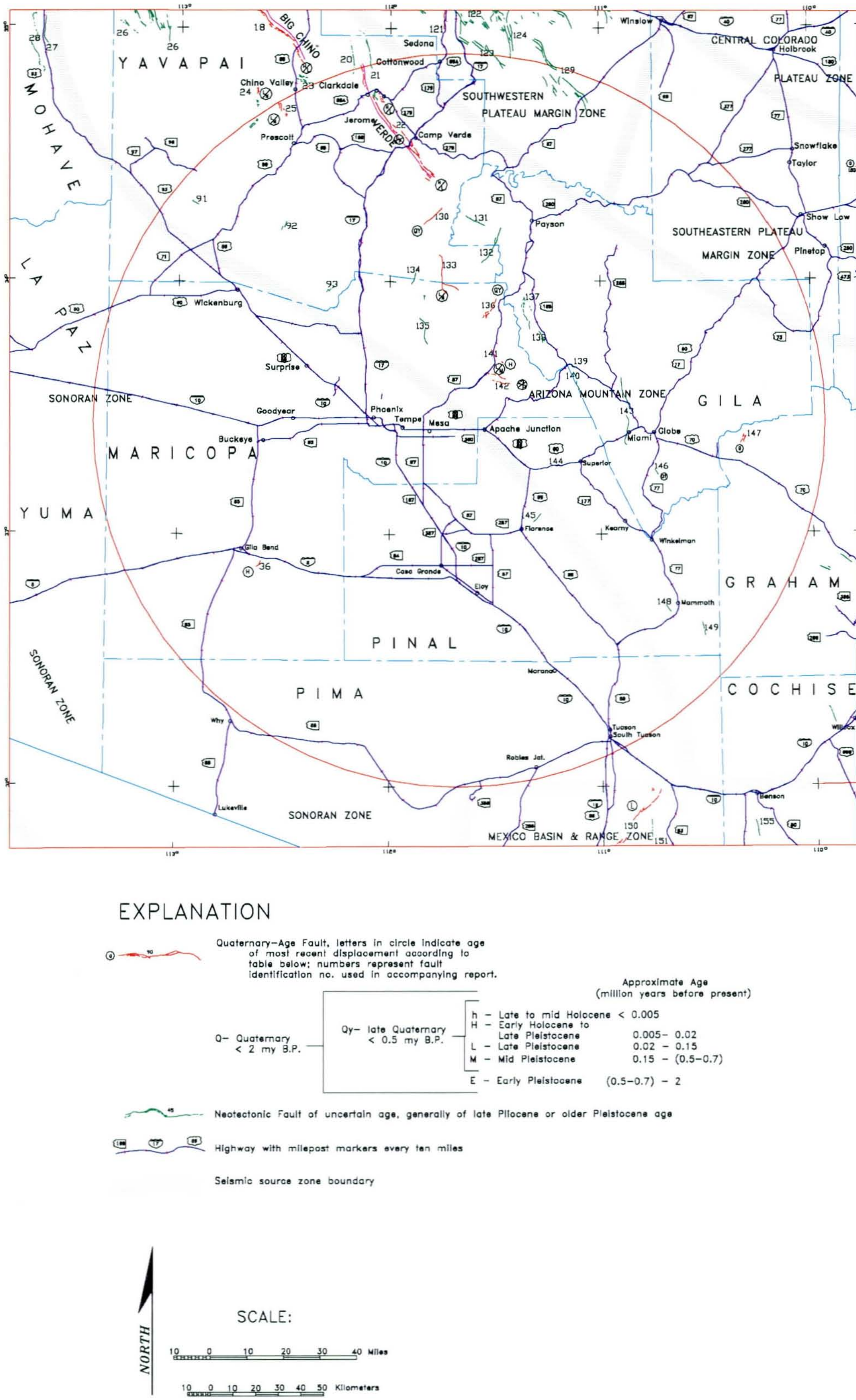
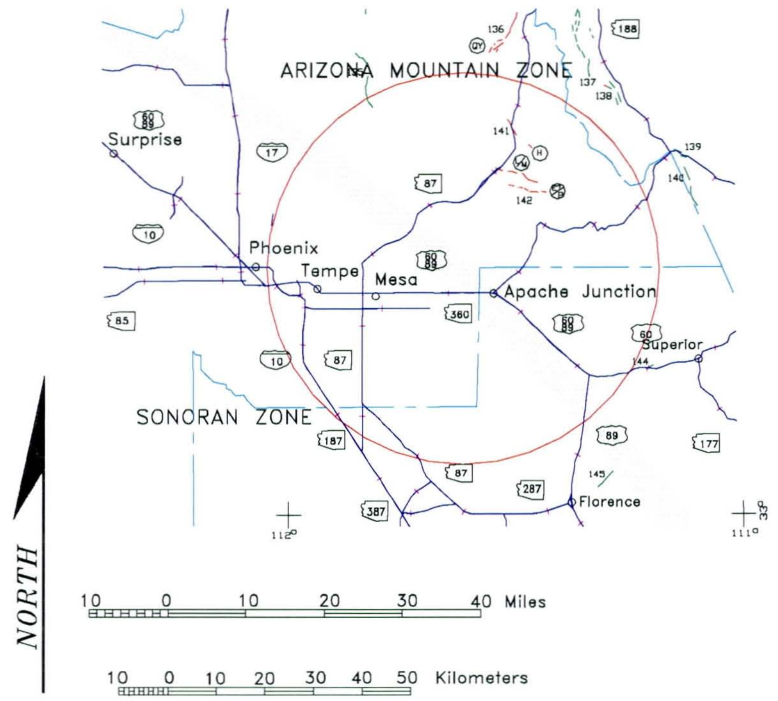


Figure 2-3. Regional Fault Map 100-mile Radius.



EXPLANATION

Development of Seismic Maps for Arizona
Report Number: FHWA-AZ92-344
ADOT Contract No: HPR-PL-1(37)344

Quaternary-Age Fault, letters in circle indicate age of most recent displacement according to table below; numbers represent fault identification no. used in accompanying report.

			Approximate Age (million years before present)
Q– Quaternary < 2 my B.P.	Qy– late Quaternary < 0.5 my B.P.	h – Late to mid Holocene	< 0.005
		H – Early Holocene to Late Pleistocene	0.005– 0.02
		L – Late Pleistocene	0.02 – 0.15
		M – Mid Pleistocene	0.15 – (0.5–0.7)
		E – Early Pleistocene	(0.5–0.7) – 2

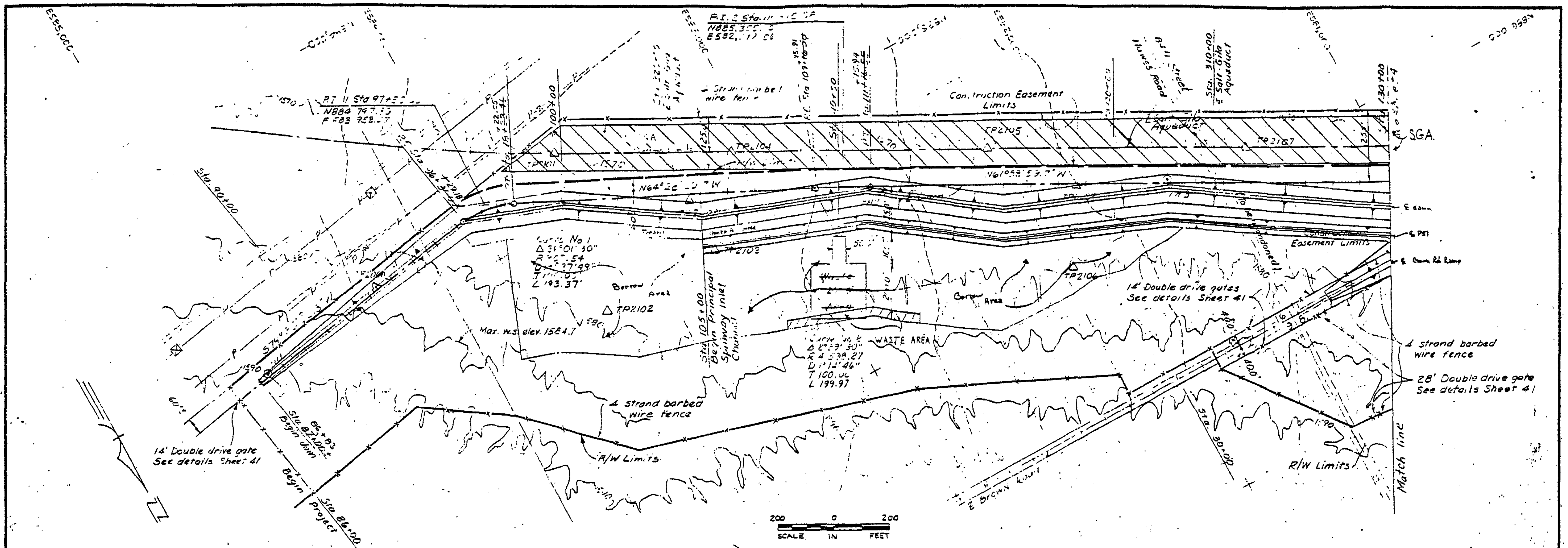
Neotectonic Fault of uncertain age, generally of late Pliocene or older Pleistocene age

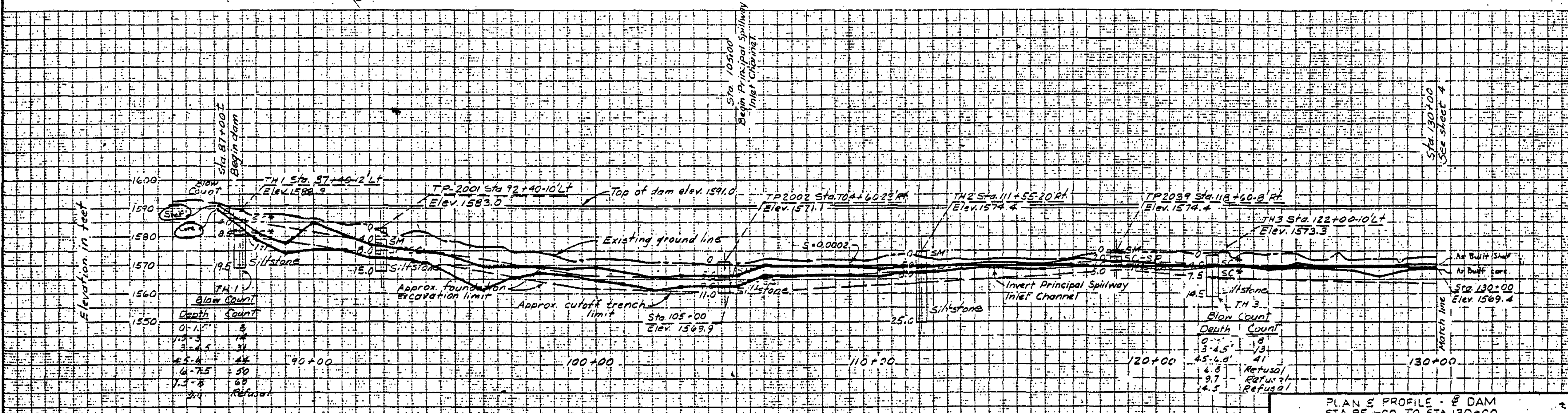
Highway with milepost markers every ten miles

Seismic source zone boundary

Figure 2-4. Area Fault Map 25-mile Radius.

SH Sheet 1





TH-1 Blow Count	
Depth	Count
0-1.5	8
1.5-3	14
3-4.5	31
4.5-6	44
6-7.5	50
7.5-8	60
9.4	Refusal

TH 3 Blow Count	
Depth	Count
0-3	13
3-4.5	13
4.5-6.8	41
6.8	Refusal
9.7	Refusal
14.5	Refusal

Notes:
1. The location of the dam, principal spillway inlet channel, stockpile areas and Salt-Gila Aqueduct Borrow Areas are given on Sheets 11 through 13.
2. See Sheet 13 for foundation and cutoff trench excavation schedules. Final cutoff trench limit to extend into siltstone, caliche or firm material as directed by the Engineer.

AS BUILT

Completed 4/10/80

REVISIONS

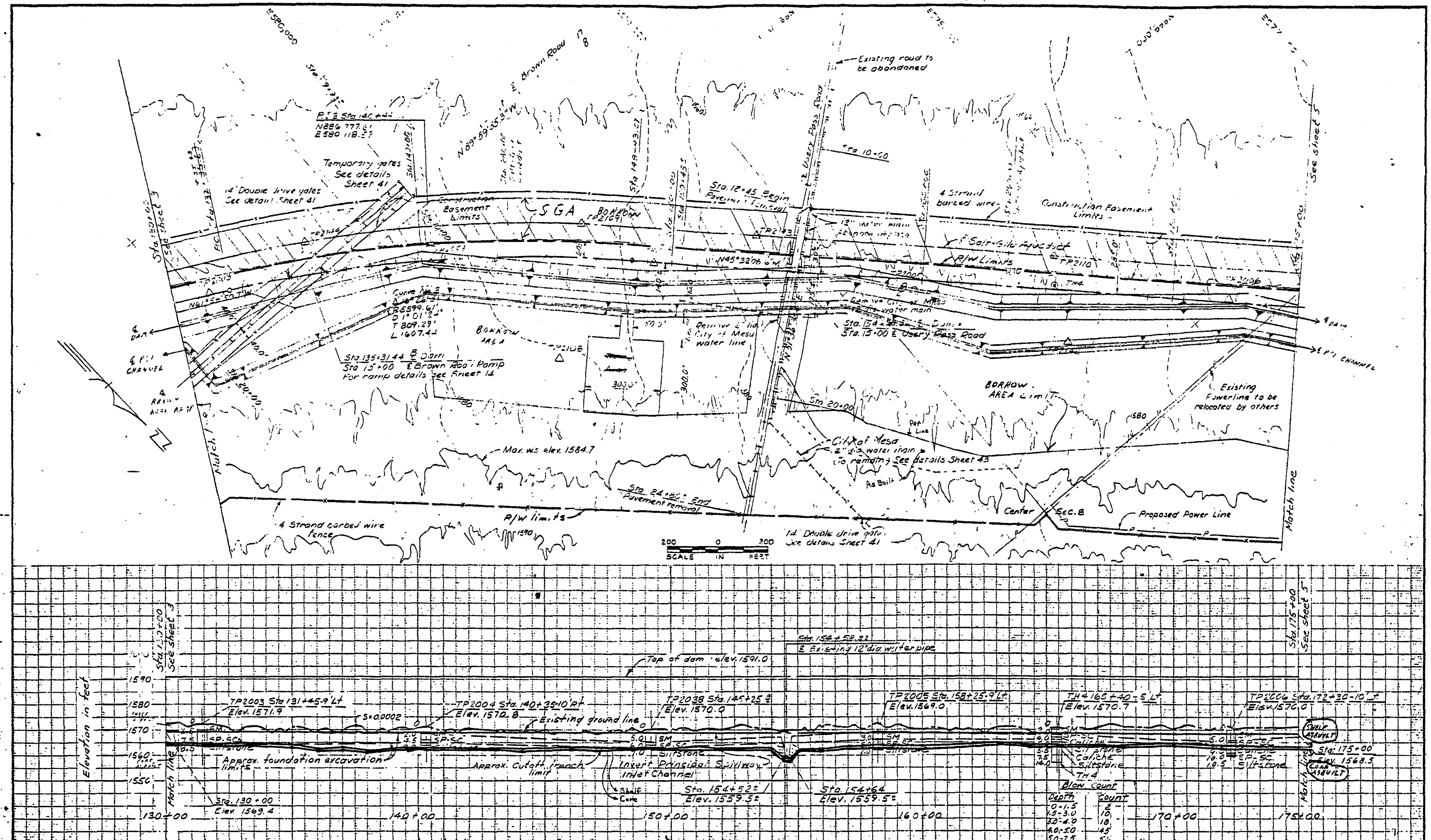
10-77 Add 2 - 28' Double drive gates North of Brown Road

PLAN & PROFILE - ℄ DAM
STA 85+00 TO STA 130+00
SPOOK HILL F.R.S.
BUCKHORN-MESA W.P.P.
MARICOPA & PINAL COUNTIES, ARIZONA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

		Date	
Designed	LLB, PJM	4-75	Approved by
Drawn	MR	4-75	Title
As built	DKH	1-80	Title
Checked	PJM	12-75	Sheet No. 3 of 45 — Drawing No. 7-E-23797

FORM SCS - 317 (NOV. 1966)



Notes:

1. The location of the dam, principal spillway inlet channel, stockpile areas and Salt-Gila Aqueduct Borrow Areas are given on sheets 11 through 13.
2. See Sheet 13 for foundation and cutoff trench excavation schedules. Final cutoff trench limit to extend into siltstone, caliche or firm material as directed by the Engineer.

AS BUILT

Completed 4/10/80

REVISIONS

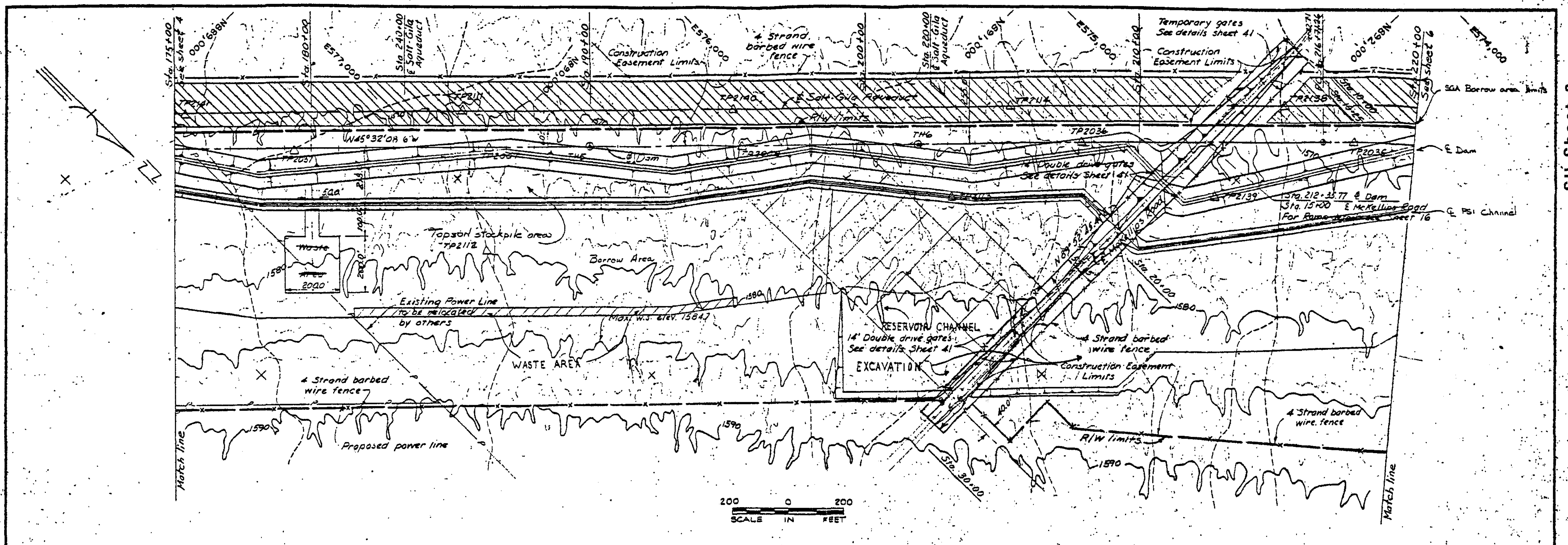
10-77 Increase Foundation Excavation Limits at Existing 12" Diameter Water Pipe

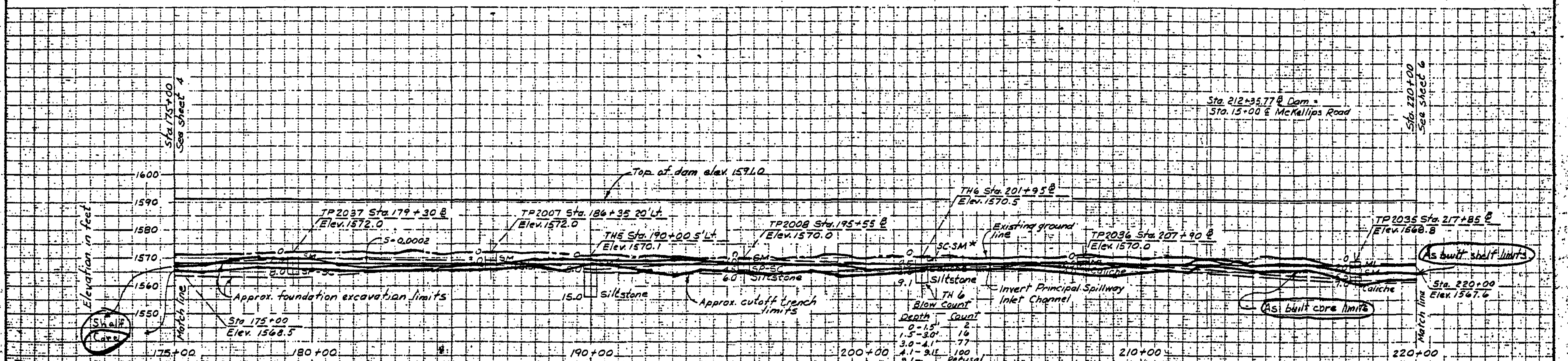
PLAN & PROFILE - ℄ DAM
STA 130+00 TO STA 175+00
SPOOK HILL F.R.S.
BUCKHORN-MESA W.P.P.
MARICOPA & PINAL COUNTIES, ARIZONA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

		Date	
Designed	LLB, PJM	4-75	Approved by
Drawn	MR	4-75	Title
Traced			Title
Checked	PJM	12-76	Sheet No. 4 of 45 — Drawing No. 7-E-23797

FORM SCS - 317 (NOV. 1966)





Notes:
1. The location of the dam, principal spillway inlet channel, stockpile areas and Salt-Gila Aqueduct Borrow Areas are given on Sheets 11 through 13.
2. See Sheet 13 for foundation and cutoff trench excavation schedules. Final cutoff trench limit to extend into siltstone, caliche or firm material as directed by the Engineer.

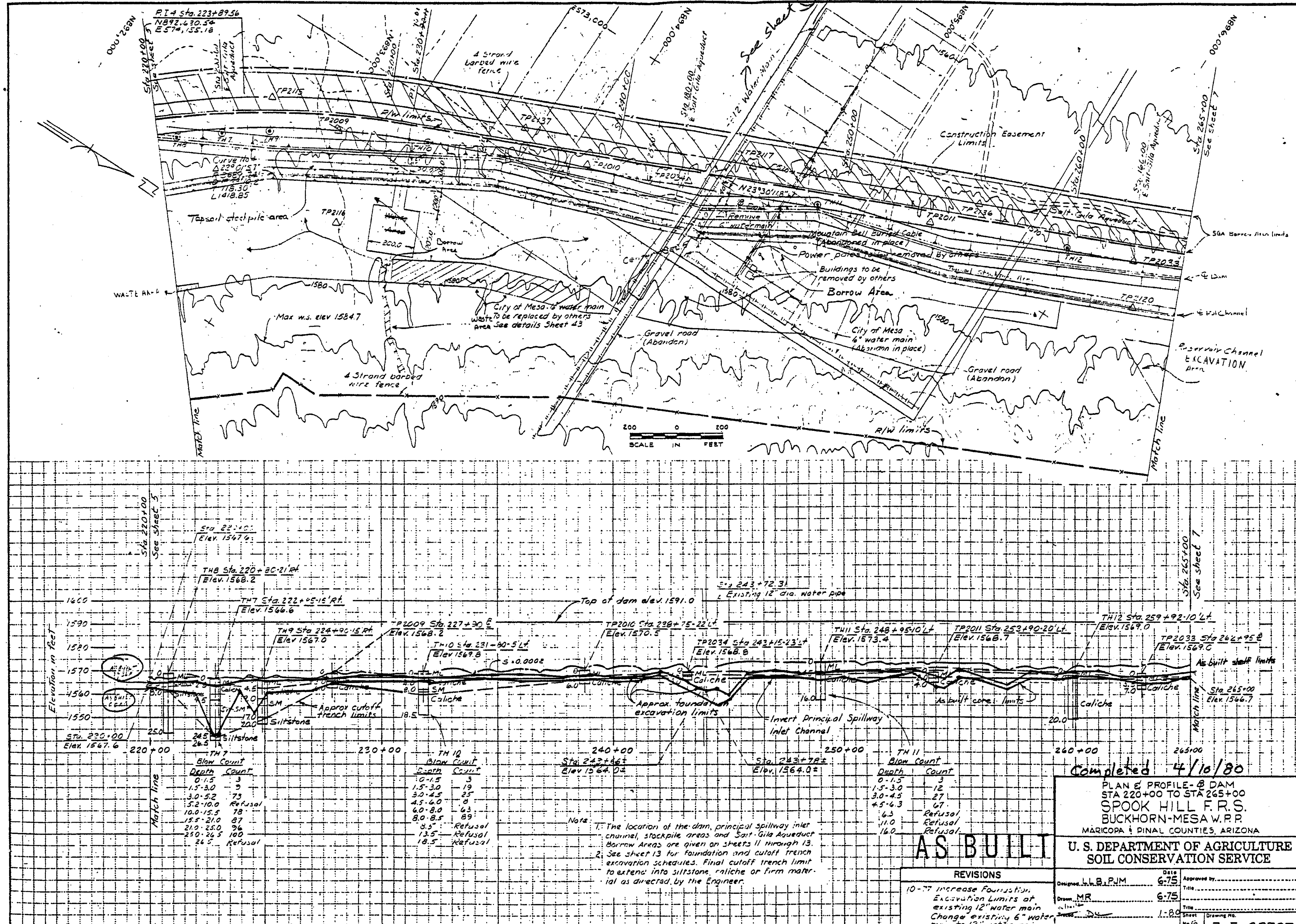
Completed 4/10/80

AS BUILT

PLAN & PROFILE - ℄ DAM
STA 175+00 TO STA 220+00
SPOOK HILL F.R.S.
BUCKHORN-MESA W.P.P.
MARICOPA & PINAL COUNTIES, ARIZONA

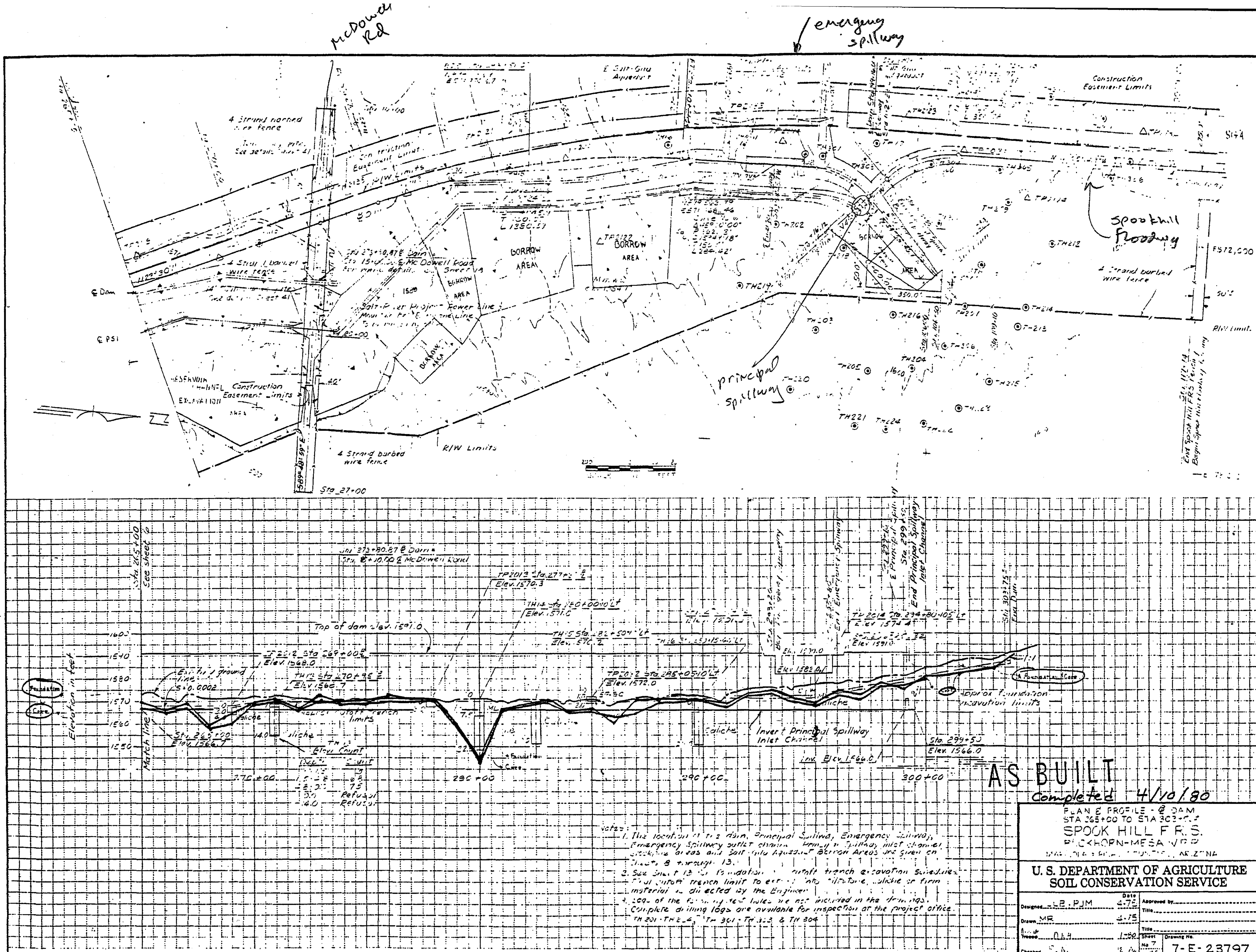
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

		Date	
Designed	LLB, PJM	4-75	Approved by
Drawn	MR	4-75	Title
As built	DC	1-80	Title
Checked	PJM	12-76	Sheet No. 5 of 45 — Drawing no. 7-E-23797



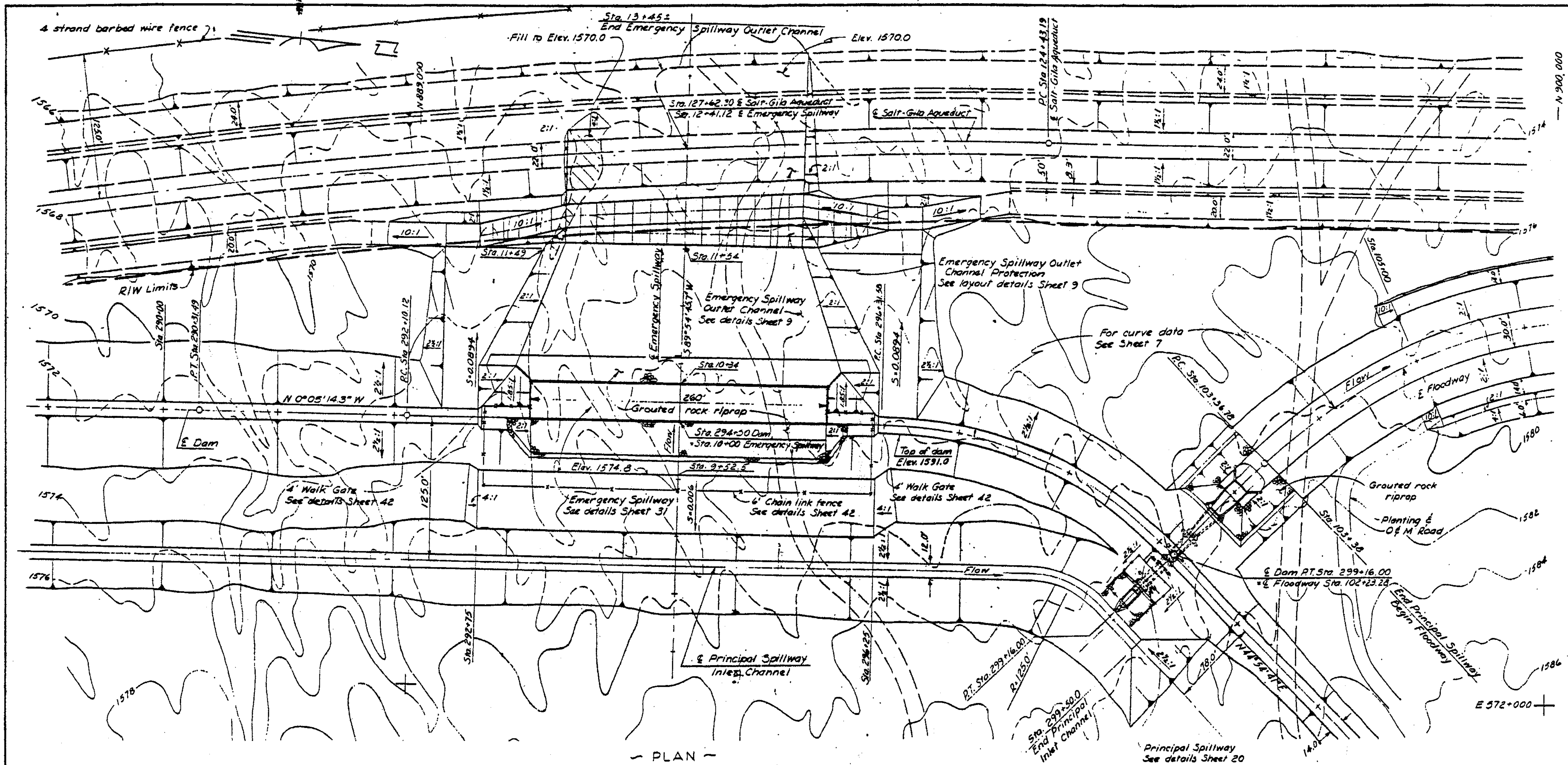
SH Sheet 4

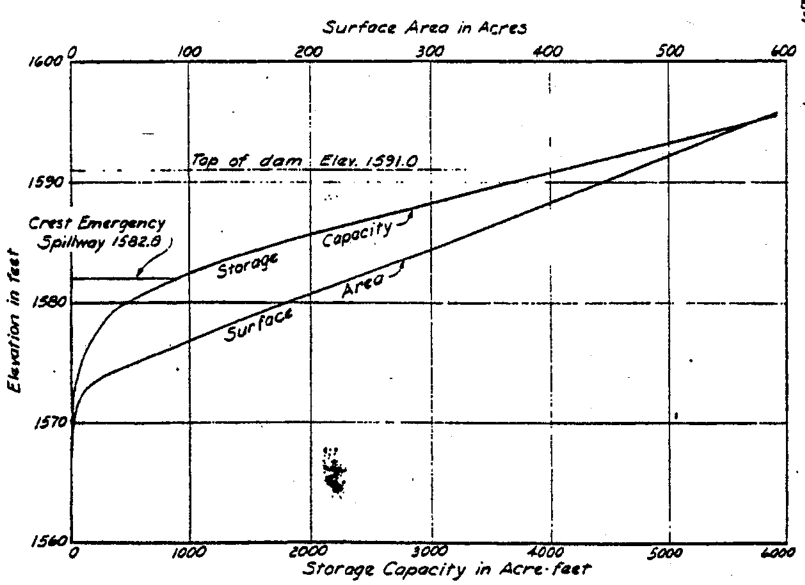
FORM SCS - 317 (NOV. 1966)



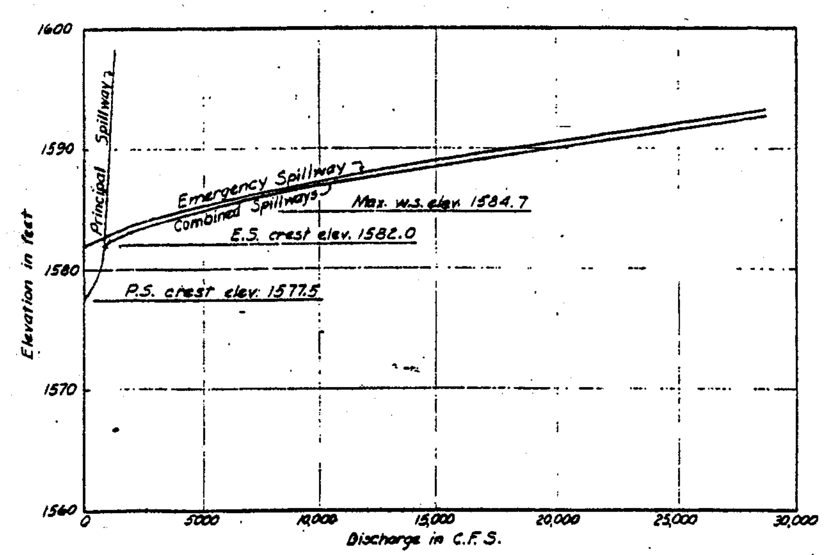
SH Sheet 5

re-copy page 7





EMERGENCY SPILLWAY STAGE STORAGE CURVE



SPILLWAY STAGE-DISCHARGE CURVES

Completed: April 10, 1980

AS-BUILT

PLAN OF SPILLWAYS

SPOOK HILL F.R.S.

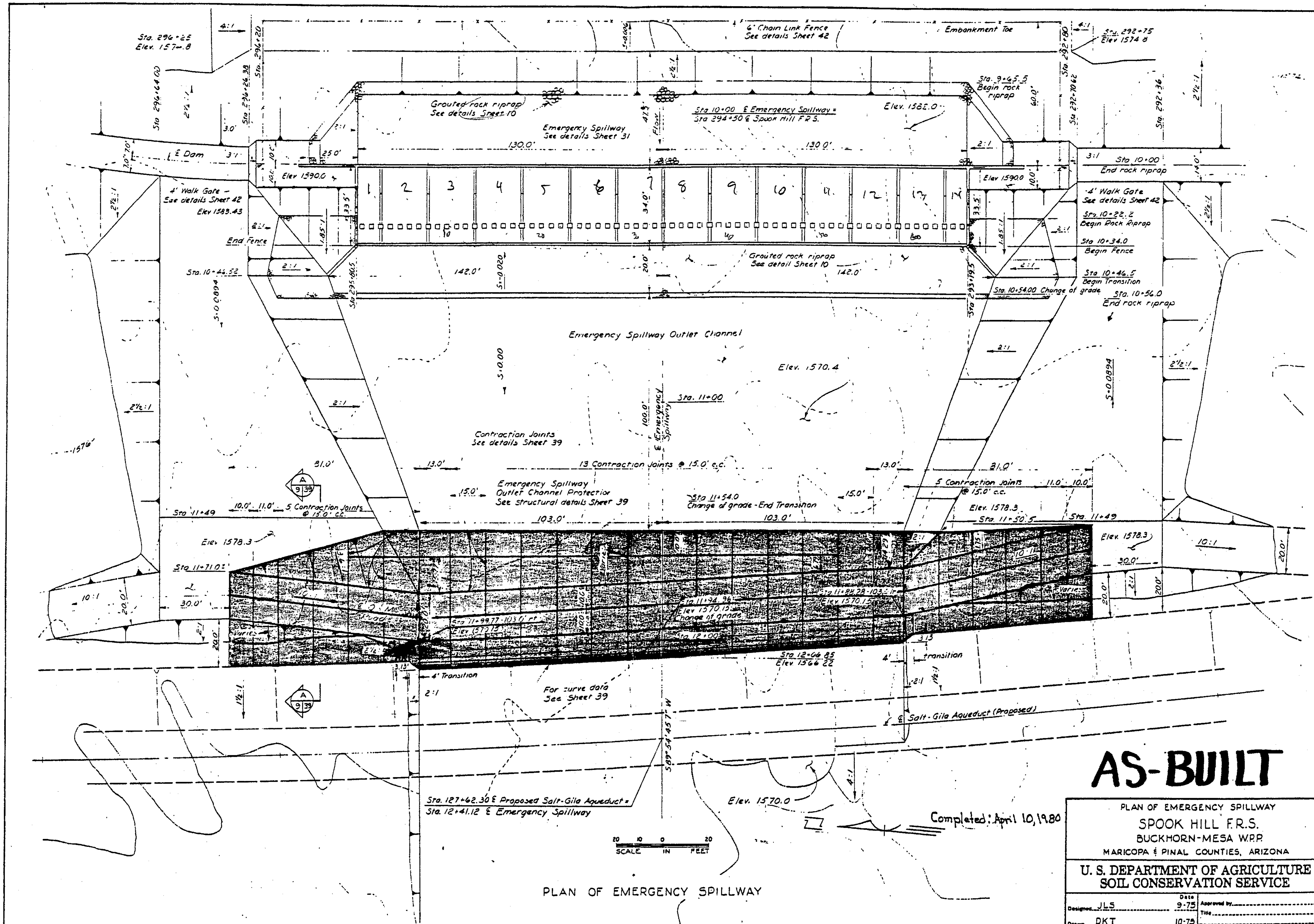
BUCKHORN-MESA W.P.P.

MARICOPA & PINAL COUNTIES, ARIZONA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

		Date	
Designed	JLS, PJM	8-75	Approved by
Drawn			Title
Traced	ES	9-75	Title
Checked	PJM	12-76	Sheet No. 8 of 45 — Drawing No. 7-E-23797

FORM SCS-313C



PLAN OF EMERGENCY SPILLWAY

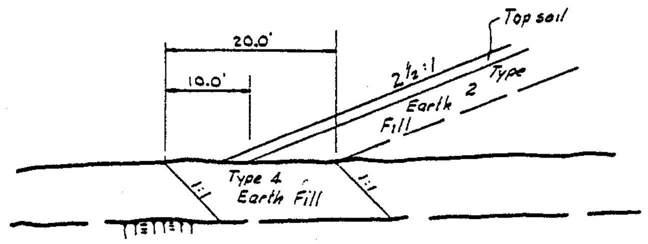
AS-BUILT

Completed: April 10, 1980

PLAN OF EMERGENCY SPILLWAY
SPOOK HILL F.R.S.
BUCKHORN-MESA W.P.P.
MARICOPA & PINAL COUNTIES, ARIZONA

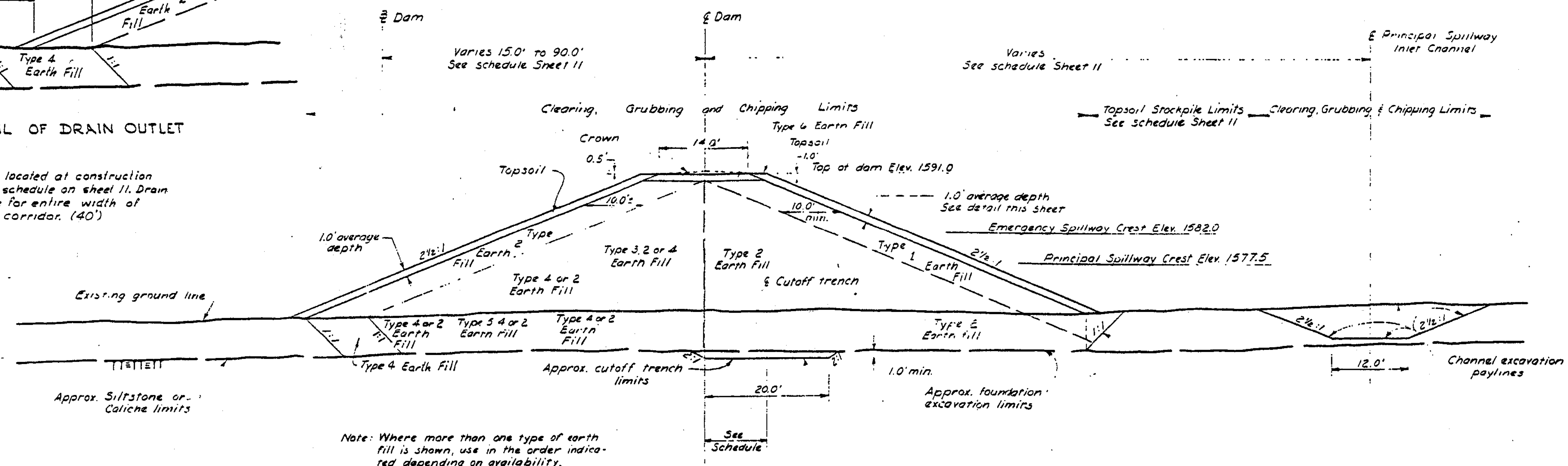
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

		Date	
Designed	JLS	9-75	Approved by
Drawn	DKT	10-75	Title
Traced	ES	11-75	Title
Checked	PJM	12-76	Sheet No. 9 of 45 — Drawing No. 7-E-23797



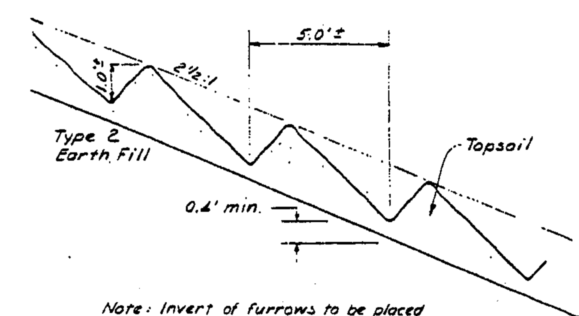
DETAIL OF DRAIN OUTLET

Note: Drain outlet located at construction corridors as schedule on sheet 11. Drain outlet will be for entire width of construction corridor. (40')



TYPICAL CROSS SECTION

10 0 10
SCALE IN FEET



Note: Invert of furrows to be placed at constant elevation.

TOP SOIL PLACEMENT DETAIL
(Not to scale)

FOUNDATION AND CUTOFF TRENCH EXCAVATION SCHEDULE

℄ Station	Foundation Excavation		Cutoff Trench Excavation		
	Approx depth ft	Approx bottom width ft	Approx. depth ft.	Offset distance ℄ to ℄ ft.	Bottom width ft.
87+00	0	-	0	0	-
87+10	4.0	12.5	9.5	0.4	20.0
98+30	4.0	92.5	9.5	10.0	20.0
104+60	5.5	108.5	10.0	10.0	20.0
118+60	2.0	92.0	5.0	10.0	20.0
122+00	4.0	90.0	8.5	10.0	20.0
131+45	2.5	104.0	8.5	10.0	20.0
140+35	2.0	112.0	5.5	10.0	20.0
149+25	5.0	111.5	7.0	10.0	20.0
158+25	3.0	103.5	6.0	10.0	20.0
165+40	3.0	111.0	5.0	10.0	20.0
172+30	5.0	109.0	7.0	10.0	20.0
179+30	2.0	102.0	9.0	10.0	20.0
186+35	3.0	101.0	4.0	10.0	20.0
190+00	6.0	106.5	6.0	10.0	20.0
195+55	1.0	115.5	5.5	10.0	20.0
201+95	2.5	114.0	3.5	10.0	20.0
207+70	2.5	111.5	3.5	10.0	20.0
217+85	2.0	122.0	6.5	10.0	20.0
220+80	3.5	133.0	4.5	10.0	20.0
222+85	2.8	131.2	25.5	10.0	20.0

FOUNDATION AND CUTOFF TRENCH EXCAVATION SCHEDULE

℄ Station	Foundation Excavation		Cutoff Trench Excavation		
	Approx. depth ft.	Approx. bottom width ft.	Approx depth ft	Offset distance ℄ to ℄ ft.	Bottom width ft.
224+90	4.5	129.5	5.5	10.0	20.0
227+90	3.0	121.0	4.0	10.0	20.0
231+80	2.7	121.3	9.0	10.0	20.0
238+75	4.0	107.5	5.0	10.0	20.0
243+15	1.5	110.0	2.5	10.0	20.0
248+95	4.5	97.0	5.5	10.0	20.0
253+90	2.0	99.5	3.0	10.0	20.0
259+92	2.0	109.5	3.0	10.0	20.0
262+95	5.5	98.5	6.5	10.0	20.0
269+00	3.0	108.5	4.0	10.0	20.0
270+95	1.9	104.6	2.9	10.0	20.0
277+85	0	111.5	1.0	10.0	20.0
280+00	7.5	106.5	8.5	10.0	20.0
282+50	0	114.0	1.0	10.0	20.0
285+05	1.0	113.0	2.0	10.0	20.0
289+75	0	104.0	1.0	10.0	20.0
291+00	1.0	105.5	2.0	10.0	20.0
29[illegible]+80	5.0	79.0	6.0	10.0	20.0
303+46±	3.0	13.5	4.0	0	20.0
303+50±	0	-	0	0	-

Void See Profile

AS-BUILT

Completed: April 10, 1980

CROSS SECTION & DAM

SPOOK HILL F.R.S.

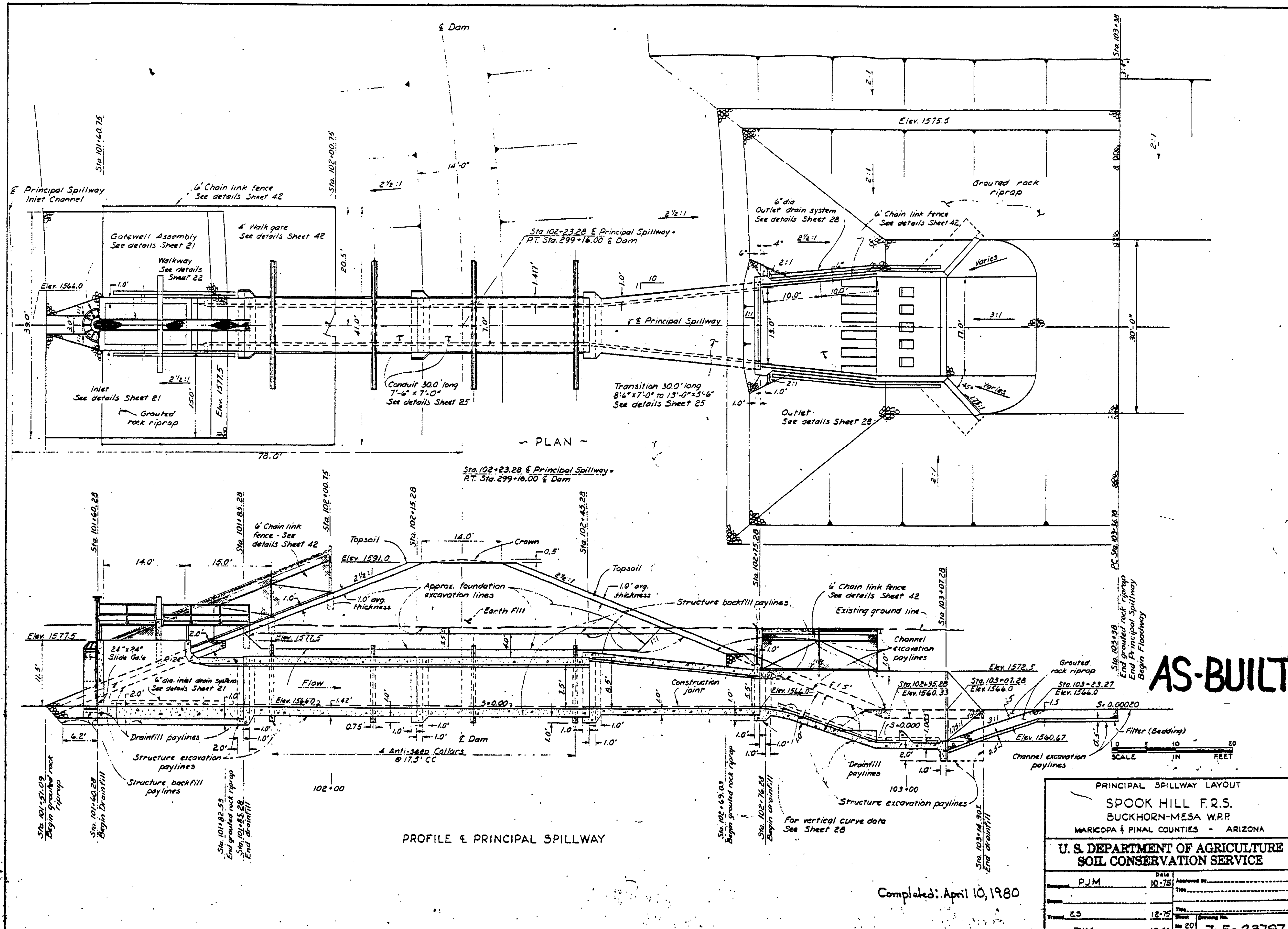
BUCKHORN-MESA W.P.P.

MARICOPA & PINAL COUNTIES, ARIZONA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed PJM	Date 7-76	Approved by	
Drawn		Title	
Traced ES	8-76	Title	
Checked PJM	12-76	Sheet No. 13 of 45	Drawing No. 7-E-23797

FORM SCS-313C



- PLAN -
℄ Dam
℄ Principal Spillway Inlet Channel
6' Chain link fence See details Sheet 42
Gatewell Assembly See details Sheet 21
4' Walk gate See details Sheet 42
Walkway See details Sheet 22
Elev. 1566.0
Inlet See details Sheet 21
Grouted rock riprap
Elev. 1577.5
78.0'
Sta. 101+60.75
Sta. 102+00.75
Sta. 102+23.28 ℄ Principal Spillway = P.T. Sta. 299+16.00 ℄ Dam
℄ Principal Spillway
Conduit 30.0' long 7'-6" x 7'-0" See details Sheet 25
Transition 30.0' long 8'-6"x7'-0" to 13'-0"x5'-6" See details Sheet 25
6" dia Outlet drain system See details Sheet 28
Outlet See details Sheet 28
Elev. 1575.5
Grouted rock riprap
Varies
Sta. 103+38
PC Sta. 103+36.78
PROFILE ℄ PRINCIPAL SPILLWAY
Topsoil
Crown
Elev. 1591.0
Approx. foundation excavation lines
Earth Fill
1.0' avg. thickness
Structure backfill paylines
Existing ground line
Channel excavation paylines
24"x24" Slide Gate
6" dia. inlet drain system See details Sheet 21
Flow
Elev. 1566.0
S=0.00
Construction joint
Drainfill paylines
Structure excavation paylines
Structure backfill paylines
4 Anti-seep Collars @ 17.5' CC
℄ Dam
102+00
103+00
Elev. 1572.5
Sta. 102+95.28 Elev. 1560.33
Sta. 103+07.28 Elev. 1566.0
Sta. 103+23.27 Elev. 1566.0
Elev. 1560.67
S=0.000
S=0.00020
Grouted rock riprap
Filter (Bedding)
Channel excavation paylines
For vertical curve data See Sheet 28
Structure excavation paylines
Sta. 101+51.09 Begin grouted rock riprap
Sta. 101+60.28 Begin Drainfill
Sta. 101+82.53 End grouted rock riprap
Sta. 101+85.28 End drainfill
Sta. 102+69.03 Begin grouted rock riprap
Sta. 102+76.28 Begin drainfill
Sta. 103+14.30 End drainfill
Sta. 103+38 End grouted rock riprap End Principal Spillway Begin Floodway
SCALE IN FEET
AS-BUILT
Completed: April 10, 1980
PRINCIPAL SPILLWAY LAYOUT
SPOOK HILL F.R.S.
BUCKHORN-MESA W.P.P.
MARICOPA & PINAL COUNTIES - ARIZONA
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed PJM 10-75
Traced ES 12-75
Checked PJM 12-76
Sheet No. 20 of 45
Drawing No. 7-E-23797

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART II SPOOKHILL FRS

Section 3.0 Field Examination

Section 3.0 Field Examination

3.1 Purpose

The purpose of the field examination is to provide a systematic visual field technical investigation in which the structural stability and operational adequacy of the FRS project features are analyzed and evaluated to determine if deficiencies exist at the FRS and associated project features. The examination was conducted by walking the length of the structure and visually examining the crest, upstream and downstream slopes, upstream and downstream toes, and appurtenant structures. Comments are recorded on an inspection log and photographs taken of pertinent observations. Cracks, holes, and burrows were probed with a hand-held 3-foot stainless steel metal rod to examine depth, extent, and resistance to probing. No other intrusive/internal examination method was used during this examination.

The field examination of the structure is accomplished to provide a basis for timely initiation of corrective measures to be taken where necessary. This examination was conducted on July 10, 11, and 12, 2000 by the following technical examination team:

3.2 Technical Examination Team

Robert Eichinger, P.E.	Project Manager, Kimley-Horn and Associates
John Sikora, P.E.	Dam Safety Engineer, URS Corp.
Ken Euge, P.G.	Principal Geologist, Geological Consultants
Diana Davisson, EIT	Civil Analyst, Kimley-Horn and Associates

Other Participants:

Tom Renckly, P.E.	Project Manager, Civil Engineer, Flood Control District of Maricopa County

3.3 Project Summary

Inspection Frequency
Spook Hill FRS is inspected on an annual basis jointly by the Flood Control District and the Arizona Department of Water Resources. The next joint District/ADWR inspection is scheduled for December 2001.

Maximum Water Surface Elevations

The District maintains a historic log of maximum water surface elevations for Spook Hill FRS. The maximum recorded impoundment for Spook Hill reservoir is 80 acre-feet with a stage of 6.74 feet at the FRS (January 11, 1993).

Spillway Erodibility

Based on District records, there has been no recorded emergency spillway flows at Spook Hill FRS. The spillway is a reinforced concrete drop structure.

Distress Observations Corrected or Operation and Maintenance Conducted Since Last Inspection

Slope erosion repair is an on-going O&M item.

Past Distress Observations Not Yet Corrected

Noted past erosion on the upstream and downstream slope. This is an on-going maintenance issue.

Flood Control District Operation and Maintenance Responsibilities

The District is responsible for total operation and maintenance of Spook Hill FRS and associated appurtenances.

3.4 Field Examination Results Summary

Embankment

The crest of the FRS is gravel plated. Most crest settlement monuments were found. Station markers were located. The crest is clear of vegetation. The access gates and fences located off and adjacent to McKellips, McDowell, and Brown Roads are operational. Longitudinal cracks were observed on the crest of the dam. All cracks were less than 1/4-inch in width but varied in length from several feet to 30-ft. During the inspection, 10 longitudinal cracks were located. The location of these cracks were at the following stations: Sta. 97+05 (thin hairline cracks 30 ft. long); Sta. 102+00 (hairline crack, brushed to expose crack 1/8-inch wide); Sta. 116+00 (small crack, 10 inches long, 1/8-inch wide); Sta. 117+00 (4-inch long hole, 2-inch deep – possibly associated with crack); Sta. 128+50 (hairline crack 2 ft. long); Sta. 139+00 (small hole and 1/16-inch wide crack, found from previous ADWR – Nov. 1999 inspection); Sta. 186+56 (crack from Sta. 186+56 to 188+26); Sta. 188+26 (centerline crack ¼-inch wide, 20 ft. long); Sta. 201+65 (centerline hairline crack, 25 ft. long, probed 2.5 ft.); Sta. 284+10 (centerline crack with holes); Sta. 233+56 (hole 3' x 6" at surface, probed to 22" on downstream side of crest above erosion gully, suspect transverse crack). No obvious transverse cracks were observed. Transverse crack detection is difficult due to the severe slope erosion.

Abutments

The north and south abutment terminus contacts appear in satisfactory operational condition. No slides, sign of instability or erosion of the abutment surfaces were observed.

Upstream Slope

The upstream slope shows minor to major erosion rills and gullies. There are some animal burrows on the slope face. The upstream toe shows very minor signs of erosion. There was no evidence of seepage, undermining, settlement or sloughing. There is rock mulch protection on the slope.

Downstream Slope

Animal burrows are evident on this slope face. These burrows range from small reptile burrows (lizards) to ground squirrel activity. The slope has a medium density of small shrubs and grasses. There are major erosion rills and gullies on the face of the downstream slope. There was no evidence of seepage, undermining, settlement or sloughing.

Principal Spillway

The approach channel was clear of debris and obstructions. The reservoir pool has a medium density stand of mesquite, acacias, and palo verdes.

The exterior of the inlet was clean. The concrete for the inlet structure showed no signs of structural distress. The trash rack was clear of debris and obstructions. The interior of the 7.0-ft by 7-ft 5-in box conduit was inspected visually by walking through the outlet structure and into the box conduit. The walls of the box conduit were clean and there were no apparent signs of seepage. Minor spalling of the concrete was observed on the interior walls of the box conduit.

The discharge outlet of the principal spillway was clear of debris. The joints of the outlet structure were straight and tight. The outlet channel was clear of debris.

Emergency Spillway

The emergency spillway is located at Station 294+00 and upstation from the principal spillway and the right abutment. The FRS emergency spillway is a reinforced concrete drop spillway structure. Concrete spalling of the wall surfaces was observed on the baffle walls of the spillway. The downstream channel was clear of any obstructions.

Instrumentation

Spook Hill FRS has a series of settlement monuments. The "A"-series are located every 500 feet along the downstream crest of the structure. The "B"-series are located approximately every 500 feet along the downstream toe of the dam in combination with the corresponding "A"-series monuments. The "B"-series monuments are offset from the downstream toe. Not all monuments from the "A" or "B" series were located during the this inspection. Monuments not readily located are most likely buried in shallow embankment fill.

A staff gauge located on the upstream slope at the principal spillway is used to indicate the level of water impounded in the reservoir. A pressure transducer is located at the inlet structure of the principal spillway. The transducer works in combination with a flood warning telemetry system, which allows signals to be sent to a centralized receiver at the District indicating water levels at the reservoir.

3.5 Conclusions

The overall conclusion of the field examination is that the Spook Hill FRS and appurtenant structures are in satisfactory operational condition.

3.6 Recommendations

The following is a list of recommended corrective actions resulting from this field examination:

a. Continuing observation should be made of the above mentioned items (erosion of slopes, spalling of concrete surfaces).
b. Evaluate erosion protection of upstream and downstream slopes.
c. Remove abandoned PVC irrigation lines.
d. Station posts need to have signs on both sides of post facing both directions of travel.
e. Repair slope erosion gullies on downstream and upstream slopes. Remove landscaping terraces.
f. Video and photograph log the interior of the principal spillway conduit.
g. Develop a plan for the repair of transverse and longitudinal cracks.
h. Prepare a monitoring plan for tracking the locations of longitudinal and transverse cracks on as-built plans or similar method.

3.7 Future Inspections

The next annual inspection by FCD is scheduled for December 2001.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
EMBANKMENT DAM INSPECTION REPORT

Each item of the checklist should be completed. Repair is required when obvious problems are observed. Monitoring is recommended if there is a potential for a problem to occur in the future. Investigation is necessary if the reason for the observed problem is not obvious.

Brief description should be made of any noted irregularities, needed maintenance, or problems. Abbreviations and short descriptions are recommended. Additional sheet(s) may be used for any items not listed and additional comments.

DAM NO.: **07.50**	DAM NAME: **SPOOKHILL FRS**	TYPE: EARTH EMBANK
CONTACTS: Tom Renckly, FCD		REPORT DATE: August 15, 2000
INSPECTED BY: Bob Eichinger-KHA, Ken Euge-Geological Consultants, John Sikora-URS Corp		INSPECTION DATE: July 11, 2000
REVIEWED BY: Doug Plasencia, KHA	DATE: August 16, 2000	PAGE 1 of _6_
STORAGE LEVEL: Reservoir Empty	TOTAL FREEBOARD: 9.0 ft.	PHOTOS? YES
Item	Comments See attached inspection log.	

Item / Comments	NOT APPLIC.	NO	YES	MONITOR	REPAIR	INVESTIGATE
1. CREST Top of dam 1591.0 ft.; 11 ft. wide; 4.11 miles long.						
a. Settlements, slides, depressions? **Last crest survey 1998.**		X				
b. Misalignment?		X				
c. Longitudinal/Transverse cracking? **Longitudinal cracks were observed on the crest at Sta. 97+05 (thin hairline cracks 30 ft. long); Sta. 102+00 (hairline crack, brushed to expose crack 1/8-inch wide); Sta. 116+00 (small crack, 10 inches long, 1/8-inch wide); Sta. 117+00 (4-inch long hole, 2-inch deep – associated with crack?); Sta. 128+50 (hairline crack 2 ft. long); Sta. 139+00 (small hole and 1/16-inch wide crack, found from previous ADWR – Nov. 1999 inspection); Sta. 186+56 (crack from Sta. 186+56 to 188+26); Sta. 188+26 (centerline crack ¼-inch wide, 20 ft. long); Sta. 201+65 (centerline hairline crack, 25 ft. long, probed 2.5 ft.); Sta. 284+10 (centerline crack with holes); Sta. 233+56 (hole 3" x 6" at surface, probed to 22" on downstream side of crest above erosion gully, suspect transverse crack).**			X	X		X
d. Animal burrows?		X				
e. Adverse Vegetation?		X				
f. Erosion? **Deep erosion gullies and rills throughout/abandoned irrigation line.**		X				
2. UPSTREAM SLOPE 2.5:1						
a. Erosion?			X	X	X	
b. Inadequate ground cover?		X				
c. Adverse vegetation?		X				
d. Longitudinal/Transverse cracking? **Cannot discern due to extensive erosion.**		X		X		
e. Inadequate riprap?		X				
f. Stone deterioration?	X					
g. Settlements, slides, depressions, bulges?		X				
h. Animal burrows? **Scattered along slope throughout intermittently.**			X	X		
3. DOWNSTREAM SLOPE 2.5:1						
a. Erosion? **Deep erosion gullies and rilling throughout / abandoned irrigation line.**			X	X	X	
b. Inadequate ground cover?		X				
c. Adverse vegetation?		X				
d. Longitudinal/Transverse cracking? **Did not locate transverse cracks at Sta. 189+80 and 165+00 as reported by ADWR. Cannot discern due to extensive slope erosion.**		X		X		
e. Inadequate riprap?		X				
f. Settlements, slides, depressions, bulges?		X				
g. Soft spots or boggy areas?		X				
h. Movement at or beyond toe?		X				
j. Animal burrows? **Scattered throughout.**			X	X		

INSPECTED BY: Bob Eichinger, Ken Euge, John Sikora | DATE: July 11, 2000

Item	Comments	N/A	NO	YES	MON	REP	INV
4. DRAINAGE-SEEPAGE CONTROL							
a. Internal drains flowing?	**Reservoir empty.**	X					
b. Boils at or beyond toe?	**Reservoir empty.**		X				
c. Seepage at or beyond toe?	**Reservoir empty.**		X				
d. Does seepage contain fines?		X					
5. ABUTMENT CONTACTS							
a. Erosion?			X				
b. Differential movement?			X				
c. Cracks?			X				
d. Settlements, slides, depressions, bulges?			X				
e. Seepage?	**Reservoir empty.**		X				
f. Animal burrows?	**Minor burrows.**			X	X		
6. OUTLET WORKS-APPROACH CHANNEL	**Unlined.**						
a. Eroding or backcutting?			X				
b. Sloughing?			X				
c. Restricted by vegetation?			X				
d. Obstructed with debris?			X				
e. Silted in?			X				
7. OUTLET WORKS-INLET STRUCTURE							
a. Seepage into structure?	**Reservoir empty.**		X				
b. Debris or obstructions?			X				
c. If concrete, do surfaces show:							
1. Spalling or Scaling?				X	X		
2. Cracking?	**Minor vertical cracking.**			X	X		
3. Erosion?			X				
4. Exposed reinforcement?			X				
d. If metal, do surfaces show:							
1. Corrosion?			X				
2. Protective coating deficient?			X				
3. Misalignment or spilt seams?			X				
e. Do the joints show:							
1. Displacement or offset?			X				
2. Loss of joint material?			X				
3. Leakage?	**Reservoir empty.**		X				
f. Are the trash racks:							
1. Broken or bent?			X				

EMB. DAM INSP. REPORT	PAGE 3 of 6	DAM NO.: **07.50**						
INSPECTED BY: Bob Eichinger, Ken Euge, John Sikora		DATE: July 11, 2000						
Item	Comments		N/A	NO	YES	MON	REP	INV
2. Corroded or rusted?				X				
3. Obstructed?				X				
g. Sluice/Drain gates:	**24-inch slide gate.**							
1. Broken or bent?				X				
2. Corroded or rusted?				X				
3. Leaking?	**Reservoir empty.**			X				
4. Not seated properly?				X				
5. Not operational?				X				
6. Not periodically maintained?				X				
7. Date last operated?	**Annually.**							
8. OUTLET WORKS-CONDUIT	**RCB 7 ft. x 7.5 ft. x 52 ft. long.**							
a. Seepage into conduit?	**Reservoir empty.**			X				
b. Debris present?				X				
c. If concrete, do surfaces show:								
1. Spalling or scaling?				X				
2. Cracking?	**Minor vertical cracks.**				X	X		
3. Erosion?				X				
4. Exposed reinforcement?				X				
5. Other?				X				
d. If Metal, do surfaces show:								
1. Corrosion?			X					
2. Protective coating deficient?			X					
3. Misalignment or spilt seams?			X					
e. Do the joints show:								
1. Displacement or offset?				X				
2. Loss of joint material?				X				
3. Leakage?	**Reservoir empty.**			X				
9. OUTLET WORKS-STILLING BASIN/POOL	**Battle block stilling basin.**							
a. If concrete, do surfaces show:								
1. Spalling or Scaling?	**Minor.**				X	X		
2. Cracking?	**Minor.**				X	X		
3. Erosion?	**Check seepage outlets for clogging.**			X				X
4. Exposed reinforcement?				X				
b. If concrete, do joints show:								
1. Displacement?				X				
2. Loss of joint material?				X				

INSPECTED BY: Bob Eichinger, Ken Euge, John Sikora | DATE: July 11, 2000

Item	Comments	N/A	NO	YES	MON	REP	INV
3. Leakage?	**Reservoir empty.**		X				
c. Do the energy dissipators show:							
1. Signs of deterioration?			X				
2. Covered with debris?			X				
3. Signs of inadequacy?			X				
10. OUTLET WORKS-OUTLET CHANNEL	**Grouted for 30 ft. then unlined. Spookhill Floodway**						
a. Eroding or backcutting?			X				
b. Sloughing?			X				
c. Obstructed?			X				
d. Poorly riprapped?			X				
e. Tailwater elevation and flow condition:							
11. EMERGENCY SPILLWAY-APPROACH CHANNEL	**Unlined**						
a. Eroding or backcutting?			X				
b. Sloughing?			X				
c. Restricted by vegetation?			X				
d. Obstructed with debris?			X				
e. Silted in?			X				
12. EMERGENCY SPILLWAY-CONTROL STRUCTURE							
a. If concrete, do surfaces show:							
1. Spalling or scaling?	**Minor.**			X	X		
2. Cracking?	**Vertical cracks.**			X	X		X
3. Erosion?			X				
4. Exposed reinforcement?			X				
b. If concrete, do joints show:							
1. Displacement or offset?			X				
2. Loss of joint material?			X				
3. Leakage?			X				
c. If spillway is unlined:							
1. Are slopes eroding?		X					
2. Are slopes sloughing?		X					
3. Is crest eroding?		X					
d. Is weir in poor condition?			X				
e. Where is control structure?	**Sta. 293+19.5 to Sta. 295+80.5**						
13. EMERGENCY SPILLWAY - CHANNEL	**None.**						
a. Obstructions or restrictions?		X					
b. If concrete, do surfaces show:							

INSPECTED BY: Bob Eichinger, Ken Euge, John Sikora | DATE: July 11, 2000

Item	Comments	N/A	NO	YES	MON	REP	INV
1. Spalling or scaling?		X					
2. Cracking?		X					
3. Erosion?		X					
4. Exposed reinforcement?		X					
c. If concrete, do joints show:							
1. Displacement or offset?		X					
2. Loss of joint material?		X					
3. Leakage?		X					
d. If an unlined channel, does it show:							
1. Erosion?		X					
2. Slopes sloughing?		X					
3. Poorly protected w/ vegetation/riprap?		X					
14. EMERGENCY SPILLWAY-TERMINAL STRUCTURE	**Stilling basin – plunge pool type.**						
a. If concrete, do surfaces show:							
1. Spalling or scaling?	**Spalling throughout structures surfaces.**			X	X	X	
2. Cracking?	**Vertical cracks.**						
3. Erosion?							
4. Exposed reinforcement?			X				
b. If concrete, do joints show:							
1. Displacement or offset?	**Repairs completed on joint between left wing wall and site wall. Monitor.**			X	X	X	
2. Loss of joint material?	**See previous comment.**		X		X		
3. Leakage?	**Reservoir empty.**	X					
c. Do the energy dissipators show:							
1. Signs of deterioration?			X				
2. Covered with debris?			X				
3. Signs of inadequacy?			X				
15. EMERGENCY SPILLWAY - OUTLET CHANNEL							
a. Eroding or backcutting?			X				
b. Sloughing?			X				
c. Obstructed or restricted?			X				
16. RESERVOIR							
a. High water marks?			X				
b. Erosion/Slides into pool area?	**Did not walk reservoir pool.**	X			X		
c. Sediment accumulation/Vegetation growth?			X				
d. Floating debris present?	**Reservoir empty.**	X					
e. Depressions, sinkholes or vortices?	**Reservoir empty.**	X					

EMB. DAM INSP. REPORT	PAGE 6 of 6	DAM NO.: **07.50**	N/A	NO	YES	MON	REP	INV
INSPECTED BY: Bob Eichinger, Ken Euge, John Sikora		DATE: July 11, 2000						
Item	Comments							
f. Low ridges/saddles allowing overflow?				X				
g. Structures below dam crest elevation?				X				
17. INSTRUMENTATION								
a. List type(s) of instrumentation: Staff gages, ALERT gage-water pressure transducer, settlement monuments, station markers at downstream edge of crest of dam • **Not all settlement monuments located – lost, destroyed, covered?**								
b. In poor condition?				X				
c. Not read or analyzed regularly?				X				
d. Is data available?					X			
18. CONDITION SUMMARY / LICENSE / EAP / NEXT INSPECTION								
a. Dam condition: **No Safety Deficiencies**								
b. Safe storage Level on License: **Permanent storage is not to exceed the principal spillway inlet elevation of 1,582.0 ft. Temporary storage allowed above this elevation.**								
c. List date of current License: **July 9, 1993.**								
d. Should new License be issued?			X					
e. In compliance with License?					X			
f. In compliance with Statute and Rules?					X			
g. In compliance with ADWR/District Actions?					X			
i. List current size; accurate? **Small.**								
j. List current downstream hazard; accurate? **High.**								
k. Is there a current EAP? If so, list latest revision date: **No. EAP needs to be prepared according to FEMA 64 guidelines.**				X				
l. List normal inspection frequency: **Annual.**								
m. Recommend date for next inspection: **November 2000.**								

Notes/Sketches

Spookhill FRS

Station	U/S	D/S	Crest	Observation	Detailed Description	Photo	Stake	Inspector
Start 7/11/00 5:50 AM , Temperature 82F								
90+00		X	X	Station Marker & Settlement Monument	No stamp (cap), ? Settlement monument at toe			RAE
	X	X		Vegetation	Medium density vegetation, low shrubs			RAE
			X	Vegetation	Clear			RAE
90+00	X			Photo	Photo of upstream face looking right	1292		JHS
90+00	X	X	X	Embankment	View to northwest along Spook Hill FRS	R2-16		KE
90+50		X		Erosioin	Deep erosion gulley	R2-17		KE
90+00---95+00	X	X		erosion	Rills/gullies, Downstream slope incised			RAE
90+00---303+75	X			Erosion	Upstream rill erosion due to farrowing of the upstream slope. Typically, when the embankment exceeds 10-feet in height the rill erosion is more sever.			JHS
90+00---303+75	X			Rodent Holes	Rodent holes were observed throughout the structure on the upstream slope. Typically the holes were on top of the farrows.			JHS
94+00		X		Erosion	Deep erosion gulley about 18 inches deep	R2-18		KE
95+00			X	Station Marker				DD
95+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
95+00		X		Erosion Rills	Animal holes & rills			RAE
96+00	X			Photo	Typical rill erosion	1293		JHS
96+00		X		Typical Erosion Gully		R1P13		RAE
97+05			X	Longitudinal Crack	Thin hairline crack, 30 ft long	R1P14		RAE
97+20			X	Longitudinal Crack	Longitudinal crack at crest, offset to DS side of crest	R2-19		KE
97+70			X	Longitudinal Crack	Hole, Probe 1 ft, also note irrigation box on upstream side of crest			RAE
99+00		X		Erosion/borrows	Excessive rodent activity & gulleying on lower DS embankment slope	R2-20		KE
100+00			X	Station Marker				DD
100+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
101+00		X		Erosion	Erosion gullies, incised 18-24 inches, 3/4 face of embankment	TR		TR
102+00			X	Longitudinal Crack	Hairline crack, brushed to expose crack 1/8 inch wide	R1P15		RAE
102+50		X		Erosion	Excessive gulleying on lower DS embankment slope 18 inches to 3 feet deep throughout lower one-third of DS slope			KR
104+00		X		Trees	Mature Palo Verde trees at downstream toe	D6&7		DD
105+00			X	Station Marker				DD
105+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
106+00		X		Animal Burrow	Just off downstream crest, probes to 30 inches			RAE
109+50	X			Witness Post	Just beyond upstream crest, 4 ft tall orange post, no cap found			RAE
110+00			X	Station Marker	Also found P.K. nail with white spray painted arrow			DD
110+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
114+50		X		Erosion	Gully with large rock, Probe to 12 inches			RAE
115+00	X			Photo	Sever rill erosion	1294		JHS
115+00			X	Station Marker				DD
115+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
116+00			X	Longitudinal Crack	small crack, 10 inches long, 1/8 inch wide	R1P16		RAE
117+00			X	Hole, ? Longitudinal Crack	4 inch long hole, 2 inch deep, probed to 3 inches	TR		TR

Spookhill FRS

Station	U/S	D/S	Crest	Observation	Detailed Description	Photo	Stake	Inspector
118+00			X	Hole	Hole-blowout 18"x18"x12" deep, pvc pipe exposed	R1P16		RAE
120+00			X	Station Marker		D8&9	BIRD	DD
120+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
125+00			X	Station Marker				DD
125+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
125+20			X	Witness Post	Just beyond upstream crest, 4 ft tall orange post, no cap found			DD
128+50			X	Longitudinal Crack	hairline crack, 2 ft long			RAE
130+00			X	Station Marker	also old control boxes for irrigation system, just off crest on upstream side			DD
130+00		X		Survey monument	FCDMC monument at embankment toe, no marking; had to be dug out			KE
130+02			X	P.K. Nail	On downstream side of crest , white spray paint arrow			DD
135+00			X	Station Marker				DD
135+00		X		Survey monument	No survey monuments at this station on DS side of embankment; structure sign	R2-22		KE
135+31			X	Embankment	View to northwest along Spook Hill FRS from Brown Road crossing	R2-23		KE
135+31			X	Embankment	View to southeast along Spook Hill FRS from Brown Road crossing	R2-24		KE
135+50			X	Vegetation	Looking west at upstream slope embankment	R1P17		RAE
139+00			X	Longitudinal Crack	Small hole and 1/16 inch wide crack, found from previous ADWR report			RAE
139+00	X			Woody Vegetation	Woody vegetation on the upstream slope			JHS
139+00			X	Longitudinal Crack	See above	R3-1		KE
140+00			X	Station Marker				DD
140+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
140+20			X	Photo Marker	# 6U, just off crest on upstream side			RAE
140+80			X	Witness Post	Just beyond upstream crest, 4 ft tall orange post, no cap found			DD
142+50		X		Erosion	View of DS slope showing typical gulley erosion	R3-2		KE
145+00			X	Station Marker				DD
145+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
150+00			X	Station Marker				DD
150+00	X			Photo	Upstream face looking right	1295		JHS
155+00			X	Station Marker				DD
155+00	X			Erosion	ATV erosion on upstream face			JHS
156+00			X	Witness Post	Just beyond upstream crest, 4 ft tall orange post, no cap found			DD
160+00			X	Station Marker				DD
160+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
165+00			X	Station Marker	Did not find noted ADWR transverse crack at 165+00			RAE
165+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
169+50		X		Survey monument	FCDMC monument at embankment toe, no marking; had to be dug out			KE
170+00			X	Station Marker				DD
170+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
172+00			X	Witness Post	Just beyond upstream crest, 4 ft tall orange post, no cap found			DD
175+00			X	Station Marker				DD
175+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
180+00			X	Station Marker				DD
180+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
185+00			X	Station Marker				DD

Spookhill FRS

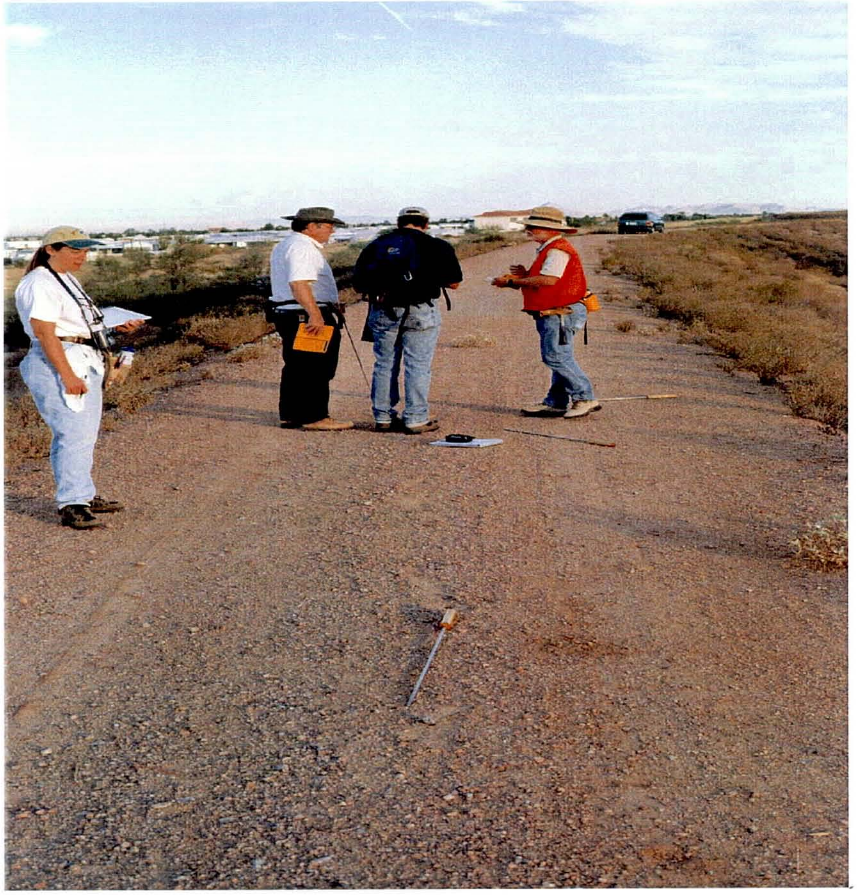
Station	U/S	D/S	Crest	Observation	Detailed Description	Photo	Stake	Inspector
185+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
186+56			X	Longitudinal Crack	Longitudinal crack @ crest from 186+56 to 188+26	R3-3		KE
187+50		X		Survey Post	Orange post, mid slope			RAE
188+26--188+56			X	Longitudinal Crack	Centerline crack 1/4 inch wide, looks fresh, 20 ft long	R1P18		RAE
188+90			X	Survey Marker	Downstream side of crest, wire with orange tape and spray painted whits arrow			DD
190+00			X	Station Marker				DD
190+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
190+62			X	Control Boxes	Old irrigation control boxes			DD
192+00		X		Erosion	Gully , 6 ft across, probe to 4 ft, 2/3 of downstream face			RAE
192+00		X		Erosion	See above	R3-4		KE
195+00			X	Station Marker				DD
195+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
199+30			X	Previous Report	Could not find previously noted longitudinal crack			RAE
200+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
200+01			X	Station Marker				DD
201+65			X	Longitudinal Crack	Centerline hairline longitudinal crack, 25 ft long, Prob e to 2.5 ft	R1P19		RAE
203+50			X	Witness Post	Just beyond upstream crest, 4 ft tall orange post, no cap found			DD
205+00			X	Station Marker				DD
205+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
209+50		X		Survey monument	FCDMC monument at embankment toe, no marking; had to be dug out			KE
209+85			X	Survey Marker	Wire with orange tape, white spray painted arrow			DD
210+00			X	Station Marker				DD
210+00		X		Survey monument	No survey monuments at this station on DS side of embankment; view of embankment northwest from McKellips Road	R3-5		KE
215+00			X	Station Marker				DD
215+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
220+00			X	Station Marker	Rodent hole off upstream crest			KE
220+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
225+00			X	Station Marker				DD
225+00		X		Survey monument	No survey monuments at this statioin on DS side of embankment			KE
230+00			X	Station Marker				DD
230+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
230+20			X	Survey Marker	Stake with orange tape on downstream side of crest, "HEI PT #1 Do Not Remove"			KE
230+75		X		Survey monument	FCDMC monument at embankment toe, no marking; had to be dug out			KE
233+56			X	Erosion	Hole (3" x 6" at surface), Probe 22 inches, on downstream side of crest above erosion gully, suspect transverse crack	R3-6		KE
235+00			X	Station Marker				DD
235+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
240+00			X	Station Marker				DD
240+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
242+00			X	Powerline Crossing	Powerline crossing, view to west	R3-7		KE
242+00			X	Powerline Crossing	Powerline crossing, view to east	R3-8		KE
245+00			X	Station Marker				KE

Station	U/S	D/S	Crest	Observation	Detailed Description	Photo	Stake	Inspector
245+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
250+00			X	Station Marker				DD
250+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
250+10		X	X	Survey Marker	Rebar, wire with orange flag at crest and rebar at toe			DD
255+00			X	Station Marker				DD
255+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
260+00			X	Station Marker				DD
264+00	X			Erosion	Deep rill erosion on upstream face			JHS
260+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
265+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
267+00			X	Witness Post	Just beyond upstream crest, 4 ft tall orange post, no cap found			DD
270+00	X			Erosion	Deep rill erosion on upstream face			JHS
270+00			X	Station Marker	Also monument at toe			DD
270+00		X		Survey monument	FCDMC monument at embankment toe, no marking; had to be dug out			KE
270+30			X	Control Boxes	Old irrigation control boxes			DD
273+80	X	X	X	Road Crossing	View to northwest along embankment @ McDowell Road crossing	R3-9		KE
273+80	X	X	X	Road Crossing	View to southeast along embankment @ McDowell Road crossing	R3-10		KE
274+50			X	McDowell Road	Photo west side looking north, drop structures/channel to reservoir area	R1P20		RAE
275+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
277+00		X		Ruts	Off road tracks/ ruts			RAE
277+00		X		Wheel tracks	Wheel track on DS slope; no rock mulch plating on slope	R3-11		KE
278+00		X		Erosion	View of DS slope w/ very little rilling or gulley erosion north of McDowell Road crossing; upper portion of DS slope appears to be flatter than lower portion	R3-12		KE
280+00			X	Station Marker				DD
280+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
284+10			X	Longitudinal Crack	Centerline crack with holes	R1P21		RAE
				Rodent Tunnel	Associated with longitudinal crack, downstream shoulder to crest			RAE
284+10			X	Longitudinal Crack	Longitudinal crack; may be associated with rodent activity	R3-14		KE
285+00			X	Station Marker				DD
285+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
288+00	X			Animal Burrow	Large animal hole on the upstream face			JHS
290+00			X	Station Marker				DD
290+00		X		Survey monument	No survey monuments at this station on DS side of embankment			KE
290+00	X			Erosion	Deep rill erosion on upstream face			JHS
291+00			X	P.K. Nail	Orange tape, painted white arrow, upstream side of crest			DD
291+50		X		Monument	Bureau of Reclamation			KE
292+00			X	Witness Post	Just beyond upstream crest, 4 ft tall orange post, no cap found			DD
293+20				Emergency Spillway		R1P22		RAE
293+20		X		Emergency Spillway	Emergency spillway, left abutment	R3-15		KE
293+20		X		Emergency Spillway	Emergency spillway, central portion	R3-16		KE
293+20		X		Emergency Spillway	Emergency spillway, right abutment	R3-17		KE
293+20		X		Emergency Spillway	Emergency spillway, dissipator structure	R3-18		KE

Station	U/S	D/S	Crest	Observation	Detailed Description	Photo	Stake	Inspector
294+00				Emergency Spillway	Photo 293+20 to 295+80	D10, 11, 12		DD
294+50			X	Photo	Looking right at emergency spillway crest	1296		JHS
294+50			X	Photo	Looking downstream right at emergency spillway outlet	1297		JHS
294+50			X	Observation	Grouted riprap ustream of emergency spillway has minor cracks and minor erosion around the edges. Minor concrete spalling on drop structure. Spillway chute walls in good shape, no deflection. No seperation between embankment and spillway chute walls.			JHS
295+00		X		Emergency Spillway	Emergency spillway, view to south from right abutment	R3-19		KE
299+16	X			Principal Spillway	Operating Gate			RAE
299+16		X		Principal spillway	Principal spillway; outlet structure looking upstream	R3-20		KE
299+16		X		Principal Spillway	Exposure of caliche cemented breccia in outlet channel slope	R3-21		KE
299+16		X		Principal Spillway	Principal spillway; view downstream of outlet structure and channel	R3-22		KE
299+16			X	Principal Spillway	Principal spillway, view of inlet structure	R3-23		KE
299+16		X		Principal Spillway	Principal spillway, view of inlet structure	R3-24		KE
299+50	X			Photo	Principle spillway inlet	1298		JHS
299+50	X			Photo	Principle spillway inlet	1299		JHS
299+50	X			Observation	Inlet free of debris, concrete in good shape, no spalling. No deflection in concrete walls. Gated outlet open control of in intlet is probably the slotted CMP.			JHS
300+00			X	Station Marker				DD
???+??		X		Principle Spillway Outlet	Photo	D13		DD
302+00				END 1:40 Pm				RAE
	Inspector Initials							
	RAE		Bob Eichinger		Kimley-Horn and Associates			
	DD		Diana Davisson		Kimley-Horn and Associates			
	KE		Ken Euge		Geological Consultants			
	TR		Tom Renckly		Flood Control District			
	JS		John Sikora		URS-Grenier Woodward-Clyde			

Spook Hill FRS. Downstream slope rill erosion Station 96+00.

Spook Hill FRS. Downstream slope rill erosion Station 115+50.



Spookhill FRS. Station 97+05. On crest 30-ft long longitudinal crack.

Spookhill FRS. Station 97+20. Longitudinal crack on crest offset to downstream side of crest.

Spookhill FRS. Station 117+00. Hole on crest. Four inches long, 2 inches deep. Probed to 4 inches.

Spookhill FRS. Station 139+00. Longitudinal crack on crest. Small hole with 1/16-in crack, found from previous ADWR inspection report.

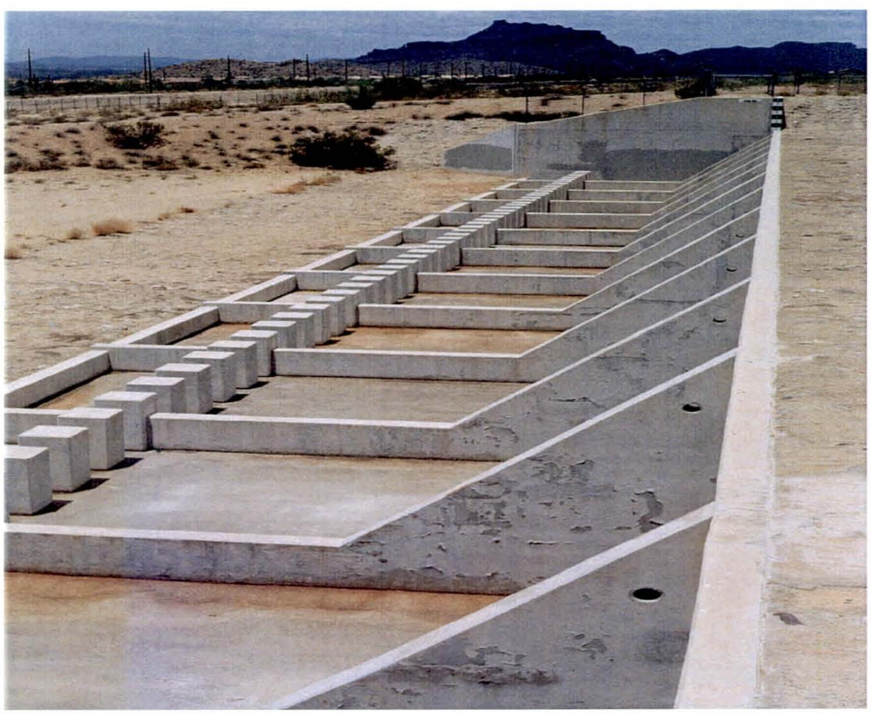
Spookhill FRS. Station 118+00. Blowout hole from irrigation line. On downstream side of crest.

Spookhill FRS. Station 188=26 to 188+56. Crest - Longitudinal crack.

Spookhill FRS. Station 201+65. Longitudinal crack on crest centerline.

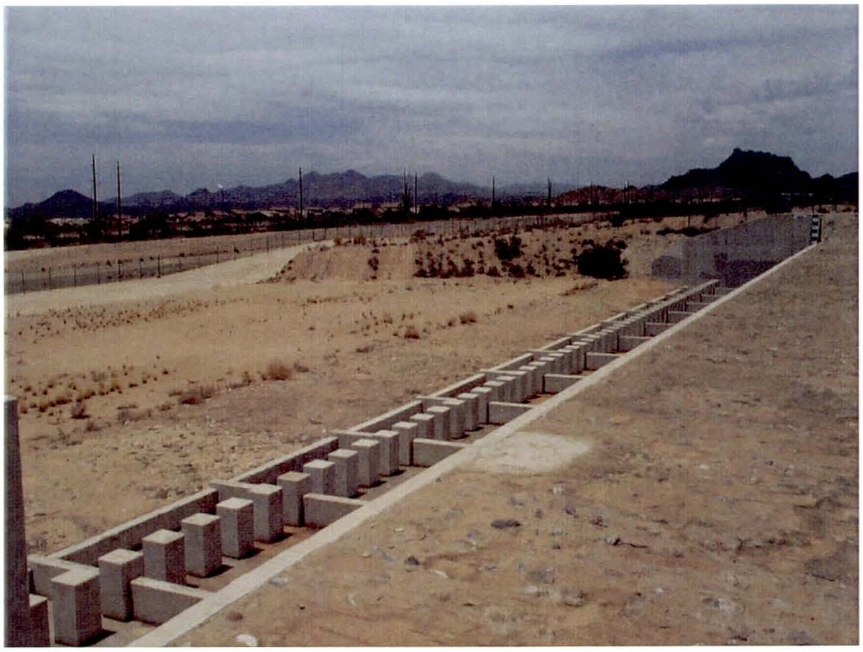
Spookhill FRS. Station 274+50. Looking on west side of McDowell Road in pool area. Newly graded channel and drop structures in channel.

Spookhill FRS. Station 284+10. Longitudinal crack on crest. Ruler is 3-ft long. Crack may be associated with rodent activity.



Spookhill FRS. Emergency Spillway looking north from left wingwall. Reinforced drop structure with bay and baffle block dissipators.

Spookhill FRS. Looking right at emergency spillway crest.

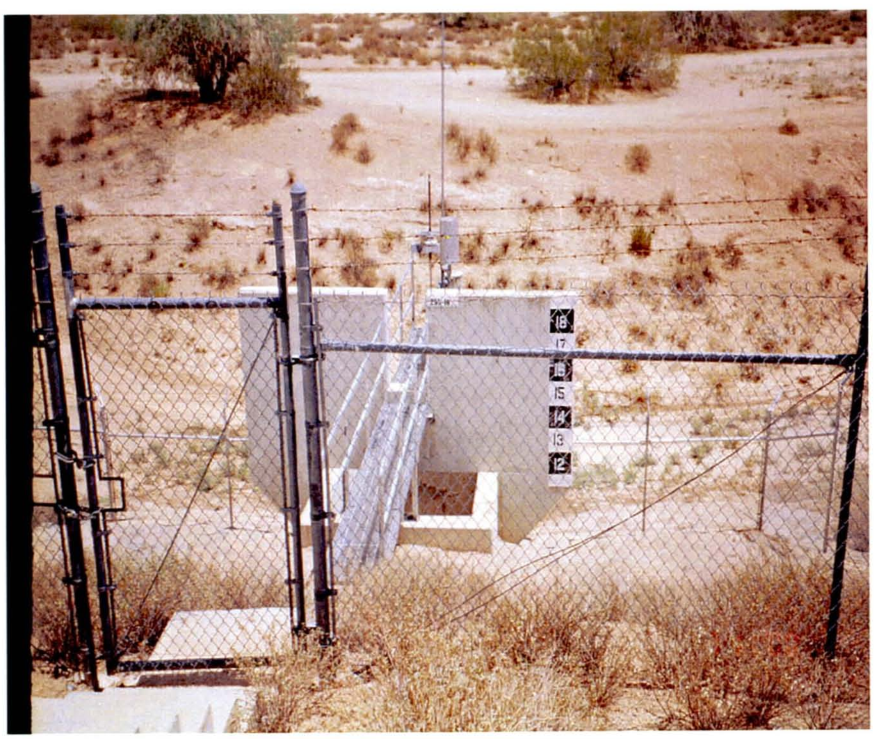


Spookhill FRS. Looking downstream from emergency spillway crest towards Central Arizona Project canal.

Spookhill FRS. Principle spillway inlet and approach channel.

Spookhill FRS. Principal Spillway inlet tower.

Spookhill FRS. Principal spillway outlet structure and energy disspator.



Spookhill FRS. Principal Spillway inlet tower from top of crest of dam

Spookhill FRS. Looking downstream from principal spillway outlet to the Spookhill floodway channel.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
EMBANKMENT DAM INSPECTION CHECKLIST

Each item of the checklist should be completed. Repair is required when obvious problems are observed. Monitoring is recommended if there is a potential for a problem to occur in the future. Investigation is necessary if the reason for the observed problem is not obvious.

Brief description should be made of any noted irregularities, needed maintenance, or problems. Abbreviations and short descriptions are recommended. Additional sheet(s) may be used for any items not listed and additional comments.

DAM NO.: **07.50**	DAM NAME: **SPOOKHILL FRS**	TYPE: EARTH EMBANK	NOT APPLIC.	NO	YES	MONITOR	REPAIR	INVESTIGATE
CONTACTS:		REPORT DATE:						
INSPECTED BY:		INSPECTION DATE:						
REVIEWED BY:	DATE:	PAGE 1 of __						
STORAGE LEVEL: ft. Above/below Spillway Crest	TOTAL FREEBOARD:	PHOTOS? YES/NO						
Item	Comments							

Item / Comments	NOT APPLIC.	NO	YES	MONITOR	REPAIR	INVESTIGATE
1. CREST						
a. Settlements, slides, depressions?						
b. Misalignment?						
c. Longitudinal/Transverse cracking?						
d. Animal burrows?						
e. Adverse Vegetation?						
f. Erosion?						
2. UPSTREAM SLOPE						
a. Erosion?						
b. Inadequate ground cover?						
c. Adverse vegetation?						
d. Longitudinal/Transverse cracking?						
e. Inadequate riprap?						
f. Stone deterioration?						
g. Settlements, slides, depressions, bulges?						
h. Animal burrows?						
3. DOWNSTREAM SLOPE						
a. Erosion?						
b. Inadequate ground cover?						
c. Adverse vegetation?						
d. Longitudinal/Transverse cracking?						
e. Inadequate riprap?						
f. Settlements, slides, depressions, bulges?						
g. Soft spots or boggy areas?						
h. Movement at or beyond toe?						
j. Animal burrows?						
4. DRAINAGE-SEEPAGE CONTROL						
a. Internal drains flowing? Est. Left __ gpm; Est. Right __ gpm						
b. Boils at or beyond toe?						
c. Seepage at or beyond toe? Estimated __ gpm						

EMB. DAM INSP. CHECKLIST	PAGE 2 of	DAM NO.: **07.50**	N/A	NO	YES	MON	REP	INV
INSPECTED BY:		DATE:						
Item	Comments							

Item	N/A	NO	YES	MON	REP	INV
d. Does seepage contain fines?						
5. ABUTMENT CONTACTS						
a. Erosion?						
b. Differential movement?						
c. Cracks?						
d. Settlements, slides, depressions, bulges?						
e. Seepage? Est. Left ___gpm; Est. Right ___gpm						
f. Animal burrows?						
6. OUTLET WORKS-APPROACH CHANNEL Unlined, Concrete, Riprap, or Other?						
a. Eroding or backcutting?						
b. Sloughing?						
c. Restricted by vegetation?						
d. Obstructed with debris?						
e. Silted in?						
7. OUTLET WORKS-INLET STRUCTURE						
a. Seepage into structure?						
b. Debris or obstructions?						
c. If concrete, do surfaces show:						
1. Spalling or Scaling?						
2. Cracking?						
3. Erosion?						
4. Exposed reinforcement?						
d. If metal, do surfaces show:						
1. Corrosion?						
2. Protective coating deficient?						
3. Misalignment or spilt seams?						
e. Do the joints show:						
1. Displacement or offset?						
2. Loss of joint material?						
3. Leakage?						
f. Are the trash racks:						
1. Broken or bent?						
2. Corroded or rusted?						
3. Obstructed?						
g. Sluice/Drain gates:						
1. Broken or bent?						

INSPECTED BY: | DATE:

Item	Comments	N/A	NO	YES	MON	REP	INV
2. Corroded or rusted?							
3. Leaking?							
4. Not seated properly?							
5. Not operational?							
6. Not periodically maintained?							
7. Date last operated?							
8. OUTLET WORKS-CONDUIT	Concrete, Metal, or Plastic						
a. Seepage into conduit?							
b. Debris present?							
c. If concrete, do surfaces show:							
1. Spalling or scaling?							
2. Cracking?							
3. Erosion?							
4. Exposed reinforcement?							
5. Other?							
. If Metal, do surfaces show:							
1. Corrosion?							
2. Protective coating deficient?							
3. Misalignment or spilt seams?							
e. Do the joints show:							
1. Displacement or offset?							
2. Loss of joint material?							
3. Leakage?							
9. OUTLET WORKS-STILLING BASIN/POOL							
a. If concrete, do surfaces show:							
1. Spalling or Scaling?							
2. Cracking?							
3. Erosion?							
4. Exposed reinforcement?							
b. If concrete, do joints show:							
1. Displacement?							
2. Loss of joint material?							
3. Leakage?							
c. Do the energy dissipators show:							
1. Signs of deterioration?							
2. Covered with debris?							

EMB. DAM INSP. CHECKLIST	PAGE 4 of	DAM NO.: **07.50**	N/A	NO	YES	MON	REP	INV
INSPECTED BY:		DATE:						
Item	Comments							
3. Signs of inadequacy?								
10. OUTLET WORKS-OUTLET CHANNEL Unlined, Concrete, Riprap or Other								
a. Eroding or backcutting?								
b. Sloughing?								
c. Obstructed?								
d. Poorly riprapped?								
e. Tailwater elevation and flow condition:								
11. EMERGENCY SPILLWAY-APPROACH CHANNEL Unlined, Concrete, Riprap or Other								
a. Eroding or backcutting?								
b. Sloughing?								
c. Restricted by vegetation?								
d. Obstructed with debris?								
e. Silted in?								
12. EMERGENCY SPILLWAY-CONTROL STRUCTURE								
a. If concrete, do surfaces show:								
1. Spalling or scaling?								
2. Cracking?								
3. Erosion?								
4. Exposed reinforcement?								
b. If concrete, do joints show:								
1. Displacement or offset?								
2. Loss of joint material?								
3. Leakage?								
c. If spillway is unlined:								
1. Are slopes eroding?								
2. Are slopes sloughing?								
3. Is crest eroding?								
d. Is weir in poor condition?								
e. Where is control structure?								
13. EMERGENCY SPILLWAY - CHANNEL Unlined, Concrete, Riprap or Other								
a. Obstructions or restrictions?								
b. If concrete, do surfaces show:								
1. Spalling or scaling?								
2. Cracking?								
3. Erosion?								
4. Exposed reinforcement?								

Item	Comments	N/A	NO	YES	MON	REP	INV
c. If concrete, do joints show:							
1. Displacement or offset?							
2. Loss of joint material?							
3. Leakage?							
d. If an unlined channel, does it show:							
1. Erosion?							
2. Slopes sloughing?							
3. Poorly protected w/ vegetation/riprap?							
14. EMERGENCY SPILLWAY-TERMINAL STRUCTURE							
a. If concrete, do surfaces show:							
1. Spalling or scaling?							
2. Cracking?							
3. Erosion?							
4. Exposed reinforcement?							
b. If concrete, do joints show:							
1. Displacement or offset?							
2. Loss of joint material?							
3. Leakage?							
c. Do the energy dissipators show:							
1. Signs of deteriation?							
2. Covered with debris?							
3. Signs of inadequacy?							
15. EMERGENCY SPILLWAY - OUTLET CHANNEL Unlined, Concrete, Riprap or Other?							
a. Eroding or backcutting?							
b. Sloughing?							
c. Obstructed or restricted?							
16. RESERVOIR							
a. High water marks?							
b. Erosion/Slides into pool area?							
c. Sediment accumulation/Vegetation growth?							
d. Floating debris present?							
e. Depressions, sinkholes or vortices?							
f. Low ridges/saddles allowing overflow?							
g. Structures below dam crest elevation?							
17. INSTRUMENTATION							
a. List type(s) of instrumentation: Staff gages, ALERT gage-water pressure transducer, settlement monuments, station markers at downstream edge of crest of							

EMB. DAM INSP. CHECKLIST	PAGE 6 of	DAM NO.: **07.50**	N/A	NO	YES	MON	REP	INV
INSPECTED BY:		DATE:						
Item	Comments							

dam						
b. In poor condition?						
c. Not read or analyzed regularly?						
d. Is data available?						
18. CONDITION SUMMARY / LICENSE / EAP / NEXT INSPECTION						
a. Dam condition: Unsafe Nonemergency / Safety Deficiencies / No Safety Deficiencies						
b. Safe storage Level:						
c. List date of current License: June 22, 1993						
d. Should new License be issued?						
e. In compliance with License?						
f. In compliance with Statute and Rules?						
g. In compliance with ADWR/District Actions?						
i. List current size; accurate? Medium						
j. List current ds hazard; accurate? Significant						
k. Is there a current EAP? If so, list latest revision date:						
l. List normal inspection frequency: Triennial						
m. Recommend date for next inspection:						

Notes/Sketchs

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART II SPOOKHILL FRS

Section 4.0 Recommendations for Further Actions/Investigations

Section 4.0 Recommendations for Further Actions/Investigations

This Section of Part II provides recommendations for further actions, work plans, and recommended investigations to be accomplished to remediate, repair, or modify, if necessary and required, the dam embankment, reservoir, and/or appurtenant structures. These recommendations are based on the technical review of historic documents (designs, reports, construction plans, as-builts, specifications, etc), review and evaluation of District procedures regarding operation and maintenance and inspection of dams, and from the field examinations of the structures. Structure specific recommendations and work plans are developed for each of the Work Assignment No. 3 dams as well as general operation and maintenance recommendations. The recommendations are in response to District and ADWR concerns and questions on methods and procedures to monitor, investigate, evaluate, repair, or modify a structure showing signs of distress or evaluate previous dam repairs or modifications.

4.1 Detailed Dam Safety Inspections – A procedure for detailed dam safety inspections was provided in the companion report "Policy & Program Report". The report provided in Appendix H detailed inspection guidelines, inspection checklists, and an inspection equipment checklist.

4.2 Phase II Engineering and Geotechnical Investigations – Phase II engineering and geotechnical investigations for the Spook Hill FRS should include the following:

Risk Assessment - A risk assessment of Spook Hill FRS should be conducted. It is recommended that the initial level for the risk assessment be conducted to evaluate the failure modes and effects analysis. Failure modes will need to be identified for Spook Hill FRS and may consist of failures due to transverse cracks, piping, or changes in upstream hydrology. Failure modes and effects analysis should be conducted through the use of an outside facilitator.

Geotechnical - It is recommended that an evaluation be conducted to examine the need for a transition filter (and finger drains) along the longitudinal centerline embankment and key the filter into the foundation. This recommendation is based on the design and construction of transition filters for other NRCS earth embankment dams in Maricopa County. Based on the review of records, embankment cracking was not factored into nor considered in the original embankment design.

Although limited slope stability analyses were conducted by the NRCS (SCS), KHA recommends that a slope stability analysis of the exiting dam embankment under various loading conditions be conducted. The stability analysis can be used with a computer model such as UTEXAS3. The results of the study will provide factors of safety for the embankment given the loading conditions anticipated and can be compared against ADWR rules and ADWR recommended factors of safety for embankment dams.

A slope erosion control and repair plan should be prepared for the Spook Hill FRS. The embankment slopes are currently undergoing severe erosion by concentrating runoff into gullies, which is eroding the surface vegetation soil layer. Alternative slope repair methods should be evaluated including 1) scarification, wetting, and recompaction of the slopes, 2) filling the gullies with moist earthen materials and compacting, 3) placement of rock mulch on the slopes, 4) establishment of low shrubs and grass vegetation cover, 5) overfilling slopes to create a vegetative layer, and/or 6) some combination of the above. A concept work plan is presented below for repair of the embankment slopes.

Hydrology/Hydraulics - It is recommended that the District develop an updated hydrologic model of the Spook Hill FRS watershed to include recent watershed improvements. The updated model should be based on District methodology and the HEC-1 computer program. The rating curve developed by the District in 1997 and the 1993 mapping should be used to develop new outflow discharges from the principal spillway and emergency spillways. The full PMF should be routed through the dam, reservoir, and emergency spillway and examine the impacts of the PMF on freeboard for the dam and spillway. The results should be compared with ADWR dam safety requirements. A consideration as part of this study would be how to handle possible concurrent Signal Butte floodway flows from the Signal Butte FRS and watershed upstream from the floodway since the watersheds are adjacent to one another, are of similar hydrologic characteristics, and are hydrologically and hydraulically interconnected.

A future watershed conditions land use hydrologic model should also be prepared and evaluated. This model should incorporate the impacts of the Pinal County drainage criteria on the upstream system elements (Apache Junction FRS and Signal Butte FRS). It is recommended that the District review any requests for drainage clearances submitted to Pinal County that are within the contributing watersheds.

An evaluation of upstream and downstream watershed conditions should be conducted during every other inspection of this structure. The purpose for conducting an examination of the upstream and downstream watershed conditions is to evaluate changes within the watershed such as urbanization which may affect in the inflow design flood (IDF).

Current techniques for calculating the IDF involve using HMR-49 to estimate the Probable Maximum Precipitation (PMP). HMR-49 is generally considered to be conservative, especially for large watersheds over 50 square miles. A recommendation is to conduct a site specific PMP for this watershed prior to reevaluating the hydrology and hydraulics of the dam. A site specific PMP will evaluate storm centering on the watershed and storm distribution. A typical PMF evaluation will assume uniform rainfall and a storm distribution such as the SCS. This design storm approach while it may be valid for small watershed and lower frequency events it may be unrealistic for major storm events on large watersheds.

An Incremental Damage Analysis (IDA) could also be performed on this structure. The purpose of an IDA analysis is to estimate if there would be additional damage to downstream structures if the dam were to fail during a large storm event over no structure in place and a large flood event occurring within the watershed. If the analysis demonstrates that for a lesser flood event than the full PMF there would be an insignificant difference in damage with or without the dam in place, the dam would only have to be upgraded to that ratio of the IDF.

Sediment Yield - A new sediment yield study should be undertaken to determine the sediment yield from the upstream watershed. The original methods undertaken by the NCRS for the design of the sediment reservoir were based on USGS topographic mapping with 4-foot contours. With new aerial mapping and updated sediment yield methodologies the results may indicate that there is less sediment contribution to the reservoir that originally designed.

Capacity Analysis - Recent aerial topographic mapping was prepared for the District in 1993. The District conducted a capacity analysis of the Spook Hill FRS in 1997. The results of this study indicate that the dam may have more than 100-year capacity and provides a higher level of flood protection. The dam may have a greater capacity than the design capacity, especially if the 100-year sediment volume is reduced upon the above suggested reanalysis. The District should re-survey the elevation of the emergency spillway crest elevation. The benchmark and the results of the survey should be compared against the District study conducted previously in 1997.

The 1993 mapping and the new mapping prepared as part of the Spook Hill Area Drainage Master Study (ADMS) can subsequently be used for future settlement/subsidence surveys, used as base mapping for crack location and monitoring, and used as base sheets for future alterations or modifications of the dam.

Utility Database - A utility database should be prepared. The database would consist of utility records that cross over, under, or through the dam embankment and/or ancillary features (such as the emergency spillway or outlet channels), or within the FCD right-of-way or easements. The database would track at a minimum: the type of utility crossing, location of crossing, skew to centerline of dam, depth of burial, type of encasement, provisions for piping and seepage control, utility owner (name, address, phone, contact person), location of as-built drawings, utility monumentation on dam, and method of construction (trenching, bore and jack).

Operation and Maintenance Plan - No operation and maintenance plan could be located for Spook Hill FRS. It is recommended that an O&M plan be prepared according to the minimum guidelines provided in the "Policy and Program" report (KHA, April 2000).

Emergency Action Plan - It is recommended that an emergency action plan be prepared according to the minimum guidelines as published by FEMA in their report titled "Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners"

(FEMA 64, October 1998). A peacetime disaster plan was prepared for Spook Hill FRS by the Maricopa County Department of Emergency Affairs. However, this plan does not meet the requirements stated by FEMA 64 and the ADWR rules for dam safety.

4.3 Work Plan for Repair of Slope Erosion

The Spook Hill FRS was constructed with terraced embankment slopes. The terraces were uncompacted 1-ft parallel benches designed to provide a surface to detain/retain irrigation and rainfall for plant establishment. The terraced slopes were part of an attempt at landscaping the embankment for visual aesthetics. The embankment slopes are currently undergoing severe erosion through the formation of rills and gullies. The material being eroded is the surface material used to construct the terraces. Recent inspections by KHA (July 2000), the District, and ADWR (November 1999) indicate that the depths of some of the more severe gullies are deeper than the original constructed terraces. This is because the excess runoff is being directed to these gullies instead of allowing the runoff to sheet flow. These observations mean that the depths of the erosion is extending into the compacted embankment. The severity of the slope erosion is to such an extent that major repairs are required.

Methods to repair the embankment slopes range from compacting fill into the rills and gullies; completely repairing the slopes by regrading and recompacting; and overbuilding the slopes (adding fill to the existing slopes to provide a vegetative sacrificial layer). All of these methods will remove the landscape terraces.

A suggested concept work plan for repair of the Spook Hill FRS embankment slopes includes the following steps:

Office Preparation

1. Conduct geotechnical investigation to design the embankment restoration and related plans and specification.

Evaluate embankment and terrace soil characteristics and physical properties and determine the range of properties that will reduce erodibility factors thereby improving the long-term performance of the restored embankment. The soil characteristic evaluation should include:

a. Grain size distribution and plasticity of embankment materials and borrow materials
b. Moisture content and soil density
c. Construction compaction effort
d. Method of compaction
e. Revegetation and armoring compatibility
e. Slope inclination angle and slope length
f. Constructability

Define embankment restoration design that includes soil and slope characteristics that will minimize erosion over time.

2. Obtain required permits
3. Prepare design plans to restore embankment slopes to 2.5:1 (H:V).
4. Prepare slope erosion plans (landscaping, mulching, etc.).
5. Develop construction specifications for materials and testing.

Construction

1. Clear and grub slopes. Remove trees, shrubs, and debris within established clear zone.
2. Remove abandoned irrigation systems.
3. Areas identified as major erosion gullies (gullies exceeding 1-foot in depth) are to be:
   - Excavated to the depth of the erosion from the top of the gully to the toe of the embankment
   - Minimum excavation shall be 8-feet width a minimum of 2:1 (H:V) side slopes
   - Excavated area shall be wetted to optimum moisture content (plus/minus) 2 percent
   - Fill material compatible with embankment material of optimum moisture content (plus/minus) 2 percent shall be placed in 8-inch loose lift and compacted by a minimum of 6 passes with a D8 or equivalent equipment
   - Excavated areas shall be filled to be even with adjacent slopes
4. Areas identified as minor erosion gullies (less than 1-foot in depth) are to be:
   - Excavated to the depth of the erosion gully from the top of the gully to the toe of the embankment with 2:1 (H:V) side slopes
   - Excavated area shall be wetted to optimum moisture content (plus/minus) 2 percent
   - Fill material compatible with embankment material of optimum moisture content (plus/minus) 2 percent shall be compacted by a minimum of 6 passes with a D8 or equivalent equipment
   - Excavated areas shall be filled to be even with adjacent slopes
5. Top soil furrows are to be:
   - Wetted to optimum moisture (plus/minus) 2 percent
   - Spread evenly and parallel to the existing slope
   - Compact by a minimum of 6 passes of a D8 or equivalent equipment
6. Place rock mulch. Seed with native grasses and shrubs.

4.4 Work Plan for Repair of Transverse Cracks

Reconnaissance of the embankment since construction has revealed only limited visual distress consisting of localized holes and animal furrows along the crest. The limited transverse and longitudinal cracking that has occurred at the Spook Hill FRS is typical of low height dams constructed of homogenous sections of sandy clays and silty sands in arid regions of the southwestern U.S. The cracking that has occurred is the result of (1) differential settlements of the foundation soils and (2) desiccation or shrinkage due to drying. A major concern is the transverse cracking that creates a potential flow path of concentrated seepage through the dam embankment.

Various methods have been employed to seal surface cracks of earth dams in the southwest. The most common and preferred method has been to excavate a trench about 3 to 6 feet in width along the crack to the depth at which the crack disappears and then to backfill the trench with impervious hand–placed and compacted fill. This method has generally been satisfactory provided no further large settlements or cracking occur.

Another method that has been used to repair small dams in the southwest is to fill the cracks with a mud slurry consisting of natural clayey soils and water. Typically, the slurry is mixed in a pit(s) excavated near the dam and a rotary drill rig used as a mixer. The slurry is pumped through a 2-inch diameter hose and discharged into the cracks under gravity. Small dikes and sandbags are used to prevent the slurry from flowing out of the cracks in the embankment.

Before pumping the mud slurry, the cracks are washed with water. A drill rig pump is typically used and the water jetted into the cracks. The water under pressure is injected into the cracks with a ½-inch to ¾-inch diameter pipe about 10 feet in length and starts in the lower elevations of the dam.

The most important advantage of this method is economy and minimizing disturbance to the dam. A cracked dam can be repaired for a fraction of the cost of excavating and rebuilding the cracked portions of the embankment. The grouting process can be repeated economically on a maintenance basis if cracking continues. The equipment used is easily obtained or rented by County maintenance personnel or the work can be performed by a contractor.

Excavating and backfilling cracks are a common approach to repairing cracks in an earthen dam. However, when cracking is extensive or when the cracks extend far into the embankment a significant portion of the structure would need to be removed and replaced. Grouting has been used in Woodcrest Dam in southern California (flood control dam, 40-feet high). The SCS starting in 1953 has repaired approximately 12 small dams in OK, TX, and WI by filling the cracks with a slurry consisting primarily of clay and water. Centerline drains and finger drain outlets were used by the SCS to control cracking in the Rittenhouse FRS and others in the early 1980's.

Crack Monitoring Program – It is recommended that the District monitor the location and size of surface expressed transverse and longitudinal cracks. This effort goes beyond just documenting the observations of cracks in inspection reports. A crack location plan needs to be prepared using the dam construction plans or the previously discussed topographic mapping as a base. It is recommended that the plan is developed in AutoCad or some other electronic plan retrieval system (HIS for example). Observed crack locations can be plotted on the crack plan and coded by type. A database of transverse and longitudinal cracks needs to be prepared. The input to the database includes location of crack (station: location on upstream slope, downstream slope, or crest), width of crack, depth of crack, and any other distinguishing characteristics. A photograph should be taken and labeled for each crack. Follow-up observations and notations can then be compared to previous observations and conclusions drawn regarding crack propagation. The long-term benefit of the crack monitoring plan is to determine if particular segments of the embankment are more predominant in showing signs of cracking than other segments. In this fashion, the District may consider future requirements for rebuilding of a particular segment of the dam embankment.

4.5 Operations and Maintenance

Landscaping: Where the safety of the structure is not compromised and effective flood-fighting and maintenance of the structure is not seriously affected, appropriate landscape plantings can be incorporated into the design of dam embankments (Corps of Engineers, "Guideline for Landscape Plant and Vegetation Management at Floodwalls, Levees, and Embankment Dams", January, 2000).

The primary objectives of plantings at dam embankments are to harmonize the development with the surrounding natural and human environment, enhance structures, control dust and slope erosion, provide privacy or screen out undesirable features, provide incidental habitat for wildlife, and create a pleasant environment for recreation. Plantings should be naturalistic and should avoid "arboretum-type" plantings.

Landscape plantings (aside from slope protection for erosion control) for <u>flood control</u> embankment dams should be confined to areas adjacent to the dam embankment. Because of the need for access at the upstream and downstream toe area by maintenance and construction equipment during periods of flooding, a minimum 50-foot vegetation-free zone should be maintained immediately downstream and upstream of the toes of the dam in the floodplain and on the abutments.

One method of establishing landscape plantings on embankment slopes is to provide for overbuilt areas on the dam faces. After establishing the minimum embankment section required satisfying stability requirements, additional material could be added to the base section to provide an area to support plantings. Overbuilt areas must include adequate consideration of the internal drainage system for the main structure. In no case should trees be directly planted on embankment slopes or crest.

Overbuilt areas require a root-free zone, which provides a margin of safety between the greatest extent of plant roots and the beginning of the basic structure. The basic structure is the engineered feature required for human safety. The bottom of the root-free zone will be the external limits of the cross section of the embankment established by the engineer for stability and/or seepage control.

Vegetation Management: Vegetation management at an earthen dam takes the form of trimming of overgrown vegetation and the clearing of unwanted growth (large shrubs and trees). Trimming is conducted so that inspection of the slopes can be conducted without hindrance from vegetation. Locally, grasses and small shrubs are ideal for embankment dams along with rock mulch for slope protection against erosion. Vegetation should be trimmed on an ongoing basis and not be allowed to grow any higher than two to three feet. Trimming methods are labor intensive, usually involving gas powered weed trimmers or boom mowers.

Removal of dead trees and debris is recommended within the approach channels to principal spillways. This will reduce the chance that the inlet to the principal spillway would become clogged with debris. Typically, District dams have trash racks and/or a multiple-staged or tiered inlet for the principal spillways. In the event debris accumulates at a lower level on the inlet/trash rack, floodwater can still overtop the debris and flow into the principal spillway conduit. This type of inlet structure is recommended for all District dams where debris might be a concern.

Debris blockage of the principal spillway can cause operational constraints on the performance of the spillway to evacuate floodwaters. Depending on the volume of inflow, a blocked principal spillway can become non-functional and cause flow to occur in the emergency spillway for storm events less that the inflow design flood. Several of the District dams have a pedestrian/maintenance bridge that connects to the crest of the dam and the inlet tower of the principal spillway. In the event that the principal spillway becomes clogged during an event, District forces have the capability to remove the debris by standing on the bridge and using rakes or other means to remove debris.

Sediment Management: Sediment markers should be installed within the reservoir impoundment area. The sediment markers will provide the District with an indication of the rate of sediment build-up as well as when sediment removal activities are required.

Generally, District forces remove sediment when sediment build-up becomes apparent at the inlet and outlet structures of the principal spillway. No sediment maintenance has been conducted for the sediment pool. This may be due to the fact that: 1) there is no method to measure the level of sediment buildup in the pool, and 2) sediment build-up has not been an apparent maintenance issue.

The District should develop a sediment management plan for District dams. The plan elements would require identification of the equipment, manpower, and for the disposal of removed sediment.

Clean Water Act (CWA)– Section 404: Certain activities relating to excavation-only activities are exempt from Corps jurisdiction under Section 404 of the CWA. However, the Corps' definition of exempt excavation activity is based on 'incidental fallback" and is very restrictive. The generally accepted definition of "incidental fallback" allows only for the spillage of material from the actual excavation device. This prohibits the pushing, windrowing or stockpiling (even temporarily) of material during the excavation activity. Sediment must be lifted (as opposed to pushed) from the site and deposited outside of the jurisdictional boundary to be exempt from Section 404. Sediment cleaning operations conducted with a backhoe or front-end loader (bucket equipment) would likely be exempt, while sediment clearing conducted with a grader or other blade equipment would not be exempt.

Sediment removal activities may also be subject to Section 401 and Section 402 regulations regardless of their Section 404 status. Ground disturbance of greater than 5 acres is subject to authorization under Section 402 of the CWA and Section 401 authorization may be required if the site will have a surface water discharge to jurisdictional areas. The ESA and Migratory Bird Treaty Act regulations may apply to areas of potential inhabitation or suitable habitat particularly if the area is vegetated. .

Flood control structures may result in increased vegetation growth. Structures in ephemeral channels can impound water for short periods after flow events, therefore increasing the hydroperiod of the site. An increase in available moisture can result in increased vegetation density or enhanced vegetation species composition.

In general, the type of vegetation communities created or enhanced by flood control structures will benefit wildlife species associated with riparian habitat or those species requiring a more dense growth of vegetation. Such habitat is rare in most areas of Arizona. Therefore, the vegetation communities have a higher probability for providing habitat for several Endangered Species Act (ESA) listed species. Depending on the type of structure other habitat may be created or enhanced.

The ESA and the Migratory Bird Treaty Act provide protection to listed species and to the species habitat. Removal of this vegetation may be considered a violation of the ESA and/or the Migratory Bird Treaty Act. Restrictions on activity timing and the extent of the activity may be imposed under these regulations.

Further, the removal of the vegetation may require permit authorization under Section 404 of the CWA. The removal of vegetation by mechanized land clearing (grubbing) is not considered an exempt activity under the Clean Water Act. The Corps' believes that the soil clinging to the roots will be dislodged in the process and will fall into other areas thus creating a discharge or fill situation. Removal of vegetation by cutting is not considered a jurisdictional activity. If stump or whole vegetation is removed in such a manner that the stump/stem is lifted from the site (as opposed to pushed across the site) the activity is considered to be exempt from Section 404 jurisdiction.

Vegetation clearing activities may be subject to regulation under Section 402 of the CWA if more than five acres of ground is disturbed and may also be restricted under the ESA adherence clause of the National Pollution Discharge Elimination System (NPDES) permit. Vegetation clearing may be subject to Section 401 if the area may discharge to a jurisdictional area or require a Section 404 authorization.

Riprap Placement/Repair: The placement of riprap or other armoring material is a jurisdictional activity under Section 404 and is subject to Corps' approval. In most instances this includes the repair or replacement of previously installed materials (As noted in Nationwide Permit #3 – NWP#3). Riprap activities may be subject to regulation under Section 402 of the CWA if more than five acres of ground or vegetation will be disturbed. Riprap material may also be subject to Section 401 approval.

Recommendations for Section 404 Regulatory Compliance

Clean Water Act.

- Conduct Jurisdictional Determinations on areas subject to periodic maintenance.
- Train Maintenance Workers in the identification of potential CWA Section 404 jurisdictional areas and the restriction of activities within jurisdictional boundaries.
- Conduct an audit of existing facilities to determine which have been previously authorized under Section 404 or other applicable regulation.
- Develop a vegetation management program that monitors and controls growth of vegetation to prevent the establishment of wetlands. (By definition a wetland must be vegetated). Under the proposed regional conditions of the new Nationwide Permit Program impacts to wetlands are not allowed, with certain exemptions for NWP 3 and 31.
- Coordinate with the Corps to develop a standard procedure for sediment removal, which identifies the type of equipment and methodologies that will be exempt from Section 404 jurisdiction based on the incidental fallback rule.
- Develop Best Management Practices (BMPs) and standard procedure for earth disturbance activities associated with maintenance activity to satisfy Section 402.
- Design and permit new facilities to include the appropriate maintenance activity in the original Section 404/401 authorization.
- Establish baseline conditions for existing facilities (Required under Section404 NWP31)
- Coordinate with Corps to determine if a Regional or other General permit for all maintenance activity is appropriate.
- Coordinate with the Arizona Department of Environmental Quality (ADEQ) and the Environmental Protection Agency (EPA) to determine if a Section 401 water quality certification is applicable.

Endangered Species Act/Migratory Bird Treaty Act

- Train Maintenance Workers to identify potential habitat and to be aware of seasonal nesting times.
- Obtain appropriate ESA permit to allow for field survey and possible incidental take of certain listed species.
- Coordinate with United States Fish and Wildlife Service (USFWS) to determine appropriate habitat conditions and survey protocols for areas of potential ESA restrictions.
- Develop a Maintenance Schedule that avoids activity in suitable habitat during the breeding season.
- Coordinate with USFWS regarding the potential development of suitable habitat in or adjacent to flood control structures. This may include the establishment of a pseudo Safe Harbor agreement.

- Design new facilities to provide for enhanced habitat outside of the area of maintenance disturbance. Thus developing long-term enhanced habitat and mitigation areas.

Federally Managed Areas

- Identify responsible Management Agency.
- Determine Management requirements for specific area.
- Conduct necessary National Environmental Protection Act (NEPA) documentation to support a categorical exclusion (CATEX).
- Include an ongoing Maintenance Plan in required NEPA documentation for new projects.

State and Local Regulations

- Coordinate with SHPO regarding potential historical significance of older facilities and of potential eligibility of areas requiring periodic maintenance.
- Train Maintenance Workers in the identification of vegetation listed in the various Native Plant regulations.
- Develop potential donor sites and acceptable salvage protocol for native vegetation removed from maintenance areas.

4.6 Subsidence and Earth Fissure Monitoring Program

Although the Spook Hill FRS is believed to be outside the limits of active ground subsidence in the East Valley area, conducting a horizontal and position survey of established benchmarks in the vicinity of the FRS should verify this assumption. The control benchmark for this survey must be a witnessed, established benchmark in bedrock that has been in place for at least 30 years.

Subsidence due to groundwater withdrawal is not expected to be an issue at the Spook Hill FRS due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment. Spook Hill FRS is located on the Usery Mountain granitic pediment with bedrock at a relatively shallow depth (probably less than 50 feet) beneath the FRS structure.

Earth fissuring at the Spook Hill FRS site and local vicinity should have a low degree of concern due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment on which the Spook Hill FRS is founded. The nearest ground subsidence-related earth fissure is about two and one-half miles south of the south end of the FRS.

The Spookhill FRS is located near an area of active ground subsidence and earth fissures. However, due to the presence of shallow granite pediment in the FRS area, earth fissuring is not expected to impact the Spookhill FRS. Likewise, ground subsidence at the FRS is expected to be negligible. The Spookhill FRS should be included in an area-wide monitoring program because of its proximity to the ground subsidence area and associated earth. However, general guidelines have been prepared and should be implemented if the physical regional characteristics change in the vicinity of the dam. The following presents recommended guidelines for subsidence and earth fissure monitoring.

General Guidelines for Recommended Subsidence and Earth Fissure Monitoring

Many embankment flood control dams under the jurisdiction of the District are located in areas of active ground subsidence and earth fissures. The prognosis for continued ground subsidence and earth fissure development is high for the foreseeable future. Therefore, the assessment of existing and future potential ground subsidence and earth fissures and their impact on the safety of existing District dams is a critical element of the dam safety evaluation process

KHA recommends the District subsidence monitoring program outlined by Staedicke (1995) be adopted. It should also be refined and modified or amended where appropriate for application to District dams and to satisfy other regulatory requirements. The following outline incorporates the salient items of the District program and lessons learned by the Bureau of Reclamation (BuRec), NCRS, and consultants with professional experience dealing with ground subsidence and earth fissures.

Ground subsidence due to groundwater withdrawal from deep aquifers is known to impact alluvium-filled basins in central Arizona including the District. The surface manifestations of ground subsidence include lowering of the ground surface over time and the development of earth fissures (or ground cracks) due to induced tensile stresses within the alluvium-filled basins. The initial activity of the subsidence monitoring program will be an evaluation of known subsidence within the District. This evaluation would be performed to assess current ground subsidence conditions and characterize the earth fissures present. These results will help formulate the general parameters of the monitoring program and the specific details for monitoring at each of the District's embankment dams. Where critical subsidence and each fissure conditions exist that might jeopardize dam safety, the monitoring program results could help to develop mitigation measures to reduce potential ground subsidence impacts caused by regional groundwater withdrawal.

The recommended scope of activities to accomplish the subsidence evaluation is separated into three tasks. Task 1 would be directed to an overview assessment of the District using available geological and hydrogeological data and geological interpretation of available aerial photography. Output from Task 1 would be a preliminary map of the District area identifying potential and known subsidence areas and earth fissures. This information would be used to target sites for direct field examination during Task 2. Task 2 would verify the presence of fissures close to District structures. Task 3 includes the preparation of comprehensive settlement/subsidence and earth fissure monitoring program tailored to each embankment dam structure. The monitoring programs would be designed to incorporate trigger mechanisms that would be used when excessive subsidence or earth fissure emergency conditions are identified.

Task 1: Compile Preliminary Subsidence/Earth Fissure Map:

- Research and compile existing earth fissure and ground subsidence data pertaining to the District service area.

- Assess future potential ground subsidence induced by groundwater withdrawal at the site and in the site vicinity. Data to complete this assessment will be obtained from the Arizona Department of Water Resources, U.S. Geological Survey Water Resources Branch and private sector hydrogeological consultants familiar with the area.

- Acquire aerial photographs from available sources, such as Maricopa County, Arizona Department of Transportation, Bureau of Reclamation (BuRec), NCRS, and private sector companies. Aerial photographic interpretation would be used to identify suspect ground subsidence areas and earth fissures.

- Compile and analyze the data gathered and prepare a preliminary subsidence/earth fissure map of the District area and target areas for the Task 2 field reconnaissance. Use available subsidence monitoring data to evaluate past subsidence and calculate future potential ground subsidence estimates.

- Prepare summary report documenting the Task I study findings and conclusions.

Task 2: Subsidence/Earth Fissure Field Reconnaissance

- Conduct a ground-truth field reconnaissance within a 5-mile radius of flood control embankment dams, identified in Task 1, that are in a subsidence area to:

  (1) Verify, or refine, and update the earth fissure and ground subsidence data compiled during Task 1.

  (2) Identify and map earth fissures or other related 'suspect' features that may be present and potentially affect District flood control dams.

  (3) Evaluate the rate of earth fissure growth where feasible using Task 2 information and historical aerial photography or other documentation.

- Stake and survey the location of the earth fissures and identify exploration sites.

- Prepare a Task 2 summary report documenting the results of the field reconnaissance.

Task 3: Prepare Preliminary Subsidence and Earth Fissure Monitoring Program

- Locate, relocate, or reestablish settlement/subsidence monitoring monuments on crest and downstream toe of embankment dams. Establish new monuments where deemed necessary. Relocated, reestablished, or new monuments should be constructed in accordance with recognized plans and specifications (NRCS, BuRec, ADOT, District). The number of survey monuments should be evaluated considering the future potential subsidence in the dam area, the structure hazard classification, and other factors that may be deemed critical based on discussion with District staff.

- Locate, relocate, or reestablish monitoring benchmarks in bedrock tied to an established survey network such as the National Geodetic Survey. All benchmarks should be thoroughly documented and witnessed.

- Identify and find wells near each embankment dam that can be used to monitor changes in groundwater levels. This information would be used to refine estimates of future potential ground subsidence.

- Verify benchmark survey control and survey the elevation of all monitoring monuments. Using the new survey data, rectify previously obtained subsidence monitoring data relative to an established survey datum.

- Based on the results of the new survey and the rectifying of past data, develop a resurvey schedule suited to each dam structure. The surveys should be rerun at yearly intervals for two or three years to see if any trends exist. The monitoring intervals could be changed to range from one year to four or five years depending upon trends established or the calculated estimates of future potential subsidence. A suggested monitoring schedule is provided in the following table.

Table 4-1. Recommended Subsidence & Earth Fissure Monitoring Schedule.

Dam Hazard Classification	Monitoring Schedule			
	Ground Subsidence	Earth Fissures		
		≤ ¼ mile	¼ mile < D < 1 mile	1 mile < D < 5 miles
High	Annual	Annual	Annual	Biennial
Significant	Biennial	Annual	Biennial	Biennial
Low	Triennial	Triennial	Triennial	Pentad
Very Low	Pentad	Pentad	Pentad	Pentad

The monitoring schedule should be reevaluated on a triennial basis and revised if deemed necessary.

- Earth fissure monitoring should be conducted concurrently with the subsidence monitoring program. In areas of known active earth fissures, the monitoring intervals may need to be more closely spaced especially where an earth fissure is located within one mile of a District structure. Earth fissure monitoring could be conducted using (1) direct examination on the ground by geologists or geotechnical engineers or (2) low-sun-angle aerial photography. The earth fissure survey should also include measurement of its surface expression (length, width, depth, orientation, differential displacement, evidence of activity or inactivity).

- Surveying of subsidence benchmark and structure monuments should be conducted using currently accepted surveying methods and standards of practice. Survey accuracy standards should be 0.05 foot (or about 2 centimeters).

- Data collected should be recorded in an easily used format such as Microsoft EXCEL. As a minimum, reporting should be done annually. The report should be distributed to other interested parties including BuRec, Corps, USGS, AGS, ADOT, ADWR, County highway departments, and local jurisdictions. Supplemental reports could be necessary where rapidly occurring subsidence is documented or when earth fissure growth or development is observed.

Subsidence Monitoring For Spook Hill FRS

Settlement monuments were established on the embankment crest (A-series) and along the downstream toe (B-series). Some of the monuments have been destroyed or damaged.

A review of settlement data for Spook Hill FRS indicated changes when comparing 1987 survey data with 1998 survey data. KHA recommends a resurvey of monuments following a thorough search to locate the A-series and B-series survey monuments. This search should include the use of a metal detector to assist with monument locations. We also recommend using the NAD 27 datum for any resurveys conducted.

The monitoring program should consist of a series of elevation data measurements taken at both the "A"-series and "B"-series monuments located along the Dam. The A-series and B-series monuments are located approximately every 2,000 feet along the crest and toe of the embankment, respectively. A recent dam safety field investigation revealed that many of these benchmarks have either been removed or destroyed. Additional survey monuments should be installed on the upstream and downstream toe and the upstream and downstream crest of the dam. The District database should be updated to store and plot the new settlement data to detect trends or movements.

Once all survey monuments are in place, a survey of the elevation of each monument should be conducted in accordance with the recommended schedule for high hazard potential dams. The survey method used should have a vertical accuracy to at least 0.05 foot (2 centimeters). The results of the surveys, over time, would give:

- Subsidence/settlement measurements
- Subsidence/settlement rates (increase/decrease)
- Data on differential subsidence/settlement.

Although ground subsidence and earth fissures are expected to have a negligible impact on the Spookhill FRS, subsidence data gathered at the Spook Hill FRS should be obtained, compiled, analyzed, and reported (to ADWR) in accordance with the general ground subsidence/earth fissure monitoring program guideline.

A summary of the Phase II recommendations is provided in Table 4-2 on the following page.

Table 4-2. Summary of Recommendations for Spook Hill FRS.

Recommendation		Remark
Dam Safety Program Elements	Dam Safety Inspections	See "Policy and Program" Report
	Develop Utility Database	See "Policy and Program" Report
	Update Operations and Maintenance Plan	See "Policy and Program" Report
	Prepare Emergency Action Plan to meet Minimum requirements of FEMA 64	See "Policy and Program" Report
	Develop/prepare Crack Monitoring Plan	
	Install Sediment Markers in Reservoir	
	Continue Settlement Surveys	See "Policy and Program" Report
	Prepare Subsidence and Earth Fissure Monitoring Plan	See "Policy and Program" Report
Phase II Analyses	Conduct Risk Assessment	See "Policy and Program" Report
	Conduct Slope Stability Analyses	Design vs Existing vs ADWR requirements
	Update Hydrologic Models (100-yr, PMF)	See Spook Hill ADMS By Wood Patel
	Prepare Future Conditions hydrologic model	Evaluate detention/retention
	Evaluate upstream/downstream land use and watershed conditions	Impact on IDF
	Conduct Incremental Damage Analysis	Impact on IDF
	Conduct updated Sediment Yield Analysis	Reservoir capacity and upstream development
	Conduct updated Reservoir Capacity Analysis	
	Examine need for transition filter along longitudinal centerline of embankment	
	Prepare Slope Erosion Repair Plan	Repair of slope erosion
	Prepare Work Plan for Repair of Transverse Cracks	Repair of transverse cracks

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Appendix A – Summary of NRCS Design Criteria

Item	NRCS Criteria	ADWR Criteria	Comment/Remarks
Publications and References for Corps, NRCS, and ADWR Criteria	Technical Release No. 60 TR-60. Earth Dams and Reservoirs. Oct. 1985. Amended Jan 1991	Rules for Dam Safety Procedures	
Size	Maximum ht = 22.0 ft Floodwater storage = 900 AF Sediment storage -- 317 AF	**Intermediate:** 40' <height< 100' and 1000 ac-ft < capacity< 50,000 ac-ft	Presently an intermediate dam. Check capacity - maybe reduced to small dam based on storage
Structure Classification (Hazard Classification)	**Class C**. Failure may cause loss of life, serious damage to homes, industrial and commercial buildings, important public utilities, major highways, or railroads	**High**: probably loss of life and low to high economic losses	Currently a high hazard dam;
Inflow Design Flood (IDF)	One-percent event (100-year)	**0.5PMF to PMF**: High hazard class with any size class will vary based on downstream population and potential economic losses (pg 26)	May be required to pass 0.5 PMF with change in classification
Total Freeboard	6.3 ft per design plans (between Emergency Spillway crest and the settled top of the dam crest)	ADWR definition: vertical distance between the emergency spillway crest and the top of the dam Shall be the largest of the following : (note: this is for new dams) a) the sum of the IDF max water depth above the spillway crest plus wave runup b) the sum of the IDF max water depth above the spillway crest plus 3 ft c) The minimum of 5 ft	
Residual Freeboard	between maximum water surface elevation to dam crest		
Principal Spillway Design Flood	100-year	N/A	100-year
Principal Spillway Capacity	(a) Discharge through the emergency spillway will not occur (b) Adequate to empty the retarding pool in 10 days or less. Or adequate to empty 80 percent or more of the maximum volume of retarding storage after 10 days. The 10-day is measured starting from the time the maximum water surface elevation is attained during the passage of the principal spillway flood	N/A	(a) Discharge through the emergency spillway will not occur (b) Adequate to empty the retarding pool in 10 days or less. Or adequate to empty 80 percent or more of the maximum volume of retarding storage after 10 days. The 10-day is measured starting from the time the maximum water surface elevation is attained during the passage of the principal spillway flood (
Initial Reservoir Stage for Principal Spillway Hydrograph Routing	Crest elevation of the lowest ungated principal spillway inlet or the anticipated elevation of the sediment storage, whichever is higher	N/A	Crest elevation of the lowest ungated principal spillway inlet or the anticipated elevation of the sediment storage, whichever is higher
Design Procedures for Principal Spillways	TR 60 Chapt 6 Principal Spillways	for high and significant hazard dams principal spillway shall be 36-inches or greater; all high and significant hazard dams shall have the capacity to evacuate 90% of storage capacity of reservoir within 30 days, excluding reservoir inflows; corrugated metal pipe not acceptable	
PMP Storm Types	General and local. HMR No. 49	N/A	N/A
Minimum Emergency Hydrologic Criteria	For Class C Structure 1: emergency spillway hydrograph P100 + .26(PMP - P100) 2: freeboard hydrograph = PMP	N/A	
Emergency Spillway Capacity	(a) Pass the emergency spillway hydrograph resulting from P100 at the safe velocity (b) Pass the freeboard hydrograph with the water surface elevation at or below the design top of the dam (c) Capacity must not be less than that determined from Figure 7-1 on Page 7-8 in TR-60	Spillways and outlets of flood control dams shall be able to pass all the flood water at a discharge rate as calculated on the basis of the spillway design flood.	

Item	NRCS Criteria	ADWR Criteria	Comment/Remarks
Emergency Spillway Crest Elevation	(a) Satisfy the 2500 ac-ft total capacity limit (PL 83-566, NWM 500.20) (b) The discharge through the emergency spillway will not occur during the routing of the principal spillway hydrograph (c) If the 10-day drawdown requirement is not met for principal spillway capacity design, then the crest elevation of the emergency spillway will be raised as noted on Page 6-1, Capacity of Principal Spillway.	N/A	(a) Satisfy the 2500 ac-ft total capacity limit (PL 83-566, NWM 500.20) (b) The discharge through the emergency spillway will not occur during the routing of the principal spillway hydrograph (c) If the 10-day drawdown requirement is not met for principal spillway capacity design, then the crest elevation of the emergency spillway will be raised as noted on Page 6-1, Capacity of Principal Spillway.
Initial Reservoir Stage for Emergency Spillway Hydrograph Routing	The highest value from the following elevations: (a) Elevation of the lowest ungated principal spillway inlet (b) The anticipated elevation of the sediment storage (c) The elevation of the water surface associated with significant base flow (d) The pool elevation after 10 days of drawdown from the maximum stage attained when routing the principal spillway hydrograph. (Page 7-2 in TR 60)	N/A	
Sedimentation	100-year sediment reservoir	N/A	
Dam Breach		Unless waived by the Director, owners of high and significant hazard potential dams shall prepare, maintain, and exercise Emergency Action Plans for immediate defensive action to prevent failure of the dam and minimize threat to downstrem development.	Develop EAP
Special Requirement for Storage	2500 ac-ft (total reservoir capacity = water volume plus the anticipated sediment volume) according to Table 500-2 in Public Law 83-566, National Watershed Manual-Part 500.20. Based on Table 500-2, any amount for construction costs and >4,000 ac-ft of total capacity require a committee on Environment and Public Works of the Senate and committee on Public Works and Transportation of the House of Representatives.	The temporary storage will be evacuated as soon as possible following such periods of flood.(from License)	
Seismic	See TR-60	There are no seismic design requirements for existing flood control dams.	See Appendix B in Engineering Pamphlet 1110-2-1155 US Army Corps of Engineers
Design for Vegetated and Earth Emergency Spillways	(a) From EM - 27 Pages Appendix F (b) Spillway will not breach during passage of the freeboard storm (f) Maximum permissible velocity in vegetated emergency spillways: Table 7-1 in TR-60 (g) Maximum permissible velocity in earth emergency spillways: Table 7-2 in TR-60(Fortier and Scobey's Study) (h) Manning's n = 0.02 for design velocity in earth spillways; Capacity of earth spillways will be based on a appraisal of the Manning's n at the site. (i) Manning's n = 0.04 for vegetated spillways	Criteria depends on whether earthen spillway is located on soils subject to liquefaction.	

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Appendix B – Settlement Monitoring Records

SETTLEMENT MONITORING OF EARTHEN DAMS
OPERATED BY THE FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

DRAFT

Prepared by

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Civil Engineering Technician III
Flood Control District of Maricopa County

June 1, 1995

Purpose

The purpose of this report is to:

a) Compile settlement monitoring data that has been acquired to date.

b) Recommend refinements to the monitoring procedure.

c) Recommend a schedule of continued monitoring.

d) Recommend that the settlement monitoring procedure be supplemented with:

  a) earth fissure monitoring procedure

  b) Periodic inspection using a team of specialists (geologist, structural engineer, etc.)

Introduction

Beginning in 1977 survey monuments were installed on the crest and downstream toe of the Flood Control District's (FCD's) earthen dams to monitor the settlement of these structures. It is assumed that changing elevations of monuments at the downstream toe of the structures indicate subsidence, and changing elevations of the crest monuments are the sum of subsidence plus expansion/contraction of the embankment fill. The difference between these two is then the apparent expansion/contraction of the fill material.

Subsidence is the downward movement or sinking of the Earth's surface caused by removal of underlying support (typically the withdrawal of groundwater). The estimated groundwater pumpage in the Salt River Valley basin area peaked in the 1950's. Due to an abundance of rainfall and surface water supply between 1976 and 1982, pumpage was greatly reduced and water levels rose over much of the basin during that time.[1] The Phoenix Active Management Area (AMA) was created by the Groundwater Management Act of 1980. Although groundwater levels have stabilized throughout much of the valley, they continue to decline in the area of Luke Air Force Base, so structures in this vicinity warrant greatest concern (White Tanks and McMicken).

The crest monuments are typically placed about 6" below the crest. Since the distance from the crest to the monument isn't constant, variation from the design crest of less than 1 foot is probably not significant. A more telling number is the settlement between years surveyed. Because groundwater pumping peaked in the 1950's, and our earliest survey data is 1977, we lack data for the most critical time period. Structures which should have the highest priority for continued monitoring are those in which the minimum elevation is more than 1 foot below design crest, or those which show the greatest settlement in the years surveyed.

Data Analysis

Appendix A contains a summary table that lists each structure and shows the maximum settlement between years surveyed, and the difference between the design crest and the minimum crest elevation. The table appears twice, sorted first by greatest settlement, and then by greatest change from the design crest.

Appendix B contains detailed comments regarding each structure.

Appendix C contains the following detailed information for each structure:

  1) Data table showing survey elevations, incremental and total settlement

  2) Plot of the crest settlement monuments

  3) Plot of the change in crest over the years surveyed.

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[1]Arizona Department of Water Resources Hydrologic Map Series Report No. 12 Sheet 1 of 3 Depth to Water and Altitude of the Water Level. Dated 1983

In each data table anomalies have been shaded. These have been checked from the plans, but they should also be checked from the survey notes. In cases where the error is obvious, it has been corrected and noted.

In addition to the data gathered in the settlement surveys, the District is in the process of conducting GPS surveys of each dam, to verify their capacities. The first of these surveys (Buckeye Structures 1,2,&3) has been submitted to the District, and the remaining surveys are to be submitted in late June. This data should be analyzed before prioritizing and conducting future subsidence surveys. Although the GPS surveys don't have the same level of accuracy, and don't include elevations of the settlement monuments, they do include spot elevations on the dams, and provide ties to the benchmarks used in the subsidence surveys. This should help us confirm those locations where enough subsidence has occurred to cause concern and/or warrant increased monitoring.

Groundwater Withdrawal Induced Subsidence fissuring

An earth fissure is a crack at or near the Earth's surface that is caused by subsidence.[2] According to SH&B's study of McMicken Dam "This kind of crack would in all probability lead to very rapid failure of the unrepaired dam in the event of major runoff into the reservoir."[3] SH&B's 1983 study of McMicken Dam states "it is considered highly probable that at least several earth fissures will form through the dam in the next few decades. The central vertical drain concept of repair yields...the only positive defence against subsidence induced fissuring through the dam."[4] It is recommended that we supplement our program of settlement monitoring with a program of monitoring fissures near FCD Dams. Fissures are known to exist in the vicinity of McMicken and Powerline Dams, and we would be wise to determine if fissures are present near other dams, and monitor their progression. The SH&B report has numerous references to publications regarding fissures, and this would be a good place to start.

Recommendations:

Recommended refinements to the settlement monitoring procedure:

1) Surveys should be tied into a grid of USC&GS monuments established in rock.
2) Surveys should include elevations of the crest, if monuments are below the surface.
3) Surveys should include the elevation of the emergency spillway.
4) Water levels in the vicinity should be checked at timing close to that of the surveys.
5) Establish monuments at the downstream toe, if they don't exist (McMicken)

Recommended schedule of continued monitoring:

ADWR has stated that after several surveys have been completed, surveys can be delayed indefinitely unless a trend of settlement has been established. The recommended survey interval is approximately 5 years, but this varies depending on the sponsor of the project. Table 1 shows the survey record and proposed schedule (assumes 5 year interval)

Corps Structures

Corps regulation no. 1110-2-100 states that their structures should be monitored at a 5 year interval.

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[2]Steven Slaff, Land Subsidence and Earth Fissures in Arizona, Arizona Geological Survey, 1993, p.11.

[3]SH&B, p. 66.

[4]Sergent, Hauskins & Beckwith, Design Report, McMicken Dam Restoration Study, 1983, Pages 2 and 3.

Recommended Periodic inspection:

Although the dams are regularly inspected by FCD's maintenance division, the Corps has stated that for their own structures they normally conduct a more formal inspection (called Periodic) at five year intervals. The settlement surveys are completed about six months prior to the inspection, so their results can be studied by the inspection team. The inspection team consists of a geologist, a structural engineer, and other specialists. It may be worthwhile for us to use this procedure, especially for dams which are in areas of known subsidence and fissuring.

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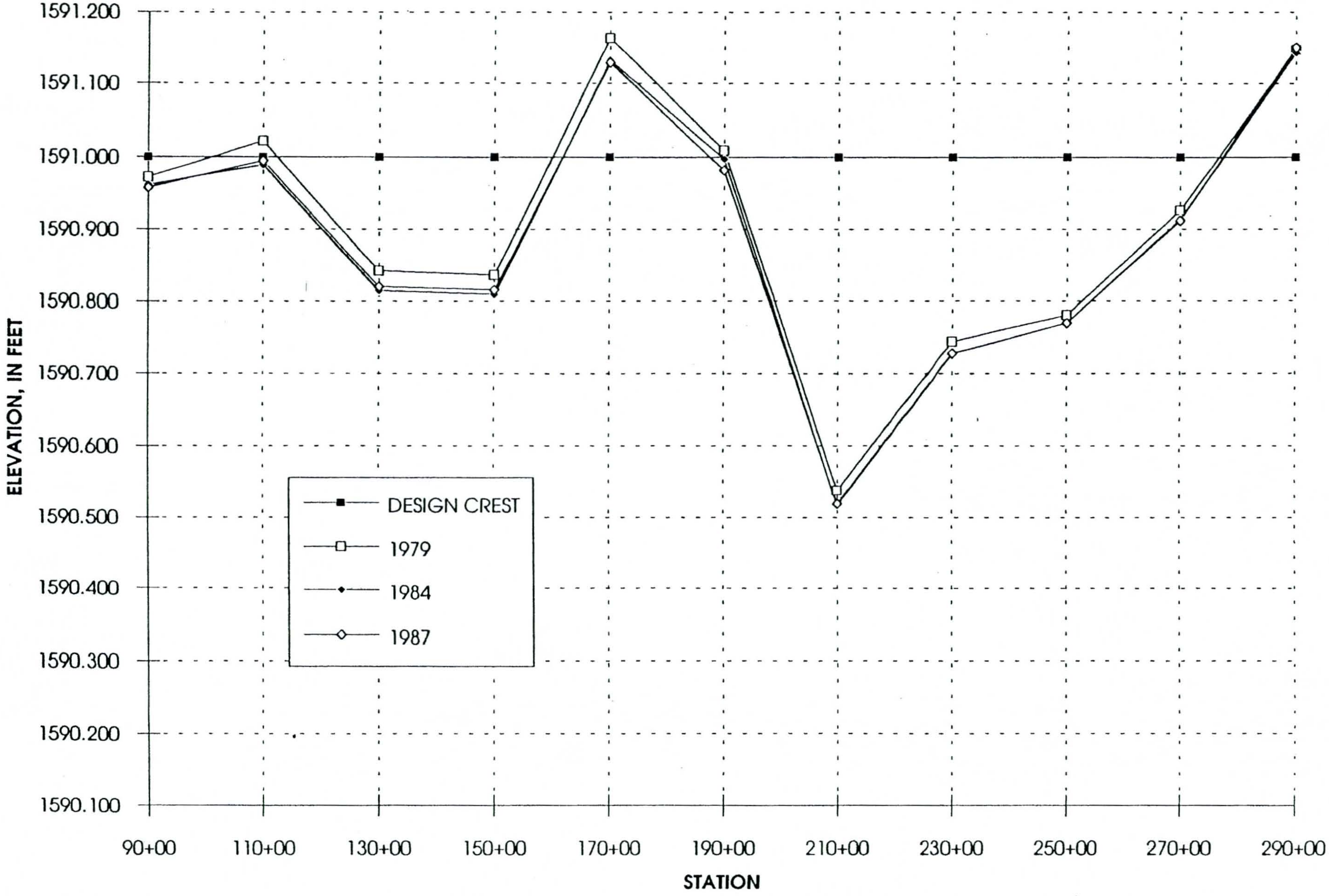
SPOOKHILL FRS CREST SETTLEMENT MONUMENTS



SPOOKHILL FRS SUBSIDENCE MONITORING								
MARKER	**STATION**	**DESIGN**	**Nov-79**	**1984**	**1987**	**1979-1984**	**1984-1987**	**1979-1987**
CREST								
SM-1	90+00	1591.000	1590.972	1590.962	1590.958	-0.010	-0.004	-0.014
SM-2	110+00	1591.000	1591.022	1590.989	1590.995	-0.033	0.006	-0.027
SM-3	130+00	1591.000	1590.842	1590.814	1590.820	-0.028	0.006	-0.022
SM-4	150+00	1591.000	1590.836	1590.809	1590.815	-0.027	0.006	-0.021
SM-5	170+00	1591.000	1591.163	1591.132	1591.129	-0.031	-0.003	-0.034
SM-6	190+00	1591.000	1591.009	1590.997	1590.982	-0.012	-0.015	-0.027
SM-7	210+00	1591.000	1590.538	1590.517	1590.519	-0.021	0.002	-0.019
SM-8	230+00	1591.000	1590.744	1590.727	1590.728	-0.017	0.001	-0.016
SM-9	250+00	1591.000	1590.780	1590.769	1590.769	-0.011	0.000	-0.011
SM-10	270+00	1591.000	1590.926	1590.914	1590.912	-0.012	-0.002	-0.014
SM-11	290+00	1591.000	1591.147	1591.143	1591.150	-0.004	0.007	0.003
EMERGENCY SPILLWAY		1582.000	1589.953	1589.953	1589.965	0.000	0.012	0.012
PRINCIPAL SPILLWAY				1577.497	1577.485	XXXX	-0.012	XXXX
AVERAGE CHANGE						**-0.017**	**0.000**	**-0.016**
MINIMUM			**1590.538**	**1590.517**	**1590.519**	**-0.033**	**-0.015**	**-0.034**
MAXIMUM			**1591.163**	**1591.143**	**1591.150**	**-0.004**	**0.007**	**0.003**
DOWNSTREAM TOE								
SM-1	90+00		1584.540	1584.539	1584.566	-0.001	0.027	0.026
SM-2	110+00		1573.712	1573.710	1573.750	-0.002	0.040	0.038
SM-3	130+00		1573.402	1573.398	1573.422	-0.004	0.024	0.020
SM-4	150+00		1570.567	1570.556	1570.587	-0.011	0.031	0.020
SM-5	170+00		1569.694	1569.695	1569.722	0.001	0.027	0.028
SM-6	190+00		1572.255	1572.243	1572.263	-0.012	0.020	0.008
SM-7	210+00		1568.932	1580.709	NOT FOUND	XXXX	XXXX	XXXX
SM-8	230+00		1569.379	1569.378	1569.387	-0.001	0.009	0.008
SM-9	250+00		1572.684	1572.690	1572.675	0.006	-0.015	-0.009
SM-10	270+00		1574.418	1574.413	1574.400	-0.005	-0.013	-0.018
SM-11	290+00		1571.356	1571.353	1571.353	-0.003	0.000	-0.003
AVERAGE CHANGE						**-0.003**	**0.015**	**0.012**
MINIMUM						**-0.012**	**-0.015**	**-0.018**
MAXIMUM						**0.006**	**0.040**	**0.038**
NOTES:								
1) CONSTRUCTION COMPLETED 1979								
2) DESIGN CREST ELEVATION = 1593.3								
3) DESIGN SPILLWAY CREST = 1582.2								
4) MAXIMUM HEIGHT = 25'								
5) SM-7 AT DOWNSTREAM TOE WAS RESET IN JUNE 1984								

SUBSIDENCE SURVEY DATA
SPOOK HILL FRS

1979 SURVEY			
"A" SERIES		"B" SERIES	
STATION	ELEVATION (ft)	STATION	ELEVATION (ft)
90+00	1590.972	90+00	1584.540
110+00	1591.022	110+00	1573.712
130+00	1590.842	130+00	1573.402
150+00	1590.836	150+00	1570.567
170+00	1591.163	170+00	1569.694
190+00	1591.009	190+00	1572.255
210+00	1590.538	210+00	1568.932
230+00	1590.744	230+00	1569.379
250+00	1590.780	250+00	1572.684
270+00	1590.926	270+00	1574.418
290+00	1590.147	290+00	1571.356
EMER. SPWY.	1589.953		
PRIN. SPWY.			

1984 SURVEY			
"A" SERIES		"B" SERIES	
STATION	ELEVATION (ft)	STATION	ELEVATION (ft)
90+00	1590.962	90+00	1584.539
110+00	1590.989	110+00	1573.710
130+00	1590.814	130+00	1573.398
150+00	1590.809	150+00	1570.556
170+00	1591.132	170+00	1569.695
190+00	1590.977	190+00	1572.243
210+00	1590.517	210+00	1580.709
230+00	1590.727	230+00	1569.378
250+00	1590.769	250+00	1572.690
270+00	1590.914	270+00	1574.413
290+00	1591.143	290+00	1571.353
EMER. SPWY.	1589.953		
PRIN. SPWY.	1577.497		

1987 SURVEY			
"A" SERIES		"B" SERIES	
STATION	ELEVATION (ft)	STATION	ELEVATION (ft)
90+00	1590.958	90+00	1584.566
110+00	1590.995	110+00	1573.750
130+00	1590.820	130+00	1573.422
150+00	1590.815	150+00	1570.587
170+00	1591.129	170+00	1569.722
190+00	1590.982	190+00	1572.263
210+00	1590.519	210+00	
230+00	1590.728	230+00	1569.387
250+00	1590.769	250+00	1572.675
270+00	1590.912	270+00	1574.400
290+00	1591.150	290+00	1571.353
EMER. SPWY.	1589.965		
PRIN. SPWY.	1577.485		

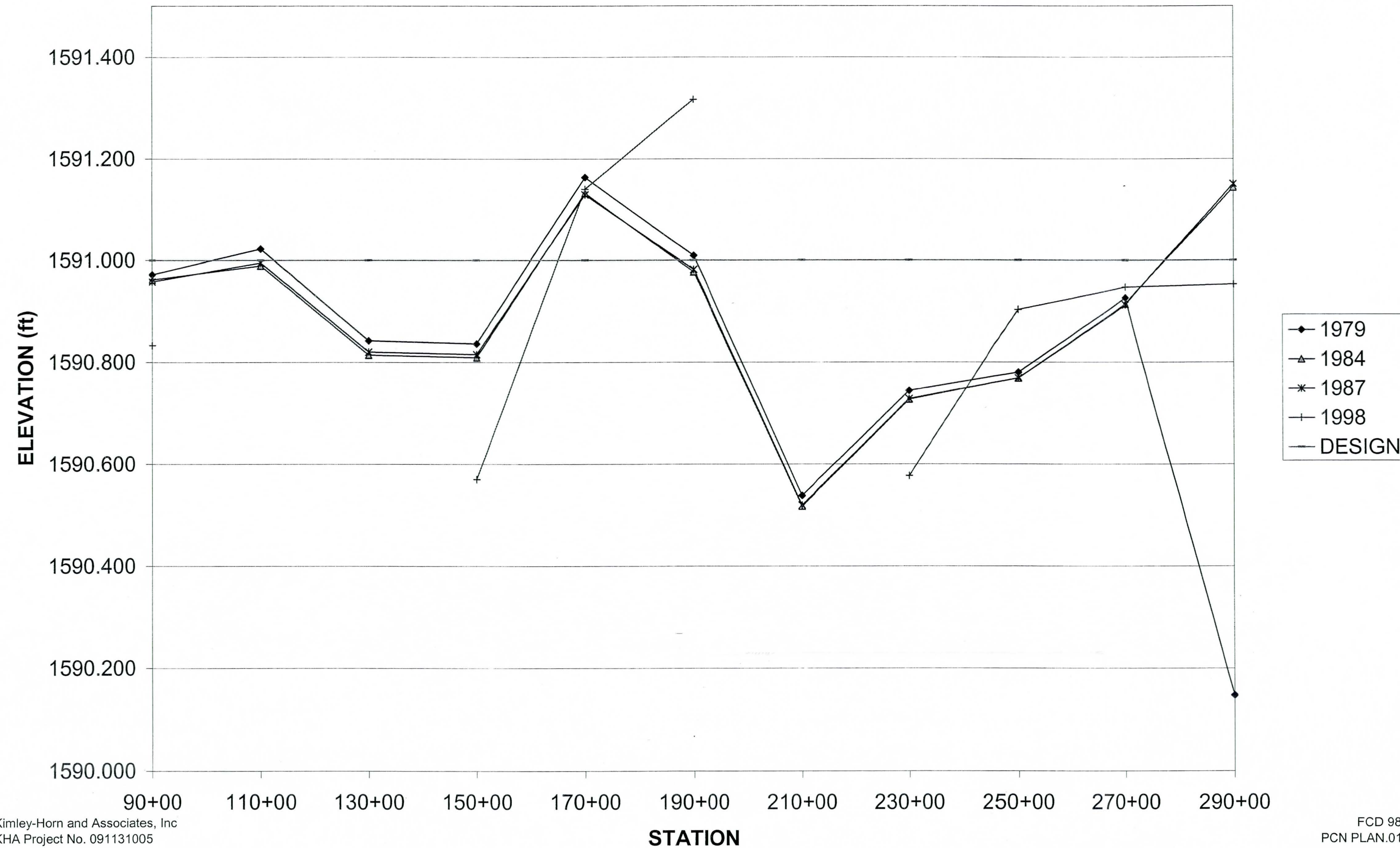
1998 SURVEY			
"A" SERIES		"B" SERIES	
STATION	ELEVATION (ft)	STATION	ELEVATION (ft)
90+00	1590.833	90+00	1584.423
110+00		110+00	
130+00		130+00	1572.930
150+00	1590.570	150+00	1570.347
170+00	1591.140	170+00	
190+00	1591.317	190+00	
210+00		210+00	
230+00	1590.577	230+00	1569.382
250+00	1590.903	250+00	1572.687
270+00	1590.947	270+00	1573.780
290+00	1590.953	290+00	1571.527
EMER. SPWY.	1589.903		
PRIN. SPWY.	1577.457		

DESIGN CREST	
STATION	ELEVATION (ft)
90+00	1591.000
110+00	1591.000
130+00	1591.000
150+00	1591.000
170+00	1591.000
190+00	1591.000
210+00	1591.000
230+00	1591.000
250+00	1591.000
270+00	1591.000
290+00	1591.000
EMER. SPWY.	1582.000
PRIN. SPWY.	

1979 SURVEY DATA SOURCE UNKNOWN
1984 SURVEY DATA SOURCE UNKNOWN
1987 SURVEY DATA SOURCE UNKNOWN
1998 SURVEY SEALED BY RICHARD D. TABOR OF GILBERTSON ASSOCIATES, INC., 9/8/98

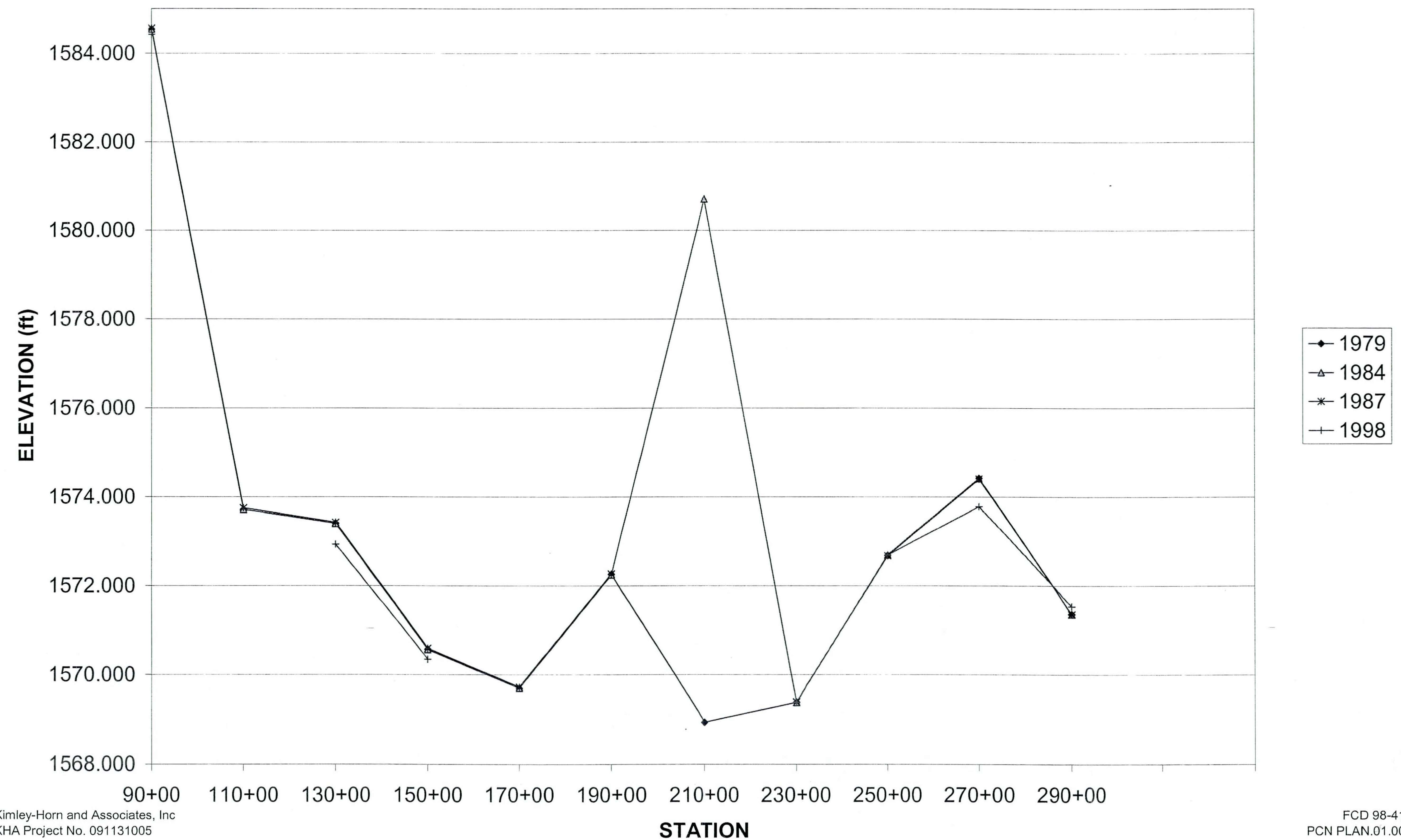
SPOOK HILL FRS CREST ("A" SERIES) ELEVATIONS

Printed 11/13/2000



SPOOK HILL FRS TOE ("B" SERIES) ELEVATIONS

Printed 11/13/2000



Kimley-Horn and Associates, Inc
KHA Project No. 091131005

FCD 98-41
PCN PLAN.01.00

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART III SIGNAL BUTTE FRS

<u>Section 1.0 Description of Dam</u>

Section 1.0 Description of Dam

The Signal Butte FRS is a structural plan element of the Watershed Work Plan for the Buckhorn-Mesa Watershed, Maricopa and Pinal Counties, Arizona. The Watershed Work Plan was prepared by the Natural Resources Conservation Service (NRCS; formerly the Soil Conservation Service, SCS) in January 1963. The watershed heads in the southwest-facing slopes of the Superstition Mountains and drains onto a wide alluvial fan on which valuable agricultural, urban and commercial developments have been constructed. The total original watershed area of Buckhorn-Mesa is 89,983 acres. The watershed is one of three for which concurrent planning efforts were conducted by the NRCS at the request of the District. The northernmost watershed is the "Buckhorn-Mesa", the central watershed is the "Apache Junction – Gilbert", and the southern watershed is the "Williams-Chandler".

1.1 Purpose of Dam

The Signal Butte FRS is one of three flood retarding structural measures designed and constructed under the watershed work plan. The other structural measures are the Spookhill FRS and the Apache Junction FRS. The purpose of the Signal Butte FRS is to provide flood and erosion control benefits for downstream developments (agriculture, commercial and urban areas). The Signal Butte FRS was designed to control runoff from the 100-year event.

1.2 Dam Location and Features

Signal Butte FRS is located within the City of Mesa. The FRS begins west of Meridian Road and north of Brown Road. The FRS is about 28 miles east of downtown Phoenix and approximately 3 miles west of the town of Apache Junction. Figure 1-1 provides a location map of Signal Butte FRS. The project consists of the FRS structure, principal spillway and an emergency spillway. The project is part of the Buckhorn Mesa Watershed Protection and Flood Prevention Project, which includes the Signal Butte and Apache Junction flood retarding structures. The Flood Prevention Project was prepared, designed, and constructed by the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS).

The reservoir behind the FRS is 140 acres with a capacity of 1,365 acre-feet. A permanent pool will not be retained in the reservoir, instead, the FRS and reservoir are designed to trap floodwater and store it only for as long as it takes to release it slowly, downstream through the Signal Butte floodway. Reservoir capacity is then restored to handle a future flood.

The emergency spillway is located near the east (left) abutment of the FRS. Construction of the FRS and appurtenant structures was completed in 1986.

1.3 Physical Features

Signal Butte FRS is a rolled earthfill structure. The length of the FRS is 7,022 feet with a maximum height of 38.5 feet and a crest width of 18 feet. The reservoir capacity is 1,365 acre-feet at the emergency spillway crest of 1712.4 ft. The reservoir total capacity is approximately 2,750 acre-feet at the dam crest elevation of 1721.0 ft. The FRS was designed with 4.8 feet of freeboard and 175 acre-feet of sediment storage (100-year). Signal Butte FRS is accessible off Meridian Road by a padlocked gate. The maximum recorded impoundment for Signal Butte reservoir is 166 acre-feet with a stage of 13.7 feet at the FRS (January 11, 1993).

The principal spillway is an ungated 36-inch diameter concrete pipe approximately 147 feet long. The design outflow is 160 cfs from the principal spillway. The trash rack is located on the upstream inlet. The outlet of the principal spillway discharges into a constructed channel through an outlet structure. A standard impact basin (energy dissipator) is located on the downstream end of the concrete outlet structure.

The emergency spillway is a reinforced concrete baffle block structure and is located adjacent to the left abutment of the FRS and 1000-ft from Meridian Road. The spillway is approximately 140 feet wide with a capacity of 2,450 cfs. The spillway crest elevation is 1712.4 feet.

The inflow design flood under ADWR rules and regulations is the ½ PMF.

Station markers are located every 500-ft along the downstream crest of the FRS. A series of staff gages is located on the upstream slope adjacent to the principal spillway. Settlement monuments are located along the crest and downstream toe of the FRS.

A central high-density polyethylene HDPE liner was constructed in the Signal Butte FRS embankment as part of the original construction. Section 2.0 of this Part III summarizes the purpose and construction of the HDPE liner.

Table 1-1 provides a summary of the physical structure data for Signal Butte FRS.

Table 1-1. Signal Butte Flood Retarding Structure Physical Data.

ITEM NATDAM ID AZ200205 STATE ID 07.60	PHYSICAL DATA
Drainage Area	10.3 sq mi
Storage Capacity Sediment Floodwater Total	 175 af 1365 af 1540af
Surface Area Floodwater Pool	 140 ac
Volume of Fill	458,000 cy
Elevation Top of Dam	1721.0 ft
Maximum Height of Dam Length of Dam	38.5 ft 1.33 mi
Freeboard	4.8 ft
Emergency Spillway Inflow Design Flood (Design FBH) Crest Elevation Bottom Width Type Percent Chance of Use Emergency Spillway Hydrograph Storm Rainfall (6 hr) Spillway Capacity Freeboard Hydrograph Storm Rainfall (6 hr)	 PMF 1712.4 ft 140 ft RC Baffle Block 1 7.0 in 2,450 cfs 13.0 in
Principal Spillway Diameter of Conduit Length of Conduit Crest Elevation Capacity at Elev Emergency Time to release	 36-in rcp 147 ft 1701.0 ft 160 cfs 10 days
Class of Structure (NRCS)	**C**
Hazard Classification (ADWR)	**High**
Size of Dam (ADWR)	**Small**

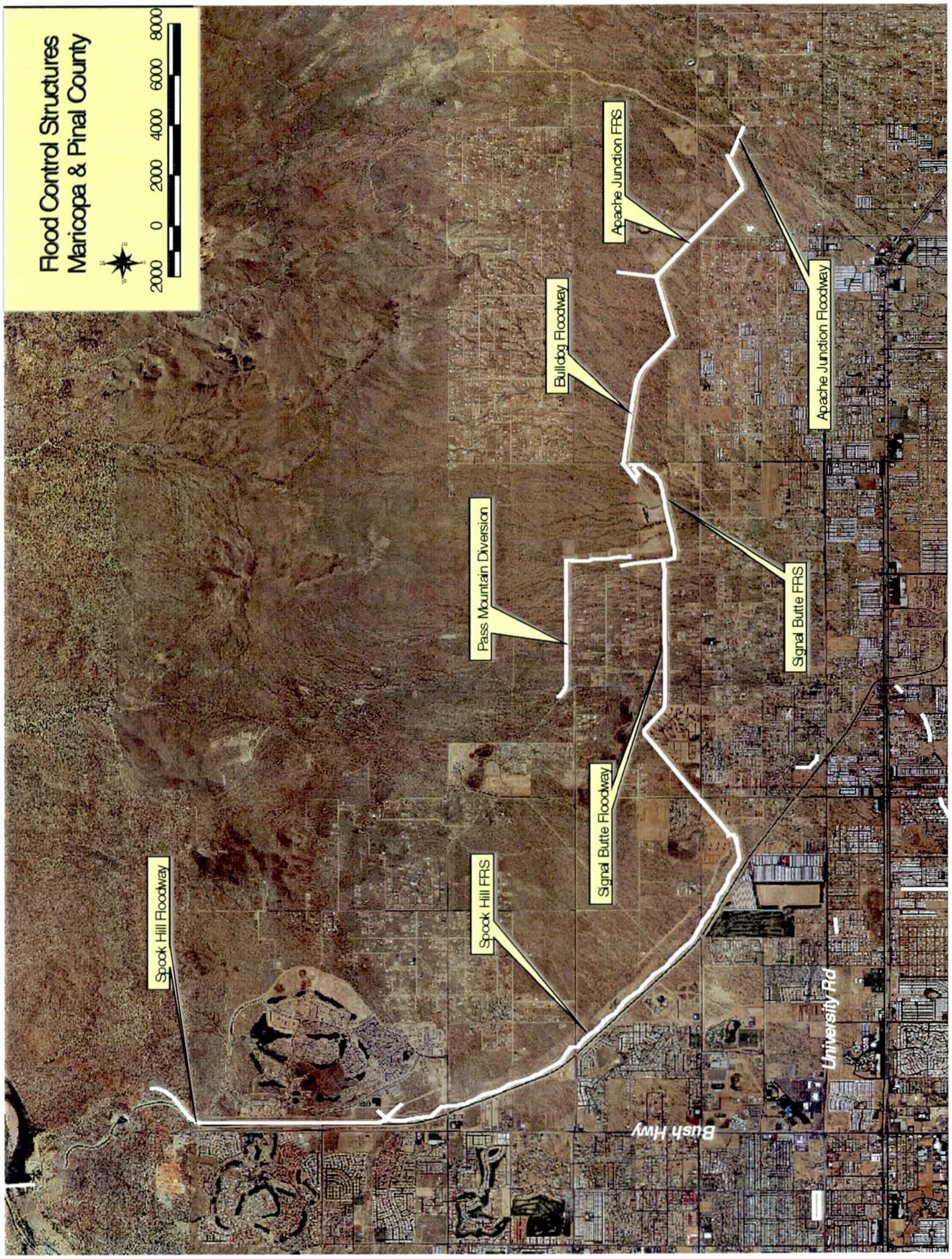


Figure 1-1. Buckhorn-Mesa Watershed Flood Retarding Structures.

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART III SIGNAL BUTTE FRS

Section 2.0 Technical Review

Section 2.0 Technical Review

The purpose of the technical review is to review the engineering records related to the dam, it's construction, and through this review familiarize the project team with the structure, familiarize the team with the history of the structure, and acquaint the team with the basis of analysis and design. The review also provides for a review of original design criteria and design guidelines.

This section of the report presents a discussion of the dam design criteria under which the dam was originally constructed versus the ADWR dam safety rules and regulations for jurisdictional dams. This section also includes a discussion of the record modifications to the dam that were constructed as related to dam safety issues and modifications to the dam that are not directly dam safety related. A discussion is presented that focuses on past dam safety signs of distress.

This section of the report also presents a review of the technical documentation for the structure. The review of the technical documentation was limited to the available reports, studies, investigations, construction plans and as-builts, specifications, and office correspondence collected as part of this study. The purpose of the review of the technical documents is to assist in the engineering assessment of the structure. The technical document review, along with the field examinations, provided a basis to evaluate the structure regarding operational adequacy, structural stability, and dam safety rules and regulations.

2.1 Dam Design Criteria

Signal Butte FRS was originally analyzed by the NRCS in the early to mid-1960's. The hydrology for the structure has been updated several times from the mid-1970's and early-1980's by the NRCS to account for planning considerations for the Buckhorn-Mesa structures (flood retarding structures and floodways). The basis of design for the FRS was originally founded in the NRCS publication "Engineering Memorandum EM-27" which is the precursor manual to "Technical Release TR-60: Earth Dams and Reservoirs" the present NRCS design guideline for earth dams. The final NRCS analysis of the FRS has been accordance with TR-60 guidelines.

Appendix A (of this Part III) provides a summary of the original NRCS design criteria (based on TR-60) for the dam and compares the criteria against ADWR dam safety rules and regulations for jurisdictional dams. Signal Butte FRS was designed to detain the 100-year event using NRCS criteria. This design event was used to size the principal spillway and reservoir volume. The hydrology for the emergency spillway design and freeboard design flood is discussed below in the Hydrology section following NRCS criteria. According to ADWR criteria, the Signal Butte FRS Inflow Design Flood (IDF) for emergency spillway capacity is the ½ PMF. Current (June 2000) ADWR regulations could change the size classification of the dam. The new size classification combined with the hazard classification could require that the IDF be changed. This IDF could be changed to between the ½ PMF and the full PMF. The NRCS, in their hydrologic study of Signal Butte FRS, has designed the dam not to overtop during the passage of the freeboard hydrograph, which was based on the full PMP/PMF (see below – Hydrology).

2.2 Dam Classification

The NRCS in their TR-60 guidelines uses a three-category "hazard" classification system. The three categories or classes are established to permit the association of criteria with the damage that might result from a sudden major breach of the earth dam embankment.

The NRCS classifies the Signal Butte FRS as a Class C structure. Class C structures are structures located where failure may cause loss of life, serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads.

The Arizona Department of Water Resources rules and regulations, in-place at the time of licensing, for jurisdictional dams classifies Signal Butte FRS as a high hazard, small size dam. Current ADWR regulations could change the size classification of the dam.

2.3 Structure Modifications Related to Dam Safety

The original construction of the embankment was completed in July 1987 by Pulice Construction. Construction was also completed for installation of landscaping treatments for the Signal Butte FRS. The landscaping treatment included providing seed mixes in the upstream borrow areas (reservoir pool). The purpose of the landscaping treatment was to minimize construction impacts and restore disturbed areas to native flora.

The left abutment or east end of the Signal Butte FRS was extended in December 1988 to tie the end of the dam to the left dike of the Bulldog Floodway. The extension of the dam is aligned parallel to Meridian Road. The purpose of the extension was to provide containment of flood flows from Bulldog Floodway into the impoundment area for the Signal Butte FRS. The NRCS evaluated three options to extend the dam to join the left dike of the floodway. The selected option included a three-foot wide central transition filter. The joint detail for combining the extension with the main dam involved placing transition material on both sides of the end of the high-density polyethylene (HDPE) membrane lining and continuing the transition into the extension. The central filter was placed along the longitudinal centerline of the extension down to foundation.

However, the constructed option was modified by the NRCS prior to construction of the extension. The modification included providing an HDPE liner in the central transition (see Sheets SB 48 - 50 at the end of this section).

2.4 Structure Modifications Non-Dam Safety Related

The construction plans for the Signal Butte FRS do not show any utility crossings either over, through, or under the embankment. A review of ADWR, NRCS, and District files indicates no previous applications for utility crossings of Signal Butte FRS and no current applications. A cautious conclusion is that there are no buried utility crossings through the embankment or under the dam. This may be due to two reasons: (1) the fact that there is an HDPE liner that was placed within the embankment and that construction of a utility and penetration of the liner would be difficult, and (2) infrastructure improvements are brought into the contributing watershed via other utility routes.

The construction plans for Signal Butte FRS provided no roadways crossings of the embankment. As of today, there are no roadway crossings of the Signal Butte FRS.

It is recommended that an extended data research effort be conducted of all District dams for documented utility crossings. The database should include at a minimum the type of utility, utility owner, size of utility, depth of utility, encasement types, cross reference to dam, construction plans and specifications, and permits.

Other modifications or repairs to the structure included ongoing slope erosion repairs and hydroseeding. District records of these types of maintenance activities are not detailed sufficiently to indicate the limits and extent of hydroseeding and slope erosion repair.

2.5 Dam Safety Signs of Distress

Inspection reports for Signal Butte FRS were reviewed from the latest reports (including ADWR and District) of November 1999 back to October 1990. KHA also conducted an inspection of Signal Butte FRS in September 2000. District inspection reports are available at the District. ADWR has provided the District with recent ADWR dam safety inspection reports for Signal Butte FRS. The inspection log from the September 2000 inspection conducted by KHA is provided as part of Section 3.0 of this Part III. Note that Signal Butte FRS was not constructed with a central longitudinal filter as was done on several other NRCS structures in the vicinity of Signal Butte (e.g., Apache Junction FRS, Powerline FRS, Vineyard Road FRS, and Rittenhouse FRS). An HDPE curtain was constructed in-lieu of the central filter (see Construction subsection of this Section 2.0 and Sheets SB 7 - 9).

There have been no reports of observations of embankment cracking at Signal Butte FRS. The reason significant cracking has not been observed at the Signal Butte FRS embankment is thought to be because the external forces, that have initiated cracks in the other embankments, have not been realized by the Signal Butte embankment. The main reasons that this embankment does not exhibit major cracking such as Vineyard Road, Rittenhouse, and Powerline structures is two fold: (1) the dam foundation and, (2) the cutoff trench has been centered within the dam. Probably the largest factors in not observing the significant embankment cracking in this structure are the proximity to the dam foundation to the hard caliche layer, the shallow underlying granite pediment, and the absence of compressible soil layers along the entire length of the embankment. This results in less differential regional subsidence and minimizes the potential for settlement of the native materials between the dam foundation and the caliche layer. The soil borings for this structure indicate mainly SC, SP and CL soils above the caliche layer. Since the cutoff trench is in the center of the dam, and if there is settlement, the settlement will be more uniform for the entire cross section of the dam. It is recommended that the District install three settlement monitoring points (for a total of four) at all of the settlement monument locations to confirm this assumption.

Desiccation cracking still may be an issue for this embankment and the HDPE liner will serve to prevent seepage or piping of embankment material along the crack. Desiccation cracking probably will tend to be more "superficial" cracking than settlement cracking. Settlement cracks from differential movement potentially could potentially tear the HDPE liner.

The ADWR and District 1999 inspection reports indicate that there is a separation of the wall joint at the right training wall of the emergency spillway. District forces have subsequently repaired this separation by installation of caulking into the joint. ADWR has recommended to the District to install a crack monitoring instrument to monitor the development of the joint separation over time. The joint monitoring instrument is scheduled to be installed at the end of summer 2001.

2.6 Review of Technical Documentation

Hydrology- The Buckhorn-Mesa Watershed Project was outlined in Part I, Section 3.0. The structural elements of the watershed project include three flood retarding structures and several interconnecting floodways. The three flood retarding structures capture and impound stormwater from their respective upstream watersheds. The floodways (Bulldog, Signal Butte, and SpookHill) convey the discharges from the principal spillways of the dams and also serve to intercept stormwater from their respective upstream drainage areas. The interception of stormwater is accomplished through the use of side inlets into the floodways. Discharges from the principal spillway of Apache Junction FRS are conveyed into the Bulldog Floodway which then discharges into the impoundment for the Signal Butte FRS. Discharges from the principal spillway of Signal Butte FRS are conveyed into the Signal Butte Floodway which then discharges into the impoundment for the SpookHill FRS. Discharges from the principal spillway of SpookHill FRS are conveyed into the SpookHill Floodway, which then ultimately discharges into the Salt River. Figure 1-1 located in Section 1.0 of this Part provides the layout of the Buckhorn-Mesa structures and floodways.

The NRCS designed the Signal Butte FRS to control the 100-year storm event. NRCS's determination of the 100-year precipitation and runoff was based on the procedures in the NRCS "National Engineering Manual – Section 4 – Hydrology" and the requirements of TR-60 for a Class C hazard structure. The NRCS used three design hydrographs to size features of the dam. The principal spillway hydrograph (PSH) is the hydrograph used to determine the minimum crest elevation of the emergency spillway. It is used to establish the principal spillway capacity and determine the associated minimum floodwater retarding storage. For a Class C structure, the PSH is based on the one hundred-year precipitation (P_{100}). The emergency spillway hydrograph (ESH) is the hydrograph used to establish the dimensions of the emergency spillway. For a Class C hazard structure, the ESH is based on a watershed precipitation depth according to the following formula: $\{P_{100} + 0.26(PMP - P_{100})\}$. The freeboard hydrograph (FBH) is the hydrograph used to establish the minimum settled elevation of the top of the dam. It is also used to evaluate the structural integrity of the spillway system. For a Class C hazard structure, the FBH is based on a watershed precipitation depth for the probable maximum precipitation (PMP).

The original hydrologic analysis for Signal Butte FRS is summarized in NCRS's 1963 Watershed Work Plan report titled "Buckhorn-Mesa Watershed – Maricopa and Pinal Counties, Arizona". The hydrographs for the 1963 ESH and FBH were based on precipitation depths of 4.0-in and 10.0-in, respectively (6-hr) (NRCS, 1963: Table 3 - Structures Data). The hydrology for Signal Butte FRS was revised by the NRCS from the original hydrology during the time period from approximately the mid-1970's to the mid-1980's. NRCS used the TR-20 hydrograph computer program to develop the inflow to the dam from the contributing upstream watershed. The hydrology was revised due to changes in project structure elements and revised drainage subbasin limits. A review of the NRCS documentation revealed that the apparent design precipitation for the Signal Butte FRS for the 100-year, 24-hr storm is 4.05-in; for the ESH - a depth of 7.07-in; and for the FBH - a depth (PMP) of 15.8-in (for a drainage area of 10.27 square miles and an emergency spillway width of 140-ft). A TR-20 model was located in the NRCS documentation that provides both the input and output from the model for the ESH and FBH design storms. The emergency spillway crest elevation used in the DAMS2 model is 1712.4-ft, which is the same elevation depicted on the as-built construction plans and the elevation-discharge rating curve for Signal Butte. The maximum water surface elevation for the ESH and FBH in the DAMS2 model was 1715.7-ft and 1720.0-ft, respectively. The peak discharges from the emergency spillway for the ESH and FBH are 2,450-cfs and 11,300-cfs, respectively (NRCS, 1984: Emergency Action Plan).

The NRCS documentation regarding the hydrologic analysis conducted for Signal Butte FRS contains what appears to be a number of preliminary TR-20 input and output printouts. There appears to be complete final design TR-20 models included in the documentation that includes full input and output for the PSH, ESH, and FBH design hydrographs. Specific final analysis of watershed parameters such as subbasin delineations, curve number development, rainfall depth and rainfall distribution, and routing parameters are found in the NRCS documents.

The emergency spillway was designed by routing the emergency spillway hydrograph through the spillway. The starting water surface for routing the emergency spillway hydrograph through the reservoir is at the elevation of the sediment pool or at the water surface elevation after 10 days of drawdown, whichever is higher. According to TR-60, the emergency spillway for Class C structures is not to be used during the 100-year event. The freeboard hydrograph for Class C structures are routed through the reservoir starting at the same water surface elevation as for the emergency spillway hydrograph.

The NRCS peak inflow for the full PMP into Signal Butte FRS is approximately 21,000 cfs with a peak emergency spillway outflow discharge of 11,300 cfs. The PMF will not overtop the structure according to the NRCS studies.

Inundation Studies and Breach Analysis – Several flood routings were made to develop inundation maps for the Signal Buttes FRS, for an Emergency Action Plan (NRCS, EAP - 1984). These consisted of the emergency spillway hydrograph, the freeboard hydrograph, and breach hydrographs based on two different breach locations, peak flows and flood volumes. Four cross sections were used for routing and were taken from planning surveys consisting of 4-foot contour interval topo maps (scale 1-in equals 400-ft). The NRCS prepared plotted copies of the cross sections used in the routings.

The emergency spillway outflow hydrograph (ESH) was routed using the TR-20 Program and assuming that the flow would be confined to the channel until it crosses Signal Butte Road. From this point downstream the flow was allowed to spread to where water surface elevations were approximately equal to the elevation of the natural ground, i.e., the flow was basically confined to the low flow areas.

The routing for the freeboard hydrograph was accomplished in a similar manner, except the lengths of the cross sections used in the routing were much longer. The flow depths were allowed to rise approximately one foot above the contour elevation selected to align the cross section. For instance Cross Section No. 1 was aligned using contour elevation 1702.0, and the maximum computed water surface elevation for the freeboard storm at this location was 1702.9.

For the breach routings, the maximum peak discharges were developed using Figure 1 in TR-66 (TR-66 is a simplified Dam Breach Routing procedure developed by SCS), and assuming the water surface to be at top of dam. The first breach was assumed to occur at or near Station 213+00. This gave a maximum depth of 30 feet and Q_{max} = 35,000 cfs. This hydrograph(s) was run using the TR-66 computer program and assuming two volumes: 2,822 acre-feet and 7,930 acre-feet. The first volume assumes no inflow to the dam at the time of the breach and is equal to maximum storage to the top of dam. The second volume is equal to the total runoff from the freeboard storm. These are the extreme conditions (with respect to volumes) for the assumed breach.

The final hydrographs were based on a breach at or near Station 288+00. This gave a maximum water depth of 38.0 feet to the top of dam, and a Q_{max} = 55,000 cfs from Figure 1, TR-66. The same two volumes described above were used with this peak to develop hydrographs for routing. For both breaches, the hydrographs were assumed to be curvilinear (SCS, TR-66), since the flow in the valley immediately downstream of the dam was calculated to be subcritical.

The same cross sections were used for both breach locations, although in actuality, they would be somewhat different; at least this is true for the cross section located at the dam, or Cross Section No. 1. Also, since a breach could occur at any point along the dam centerline, the total width of the dam is shown as floodplain. Overflow depths for all locations along the dam would be similar to those calculated at Cross Section No. 1 for the breach at Station 213+00.

The results of all the routings are provided in the tables and in the flood inundation map(s) in the NRCS document (NRCS, EAP-1984). There is not much difference in the depths or elevations of the various floods, but the width of the flooded area increases greatly as the magnitude of the flood increases. There is, however, approximately 0.5 feet difference in depth due to the increase in volumes assumed for the breach routings. For instance, at Cross Section No. 4 with Q_{max} = 55,000 cfs, the computed elevation for volume of 2,822 acre-feet is 1580.3-ft as compared to 1580.8-ft computed using the larger volume of 7,930 acre-feet. Similar differences can be noted at the other cross sections, and for the conditions where Q_{max} = 35,000 cfs.

Velocities are generally low being less than 4.0 ft/sec in most areas, except possibly in the channels or other low lying areas. Velocities are generally higher in the vicinity of Cross Section No. 1, where flow is basically confined to channel; and then decrease in a downstream direction as the flow spreads out over a much wider area. Velocities in the range of 1 to 3 feet per second can be expected in the vicinity of Cross Section No. 4, depending on the magnitude of the flood.

It should be noted that in all routings, the effect of Apache Trails Road was not included, although some increase in the depth of flooding will occur at this location due to the fill on the road. There is also a possibility that it will divert some of the flow further to the west than indicated on the inundation map(s). Other effects on downstream flows, however, should be minor, since the road will be overtopped with the freeboard and the routed breach hydrographs.

The NRCS concluded that variations in depths or elevations of flooding in a given area for different storms will be slight, usually less than one-foot; but the width of the flooded area will increase greatly as the magnitude of the flood increases. The width generally tends to increase in a downstream direction; whereas depth and peak discharges will decrease. Although flooding will continue for some distance downstream of Apache Trails, flood conditions will be similar to those experienced on the immediate downstream side of this location. Apache Trails Road will cause some ponding upstream, and could cause some diversion of flow to the west. The major areas of concern will be the channels or other low lying areas upstream of Apache Trails where depths could be as much as four feet in some locations. As the flood progresses downstream, depths will tend to decrease with maximum depths being in the 1 to 3 feet range. The greater depths again will be in small drainage ditches or channels that traverse the downstream area.

The NRCS 1984 documentation for the flood routings also provided an NRCS paper discussing the "Effects of CAP on Emergency Spillway and Breached Hydrographs". This paper presented discussion of the probable impacts of the CAP canal on spillway and breach discharges.

In November 1999 the District completed the "Delineation of Spillway Flows from Signal Butte Flood Retarding Structure". The engineering firm of A-N West conducted the study on behalf of the District. The study provided inundation limits for emergency spillway flows for the 1/3, 2/3, and the full PMF discharge from the spillway (the PMF used in the study is 11,309 cfs). The purpose of the inundation study was to provide inundation limits in the event of spillway discharge for emergency actions and evacuation. The study delineation maps provide tables with water surface elevations, flow velocity in the channel, maximum channel flow depths, and flood travel times for each discharge. This inundation study should be incorporated as part of the Signal Butte emergency action plan.

Sedimentation - The sediment storage requirements for the FRS is based on local stock pond surveys, studies of sediment sources, and factors that influence sediment yields. The major sources of sediment is from all areas above the dam site. Based on the sediment storage investigation, the NRCS estimated that the sediment storage requirements for a 50-year period was estimated at 145 acre-feet for the Signal Butte FRS (NRCS, 1963). Development of a 100-year sediment volume could not be located in the NRCS documents for Signal Butte. However, if the 50-year volume were linearly interpolated to the 100-year event, then approximately 290-af of sediment volume would be required for Signal Butte. However, in the NRCS document titled "Signal Butte FRS Design Report - Book II", there is a presentation that discusses the final design hydrology for Signal Butte FRS which includes Apache Junction FRS, Bulldog Floodway, and Pass Mountain diversion with the outlet channel. In this document, consideration for the sediment volume requirements for Signal Butte FRS included the sediment passed from Pass Mountain diversion. The sediment delivered to Signal Butte is approximately 250-af at an elevation in the FRS impoundment of 1700.75-ft. The accounting is provided in Book II as follows: Signal Butte watershed - 177-af; Apache Junction FRS watershed - 40-af, Pass Mountain diversion - 92-af, for a total of 309-af. At a 80 percent trapping efficiency, the required sediment volume in Signal Butte FRS was computed to be 247-af (and designed for 250-af).

Capacity Analysis - In March 1997, the District reanalyzed the capacity for the Signal Butte FRS based on new aerial topographic mapping provided as part of FCD Contract 93-51. The District developed new stage-storage-area curves and computed the time to evacuate a full impoundment pool. The District study found the crest of the emergency spillway elevation to be 1714.63 ft (NAVD 1988) which is a gage height of 27.1 ft for a storage capacity of 1665 ac-ft. The time to drawdown this volume of water was estimated at 4.0 days assuming no inflow into the impoundment or clogging of the principal spillway.

A District analysis conducted in July 1997 compared the design capacity versus the March 1997 computed capacity. The design emergency spillway crest elevation is 1712.62 ft while the FCD 93-51 study determined the crest elevation to be 1714.63 ft or a difference of 2.01 ft. The design capacity of Signal Butte FRS at the emergency spillway crest is 1456 ac-ft while the District study estimated the capacity to be 1665 ac-ft or an increase of 14 percent. The NRCS final design report (1984) provided a capacity rating table for Signal Butte FRS. The rating table provides for elevation 1712.47 ft a reservoir capacity of 1375 ac-ft.

Section 4.0 of the Part III provides recommendations for further investigations and analyses for Signal Butte FRS. A discussion is presented recommending a new 100-year HEC-1 hydrologic model for Signal Butte be prepared based on the revised rating curves developed by the District as a result of the aerial mapping provided under Contract FCD 93-51. A question to be resolved is "Does Signal Butte FRS provide greater flood protection than the 100-year event"?

Geotechnical/Geological - Regional Geology

The Signal Butte FRS is located within the Sonoran Desert section of the Basin & Range Physiographic Province near the boundary with the Mexican Highlands Section. The latitude and longitude of the center part of the structure is approximately 33°25'50"N and 111°35'53"W based on NAD 83 datum. This portion of the Basin and Range Province is characterized by northwest, north, and northeast trending mountains that rise abruptly to form broad, elongated, deep, sediment-filled valleys produced by block faulting and folding (Geological Consultants Inc., 1999) during past episodes of mountain/basin bounding fault movements (Cooley, 1977). The section boundary is defined on the north and northeast by the McDowell, Usery, Goldfield and Superstition Mountains and on the south by the Phoenix Basin.

The McDowell and Usery Mountains are composed of pre-Cambrian granitic and metamorphic rocks including granite and schist that is often overlain by early to middle Tertiary sedimentary and volcanic rocks. The Goldfield and Superstition Mountains are composed primarily of Tertiary volcanic rocks consisting of andesite, rhyolite, latite and dacite flows and tuffs. The bedrock is also locally overlain by Quaternary age (younger than 1.6 million years ago (mya)) alluvium. The Phoenix Basins, formed by the down faulted blocks, have been partially filled with material eroded from the higher surrounding mountain ranges. With incision of the Salt River and tectonic disturbances in Tertiary time, subsequent stream rejuvenation, combined with climatic changes in early Quaternary time, terraces were developed along the Salt River. These terraces are reportedly buried under valley fill deposits downstream in the Phoenix Basin (Pewe, 1978; Ertec-Western, 1981).

Alluvial materials deposited in the basins consist of heterogeneous unconsolidated mixtures of clay, silt, sand, and gravel which locally contain cobbles and boulders (See Figure 2-1). Near the mountain fronts the older alluvial deposits are commonly well cemented with caliche to a rock-like consistency at depths of two to twenty feet (FCDMC, 1963).

This alluvial material grades from coarser to finer grained with increasing distances from their sources in the surrounding mountains and are variably cemented by calcium carbonate. Rock hills and knobs protrude through the alluvial materials (USBR, 1982 &

1986) as evidenced by Double Knolls, located south of Spook Hill FRS. During the Pleistocene Epoch when climatic conditions were much wetter than current conditions, the alluvial basins south of the study area were charged through the percolation of excess water flows. This initial charging created large groundwater basins with abundant groundwater resources that in turn have influenced greatly recent development in south central Arizona.

According to the SCS (1982), groundwater near the Signal Butte FRS is contained in bedrock fractures and joints of granite bedrock that underlies the site. There is no record (as of 1982) that the water table has risen high enough to saturate the thin alluvium. Therefore, water level changes within the bedrock aquifer should have no impacts related to ground subsidence.

Regional Seismicity

An abbreviated discussion of seismicity and faulting was presented in the original Geologic Investigation report prepared by the SCS (1980). The report stated,

> "There is no record of recent seismic activity within a 100-mile radius of the Signal Butte FRS. Within a radius of 100 miles, several earthquake and Quaternary fault traces are shown on the following map (map not included in report copy). The nearest large recorded earthquake, which was approximately 150 miles away occurred in 1958. It measured between 5 and 5.9 on the Richter scale. Signal Butte FRS is located in seismic zone 2, which has a minimum seismic coefficient of 0.10."

A comprehensive evaluation of Arizona seismicity for the development of seismic maps for the State of Arizona was conducted for the Arizona Department of Transportation (ADOT, 1992). The ADOT database was used to prepare the following updated description of seismicity and faulting that might potentially impact the Signal Butte FRS.

Historic seismicity within a 100-mile radius of Signal Butte FRS is documented for the period from 1776 through May 2000 (Dubois et al, 1982; U.S.G.S., 2000). Several earthquake epicenter locations are depicted on Figure 2-2 within a 100-mile radius of the FRS. Fault structures identified from recent work by ADOT (1992) are depicted on Figure 2-3 for faults within a 100-mile radius from the FRS and on Figure 2-4 for structures within a 25-mile radius. Tables summarizing the seismic source zones or faults, along with their length, estimated displacement, and associated maximum credible earthquake are provided in Table 2-1 and Table 2-2.

Signal Butte FRS is located in the Basin and Range Province in the southwestern portion of Arizona, including Maricopa County and portions of Pinal County, and is astride the seismotectonic zone boundary separating the Sonoran Seismotectonic Zone and the Arizona Mountain Zone (ADOT, 1992) (Figures 2-2 and 2-3). These zones represent distinct coherent crustal blocks with varying degrees of seismic activity and their own characteristic earthquake potential. The following paragraphs, excerpted from ADOT (1992), describe the zones' seismotectonic characteristics.

Sonoran Seismic Source Zone: The Sonoran seismic source zone encompasses approximately 58,900 square miles in southwestern Arizona, southeastern California, and Mexico. The Sonoran zone is characterized by small, scattered mountain ranges (Harquahala Mountains, Big Horn Mountains, Gila Bend Mountains, Maricopa Mountains, South Mountain, Phoenix Mountains, White Mountains, Sierra Estrella Mountains, Sand Tank Mountains and San Tan Mountains) and large flat plains and valleys (Harquahala Plains, Hassayampa Plain, Rainbow Valley, Salt River Valley, Paradise Valley, and Chandler Basin). Some of these ranges and valleys are locally aligned but overall the province has no preferred directional trends. Mountains constitute approximately 20 percent of the total province area and are generally surrounded by broad pediments indicating relative geomorphic maturity. Elevations range from approximately 500 feet to 1,500 feet in the valleys to about 3,000 to 4,000 feet in the mountainous areas. Generally, local relief rarely exceeds 2,500 feet and is generally about 1,000 to 2,000 feet.

Geodetic data suggests the Sonoran zone is tectonically stable compared to the tectonically active regions in California (Burford and Gilmore, 1982). The geomorphology of river terraces along the Colorado and Gila Rivers provides longer-term verification of this tectonic stability (Schell and Wilson, 1982; Arizona Public Service Company, 1974) indicating no substantial crustal warping during late Quaternary time.

Although the Sonoran zone exhibits basin-and-range-type geologic structure, it has not experienced extensive block-faulting typical of the tectonic regime since Pliocene and possibly late Miocene time (Schell and Wilson, 1982; Menges, 1983). Presently, the zone has very little tectonic activity. Earthquakes are rare and of small magnitude and the faults are very minor. The Sonoran zone is relatively aseismic compared to adjacent zones to the northeast and southwest. The largest historical earthquake within the Sonoran zone was the magnitude 5.0 event that occurred in the southern part of the zone in 1956. The maximum credible earthquake is estimated to be $M_w = 6.5$ although events this large should be exceedingly rare.

In this vast zone there are only a few young faults and these are very minor features. Except for the Sand Tank fault, most of these faults are in proximity to the Colorado River Trough near Blyth, Needles, and Topock. These faults are short (two to eight miles) and discontinuous with low, subtle scarps indicating low rates of activity and small-magnitude earthquakes. For determining the zone recurrence interval, earthquakes of magnitude 6 were assumed to have been associated with these surface ruptures. The age of these events are poorly constrained but they appear to have occurred over the latter part of the Quaternary. Assuming that they occurred within the past 10^5 years, the average recurrence for the zone as a whole would be about 25,000 years. In addition to such events associated with surface rupture, similar recurrences should be expected for random earthquake events.

In summary, the Sonoran zone represents a nearly stable block between tectonically active regions to the northeast and southwest. The zone can be distinguished by its paucity of earthquakes, few short Quaternary age faults, mature physiography, and thin crust.

Arizona Mountain Zone: This zone has an area of about 38,000 square miles and forms an arcuate belt around the southern margin of the Colorado Plateau and the Plateau margins seismotectonic zones. The Arizona Mountain Zone encompasses a variety of mountain ranges, plateaus, and valleys between the relatively flat, high elevation Colorado Plateau to the north and the lower elevation Sonoran Zone to the southwest. Geomorphic features (mountains and valleys) were produced by erosional down cutting related to regional uplift and extensional block faulting (ADOT, 1992).

Rock units exposed within the mountainous areas are composed of nearly every rock type in the state. Predominant rock types are Precambrian igneous and metamorphic rocks and Mesozoic through Tertiary age volcanic and sedimentary rock. The wide variety of rocks is a direct result of uplift, extensional faulting, and erosion of the fault blocks exposing the deeper and older basement crystalline rocks that the overlying stratigraphic sequence.

Major neotectonic (post-Miocene age) faults, typical of the Basin and Range tectonic style, lie near the valley margins and separate down-dropped valley blocks. This zone has abundant hot spring activity and a high heat flow. The rate of faulting is slow. Major down faulted block structures are Aubry Valley, Chino Valley, Verde Valley, Tonto Basin, northern San Pedro Valley, northern San Simon Valley, Lordsburg Basin, and San Augustin Plain. In Arizona, major faults and their corresponding fault block structures generally trend north-northwesterly and northwesterly. Faulting is characterized by several young Quaternary age northwest-southeast trending normal faults such as those found in the Verde Valley and Chino Valley located north of Prescott, Arizona.

Seismicity in this zone includes small and moderate magnitude earthquakes. The largest recorded earthquake (magnitude 5.2) epicenter occurred near Prescott in February 1976, which is within a 100-mile radius of the Signal Butte FRS. The maximum earthquake associated with this zone's characteristic fault, the Big Chino Fault, is expected to be about magnitude 7.25. The maximum random earthquake, not considering discrete fault zone seismic sources, is expected to be about magnitude 6.75. Recurrence intervals determined from field investigations are estimated to be 20,000 to 30,000 years (ADOT, 1992)

Two other seismotectonic zones are within a 100-mile radius of the Spook Hill FRS including:

- Southwestern Plateau Margin Zone
- Southeastern Plateau Margin Zone

Southwestern Plateau Margin Zone: Signal Butte FRS is approximately 65 miles southwest from the boundary of the Southwestern Plateau Margin Zone. The southern margin of the zone is near the Mogollon Rim, a prominent escarpment marking the edge of the Colorado Plateau physiographic province (ADOT, 1992).

Rocks of the zone primarily comprise upper Paleozoic and lower Mesozoic sedimentary rock and volcanic rocks that are of predominantly Cenozoic age including those of the Pliocene and Pleistocene Epoch.

The Southwestern Plateau Margin Zone has numerous neotectonic faults. These faults comprise numerous minor features of short length to several major lengthy faults with relatively small displacement. The largest of these faults are the Sinyala-West Kaibab system and the Bright Angel system.

Seismicity of the zone is one of the more active in Arizona with about the same number of earthquakes as the Arizona Mountain Zone. The largest recorded event was the 1959 Fredonia earthquake of about magnitude 5.6. Reanalysis of the 1912 Grand Canyon/Marble Canyon earthquake resulted in an estimated magnitude of 6.2. There is no evidence of modern surface faulting in the zone. The maximum credible earthquake is estimated to be about $M_w = 6.5$.

The Southwestern Plateau Margin seismic source zone is characterized by low-activity Quaternary age faults and moderate seismicity. It is differentiated from the Arizona Mountain Zone by is physiography and lower rate of faulting activity, and from the Southeastern Plateau Margin zone by its higher seismicity and more numerous neotectonic faults.

Southeastern Plateau Margin Zone: At its closest point, the Signal Butte FRS is approximately 66 miles southwest from the boundary of the Southeastern Plateau Margin Zone. The southern margin of this zone extends from the central part of the Mogollon Rim eastward to the Rio Grande Rift zone in New Mexico. (ADOT, 1992).

Rocks of this zone are similar to those found in the Southwestern Plateau Margin zone. Cenozoic age volcanic rocks occur in three major fields: the Springerville, the Zuni-Bandara, and Mount Taylor volcanic fields.

Similar to the Southwestern Plateau Margin Zone, the Southeastern zone has several neotectonic faults that are expressed in the same northeast and northwesterly intersecting pattern. Very few Quaternary faults are known to exist in this zone. This may be partly due to some faults being covered by extensive late Quaternary age volcanic flow (ADOT, 1992). This seismic source zone is characterized by low to moderate historical seismicity. There has been no earthquake with a magnitude in excess of five. The maximum credible earthquake is estimated to be about $M_w = 6.5$.

In summary, the zone is characterized by young volcanic activity, a low to moderate level of seismicity, and few Quaternary faults (ADOT, 1992).

Table 2-1. Summary of Faults & Fault Zones Within 25 Miles of Signal Butte FRS (from ADOT, 1992).

Seismic Source Zone or Fault		Length (miles)		Displacement		Earthquake
Number	**Name/Location**	**Zone**	**Longest Segment**	**Latest Age**	**Slip Rate**	**Maximum Credible**
141	Sugarloaf Peak Fault: 20 miles West of Roosevelt Dam, AZ	6	3	H	-	6.75
142	Rolls Fault: 20 miles Southwest of Roosevelt Dam, AZ	6	3	L/M & E/P	-	6.5

* See Figures 2-3 and 2-4 for a listing of abbreviations and meanings.

Table 2-2. Summary of Faults & Fault Zones Within 100 Miles of Signal Butte FRS (from ADOT, 1992).

Seismic Source Zone or Fault		Length (miles)		Displacement		Earthquake
Number	**Name/Location**	**Zone**	**Longest Segment**	**Latest Age**	**Slip Rate**	**Maximum Credible**
21	Railroad/Verde River: 9 miles North-Northwest of Cottonwood, AZ	12	-	?	-	6.75
22	Verde Fault: Southwest side of Verde Valley, Yavapai County, AZ	38	17	H/L	0.01 to 0.05 mm/year	7.25
25	Prescott Valley Grabens: 10 miles North-Northwest of Prescott, AZ	5	1	L/M	0.07 to 0.2 mm/year	6.5
36	Sand Tank Fault: 7 miles E-Southeast of Gila Bend, AZ	2	-	H	0.01 to 0.04 mm/year	6.5
91	Date Fault: Northwest of Wickenburg near town of Date, AZ	2	-	?	-	6.5
92	Wagoner: 20 miles northeast of Wickenburg, AZ	4	-	?	-	6.5
93	Lake Pleasant: North of Lake Pleasant, 36 miles N-Northwest of Phoenix, AZ	3	-	?	-	6.5
123	Munds Park Fault Zone-North Segment: 5 miles West of Flagstaff, AZ	15	7.5	M/E	-	7.0
129	Chavez Mountain Faults: 40 mi. SE of Flagstaff, AZ; SE Side of Chavez Mts.	25	10	?	-	6.75
130	Turret Peak Fault: 22 miles South of Camp Verde, AZ	7	-	Qy	-	6.75
131	East Verde River Fault: 14 miles West of Payson, AZ	4	-	?	-	6.75

Seismic Source Zone or Fault		**Length (miles)**		**Displacement**		**Earthquake**
Number	**Name/Location**	**Zone**	**Longest Segment**	**Latest Age**	**Slip Rate**	**Maximum Credible**
132	Deadman Creek Fault Zone: 30 miles Northeast of Carefree, AZ	11	-	?	-	6.75
133	Horsehoe Dam Fault Zone (Tangle Peak Fault): 18 miles Northeast of Carefree, AZ	13	7-8	L/M	0.007 mm/year	6.75
134	Seven Springs Fault: 13 miles North of Carefree, AZ	3	-	?	-	6.5
135	Carefree Fault: 5 miles East of Carefree, AZ	8	4	?	-	6.5
136	Alder Creek Fault Zone: 26 miles Northwest of Roosevelt Dam, AZ	7	4	Qy	-	6.5
137	Tonto Basin-Northwest Fault: Southwest Side of Roosevelt Lake, AZ	9	3	?	-	6.5
138	Tonto Basin-Central Fault (Punkin Center Fault): 10 mi. NW of Roosevelt Dam, AZ	3	2	?	-	6.5
139	Two Bar Mountain (North & South): 2 miles Southeast of Roosevelt Dam, AZ	2	-	?	-	6.5
140	Gold Gulch Fault-West Branch: SW Side Roosevelt Lake, 11 to 24 mi. NW of Globe, AZ	6	-	?	-	6.5
141	Sugarloaf Peak Fault: 20 miles West of Roosevelt Dam, AZ	6	3	H	-	6.75
142	Rolls Fault: 20 miles Southwest of Roosevelt Dam, AZ	6	3	L/M & E/P	-	6.5
143	Miami Fault: West side of Miami, AZ	12	-	?	-	6.75
144	Picketpost Mountain Fault: 7 miles West of Superior, AZ	2	-	?	-	6.5
145	China Wash Scarp: 6 miles Northeast of Florence, AZ	3	-	?	-	6.5
146	Muscal Creek: Muscal Mountains, 16 miles Southeast of Globe, AZ	3	-	?	-	6.5
147	Antelope Flat Scarps: 28 miles East of Globe, AZ	3	-	?	-	6.5
148	Mammoth Fault: 22 miles Southeast of Hayden, AZ	9	-	?	-	6.5

Seismic Source Zone or Fault		Length (miles)		Displacement		Earthquake
Number	Name/Location	Zone	Longest Segment	Latest Age	Slip Rate	Maximum Credible
149	San Manuel Fault: 8 miles East of San Manuel, AZ	4	2	?	-	6.5

* See Figures 2-3 and 2-4 for a listing of abbreviations and meanings.

Site Geology and Soils

The Signal Butte FRS is located in east Mesa approximately one-quarter mile south of the Usery Mountain Recreation Area and about one mile north-northeast of Signal Butte. Alluvial fans extending from the mountain front off of the Usery and Goldfield Mountains coalesce to form the broad, gently sloping surface of the alluvial basin. The topography of the area consists of sparsely vegetated, flat desert, interrupted by narrow, shallow washes where vegetation is concentrated. The ground surface slopes downward to the west-southwest. Depth to granite is estimated to be less than 200 feet below ground surface in the FRS area.

The Signal Butte FRS is founded on the lower end of a pediment of primarily unconsolidated and semi-consolidated alluvial fan deposits of Quaternary-Tertiary age. Ephemeral stream channels cut across the dam centerline. Surface drainage is toward the south and southwest from the Goldfield Mountains. Caliche-cemented alluvial fan deposits are exposed in many of the washes. The exposed caliche is hard, dense, well-cemented, and usually contains gravel. Overlying, younger alluvial fan soils are composed of unconsolidated to semi-consolidated sand with varying amounts of silt, clay, and gravel.

The geotechnical investigation along the dam centerline included 31 drill holes and 43 test pits. Drill holes and test pits were placed alternately every 100 feet along centerline. Standard Penetration Tests (SPT's) were taken continuously in all drill holes until the hard caliche layer was encountered. From that depth, SPT's were taken at 5-foot intervals to the bottom of the drill hole.

The main dam is underlain by relatively thin alluvial soils consisting of unconsolidated to poorly consolidated silty sand (SM) that contains gravel with non-plastic fines. The younger alluvial soils are brown to light brown and dry. Other shallow, surface soils included clayey sand (SC), silty clayey sand (SM-SC), silty sand with some fines (SM-SP) and clean, poorly graded sand (SP) (SCS, 1984).

At relatively shallow depths (average about seven feet), tan to white gray, weakly to well cemented caliche containing well cemented silty sand with gravel is encountered below the thin surface soil zone. The caliche-cemented zone is moderately hard to hard, dense, and exhibits a rock-like consistency. The estimated average depth to the caliche zone along the dam centerline is summarized in Table 2-3.

Table 2-3. Estimated Average Caliche Depth Along Dam Centerline Signal Butte FRS (SCS, 1984).

Station Along Centerline		Depth To Caliche Zone (feet)
From	To	
194+00	210+00	3
210+00	213+00	15
213+00	238+00	8
238+00	240+00	2
240+00	242+00	25
242+00	264+00	6

Buried stream channels were documented in the SCS (1984) report where the channels had cut into the caliche-cemented layer and where the channels had been subsequently infilled with unconsolidated alluvium. Buried channels were located in the vicinity of Stations 213+00, 219+00, 228+25, 233+00, between 236+00 and 238+50, 241+00 and 252+60.

Groundwater in the immediate site area is poorly defined because the shallow alluvial sediments are barren and the underlying granitic basement that contains water in joints and fractures, does not effectively transmit water. According to the SCS (1982; 1984), regional water levels in the dam site area is about 150 to 200 feet below ground surface (elevation 1690 MSL). Because of the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment, subsidence due to groundwater withdrawal should not be a issue at the Signal Butte FRS.

Slope stability analyses were conducted for the Signal Butte FRS embankment (SCS, 1984). Two types of analysis were performed: (1) ICES Lease II and (2) infinite slope analysis. The analysis incorporated the HDPE membrane along the dam centerline, the cut off trench, and a piezometric line for pore pressure after sudden drawdown from the principal spillway elevation. Strength parameters for the analyses are summarized in Table 2-4.

Table 2-4. Slope Stability Analysis Strength Parameters Signal Butte FRS.

Soil Zone	Unit Weight (pcf)	Friction Angle Ø (degrees)	Cohesion (psf)
Zone 1-Foundation	111.0	31	0
Zone 2-Embankment, downstream	112.0	31	0
Zone 3-Embankment, upstream	112.0	15	1000

Based on review of laboratory test data sheets and summaries for the Signal Butte FRS design studies conducted by the NCRS (SCS), triaxial and direct shear tests were conducted on in-situ samples obtained along the dam centerline and from the borrow area. The tests included both "undisturbed" ring samples and remolded samples.

The SCS documents reviewed as part of this study did not indicate how the embankment stability analysis strength parameters were selected. However, the following explanation is offered as to how the strength parameters may have been selected:

> According to the SCS, the Zone 3 embankment soils upstream from the HDPE membrane were assumed to be high strength. The 15-degree friction angle is suspected to be a value that is slightly less than the median value for remolded borrow soil samples classified as SC or SC-SM. The 1,000 psf cohesion strength value is suspected to represent a lower bound value that is less than the results determined from consolidated-undrained triaxial tests. Zone 1 and Zone 2 strength parameters may represent a lower bound value determined from triaxial tests with pore pressure measured.
>
> Unit weight of the Zone 3 foundation soil is suspected to be a value determined from the calculated dry density of direct shear tests of in-situ samples obtained along the dam centerline. The Zone 2 and 3 soils' unit weights appear to approximate about 90 percent of the average proctor values obtained from borrow area soils.

The strength parameters used for the embankment design stability analysis appear to be conservative when compared to the laboratory test results. However, , it is recommended that limited Phase II sampling and testing be done to confirm the foundation and embankment strength parameters.

Results of the (NRCS) slope stability analysis are summarized in Table 2-5. A seismic coefficient of 0.1 was only employed in the ICES Lease II analysis. Based on recent ADOT (1992) data, the 0.1 seismic coefficient used is extremely conservative.

Table 2-5. Slope Stability Analysis Results Signal Butte FRS.

Condition Evaluated	Factor Of Safety	
	ICES Lease II	**Infinite Slope Analysis**
Dry Dam	1.5	1.5
Submerged (no seepage)	1.5	1.5
Phreatic Line (pool full)	Less than 1.0	--
Seepage Parallel to Slope	--	1.05

The results of the embankment stability analysis originally conducted for Signal Butte FRS appear to satisfy the current ADWR criteria for minimum factors of safety for the end of construction and steady state-no seepage (R12-15-1216, (B) (1) (c) (i) Table 5). However, the factor of safety for instantaneous drawdown-upstream slope does not meet specific ADWR criteria.

The original stability analysis included seismic forces of 0.1g, which is very conservative considering today's standard (ADOT, 1992). The peak bedrock acceleration for the Signal Butte FRS site, based on ADOT (1992) seismic acceleration contour maps, is less than 0.04g (90 percent non-exceedance in 50 years). The embankment and foundation may meet the ADWR seismic analysis requirements (R12-15-1216, (B) (2) (a) (i) using a pseudo static coefficient of 60 percent less than the maximum peak bedrock acceleration of 0.04g.

However, considering the high hazard classification for the Signal Butte FRS, we recommend the embankment stability be re-evaluated based on the current conditions. Likewise, the re-evaluation should be conducted because of the questions of how the original design analysis strength parameters were selected.

According to the SCS (1984), using the results of the infinite slope analysis, a trial analysis assuming a conservative "pool full" condition would not need to be used for design of the Signal Butte FRS.

One field permeability test was attempted along the dam centerline but the test was reportedly unsuccessful (SCS, 1984). There was no indication in the geological investigation report that laboratory permeability tests were performed from samples obtained along the dam centerline.

Although "loose materials" were identified in the dam foundation area, the material is reported to be coarse-grained soils. Based on the evaluation of the foundation soils relative density and the construction of the cutoff trench and embankment, the SCS stated that "materials under the embankment are not collapse-prone and will be consolidated by the construction operations. Removal of the foundation (soils) beyond the cutoff trench excavation is unnecessary" (SCS, 1984). No information or discussion of embankment settlement was identified in the Signal Butte FRS project files.

Foundation soils of the principal spillway reportedly have similar properties and description to that encountered along the dam centerline (SCS, 1984). Investigation of the principal spillway revealed that the depth to the caliche-cemented soil zone ranged from 2½ feet to 7½ feet below native grade. The overlying unconsolidated soils are described as clayey sand (SC) and silty clayey sand (SM-SC). The clayey sand soil has a reported dry density of 101.4 pounds per cubic foot. The principal spillway outlets into a reinforced concrete-lined floodway, thereby, eliminating any channel stability/erosion problems.

A concrete emergency spillway is constructed through the dam between Stations 204+30 and 205+70. Three exploratory boring were drilled upstream from the centerline and three were drilled downstream. Caliche was encountered at fairly shallow depths ranging from 1½ feet to 3 feet from the surface. Standard penetration tests indicated the caliche is hard, dense, and well cemented. The unconsolidated overlying soil was field classified as silty sand (SM). The caliche is reportedly considered fairly resistant to erosion and that only minor erosion was anticipated with the design discharge flow (SCS, 1984).

The borrow site for soil material used to construct the Signal Butte FRS was obtained from a 100-acre area upstream from the dam centerline and limited by the 1,720-foot contour line. A total of 96 backhoe pits were excavated on a 200-foot by 200-foot grid. Some randomly located test pits were also excavated. Materials in the borrow area consisted primarily of silty sand (SM) that is brown and for the most part fine- to coarse-grained. The soils were reportedly loose, usually dry, and contain gravel in varying amounts as well as some non-plastic silty fines. Caliche-cemented soils underlie the unconsolidated surface soil at a depth averaging about four feet. The caliche in the borrow area was reported as tan to gray, dry, moderately hard to hard, and moderately cemented to well cemented to a rock-like consistency. The caliche is strongly cemented silty coarse sand with varying percentages of gravel.

Ground Subsidence

Due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment, subsidence due to ground-water withdrawal is not expected to be a issue at the Signal Butte FRS. It appears that, like the Spook Hill FRS, the Signal Butte FRS is located on the Usery Mountain granitic pediment with bedrock at a relatively shallow depth (probably less than 200 feet) beneath the FRS structure.

Earth Fissures

Due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment on which the Signal Butte FRS is founded, earth fissuring should not be a issue. The nearest ground subsidence-related earth fissure is about two and one-half miles southwest of the Signal Butte FRS on the east site of Double Knoll Hill near the intersection of the Apache Trail at 85th Street.

Subsidence and Earth Fissure Monitoring Program

The Signal Butte FRS is located near an area of active ground subsidence and earth fissures. However, due to the presence of shallow granite pediment in the FRS area and the FRS's proximity to the pediment edge, earth fissuring should have minimal impacts on the Signal Butte FRS. Ground subsidence at the FRS is expected to be negligible. However, the Signal Butte FRS should be included in an area-wide monitoring program because of its proximity to the ground subsidence area and known earth fissures. This recommendation is repeated in Section 4.0.

Construction Plans/Specifications/Construction Methodology - Construction of the Signal Butte FRS was accomplished under contract to Pulice Construction Inc. from July 1985 to January 1987. A review of the project as-built plans indicated no significant changes were made to the original dam design during construction. Construction observation reports are available for this dam and include observation reports by ADWR. Typical dam cross sections show the embankment was constructed asymmetrically with respect to the dam centerline (see Sheets SB 7 and 8). The upstream slope is 2.5:1 (H:V) while the downstream slope is 2.0:1. The cutoff trench centerline was placed symmetrically with the dam centerline. However, the upstream distance of the cutoff trench extends to 13.0-ft while the downstream extent is 12.0-ft. The embankment was constructed in compacted lifts with appropriate moisture contents.

An HDPE curtain was installed down the longitudinal centerline of the dam from foundation (bottom of cutoff trench) to within 1-ft of the crest of the dam (see Sheet SB 7).

The source of the borrow material to construct the embankment for Signal Butte FRS came from the reservoir pool area. A materials investigation program was conducted by the NRCS to test the suitability of the native earthen materials found within the reservoir pool for embankment construction (see previous discussion above).

Settlement Monitoring – A summary of the District settlement monitoring program is provided in the District paper titled " Settlement Monitoring of Earthen Dams Operated by the Flood Control District of Maricopa County". The paper was prepared by Jan Staedicke in June 1995. The purpose of the report was to:

- Compile settlement monitoring data that has been acquired to date,
- Recommend refinements to the monitoring procedure,
- Recommend a schedule of continued monitoring,
- Recommend that the settlement monitoring procedure be supplemented with a) an earth fissure monitoring procedure, and b) periodic inspection using a team of specialists.

Appendix A of the District report contains a summary that lists each structure and shows the maximum settlement between the years surveyed, and the difference between the design crest and the minimum crest elevation. Appendix B of the District report contains detailed comments regarding each structure, while the last appendix of the District report, Appendix C, contains detailed information for each structure. This detailed information includes a data table showing survey elevations, incremental and total settlement, a plot of the crest settlement monuments, and a plot of the change in crest over the years surveyed.

The contents of the three District report appendices are included with this report (Part III) as Appendix B. However, only those portions of the District appendices specific to Signal Butte FRS are included in Appendix B. Recommendations for continued settlement monitoring for Signal Butte FRS are provided in Section 4.0 of this Part III.

Two post-construction level surveys have been conducted at the Signal Butte FRS. According to Staedicke (1995), the records indicated, when compared to the design crest elevation, negligible settlement has occurred at the Signal Butte FRS. The maximum settlement was 0.07 feet with minimum elevation change of 0.15 feet below the design crest elevation.

KHA has plotted the existing settlement surveys and are provided in Appendix B.

2.7 Structures Inspection Checklist

A customized inspection checklist for Signal Butte FRS was prepared and is based upon the inspection checklist developed by the Dam Safety Section at ADWR. The inspection checklist for Signal Butte FRS is provided in Section 3.0 of this Part III.

2.8 Maintenance Activities

The Operation and Maintenance Division has an established animal and vegetation control program for District structures, including dams and appurtenant features. The District animal and vegetation control program is documented in a recent District paper (November, 1999) that was presented at the workshop on "Plant and Animal Penetration Earthen Dams" held in Knoxville, Tennessee. A copy of the District's paper is included the Policy & Program Report. The following discussion summarizes these control programs. Further details are referenced in the District paper.

The purpose of the District's vegetation management program for District dams is twofold: (1) to minimize erosion of embankment slopes, and (2) eliminate undesired plant species from the dam crest and embankment slopes. The first purpose is actually part of the District's erosion control efforts to prevent or minimize loss of embankment material due to erosion. The District has a history of application of erosion control measures on their structures. These measures include hydroseeding slopes in attempt to establish a vegetation cover, placement of gravel or rock mulch on the embankment slopes to reduce rainfall impacts and flow velocities, and/or a combination of these two measures.

The District's methodology for establishment of vegetation covers on the embankment slopes presently consists of hydroseeding methods. The procedure is discussed in the District's paper. The paper presents the type of seed mix included in the hydroseeding program.

The second purpose of the vegetation management program is to control unwanted plant species, particularly on the embankment slopes. These undesired plant species include all deep-rooted plants typically found in Maricopa County such as desert broom, salt cedar, mesquites, and palo verdes. The method of vegetation control is explained in detail in the District's paper, but includes eradication by herbicides or manual pruning, and trimming by a boom-mower.

District O&M crews maintain low flow channels to principal spillway inlets. The maintenance conducted for the low flow channels consists of eradication of unwanted vegetation within the channel limits and removal of accumulated sediment in the channel bottom. Sediment removal is conducted with the use of a loader and dump truck and conducted on an as-needed basis.

A review of design and as-built plans for Signal Butte FRS indicates that no sediment monuments or markers were installed to monitor sediment accumulation in the impoundment area. Discussions with District staff indicate that very minor activity regarding the monitoring of sediment accumulation has ever been conducted for District impoundment areas. Hardly any sediment removal activities are conducted in the impoundment area. The design reports for the structures, however, do indicate that sediment pools were designed as part of the reservoir. The reports provide the volume of sediment storage available and the elevation of the top of the sediment pool.

District O&M crews conduct maintenance activities at Signal Butte FRS on a regularly scheduled basis. The District has conducted vegetation eradication within the low-flow channel located at the heel of the dam. The low-flow channel takes flows entering the FRS impoundment area and directs the flow towards the principal spillway. The eradication methods include physical removal of unwanted vegetation by clearing and grubbing methods using bulldozers, front-end loaders, and dump trucks. Very little vegetation eradication is conducted within the reservoir pool area outside the low-flow channel. Discussions with District O&M staff indicate that their crews may pick up dead and fallen trees and woody debris within the reservoir pool area, but the extent of the effort and frequency of removal is very limited.

The District performs very minor sediment removal from the inlet and outlet structures of the principal spillway and in the area just upstream of the inlet structure where sediment typically accumulates. Sediment removal from the inlet and outlets structures is typically conducted by hand-labor with shovels and buckets. The buckets are filled and then loaded into an awaiting dump truck. The sediment accumulated upstream of the inlet structure is removed by front-end loader and placed into the dump truck.

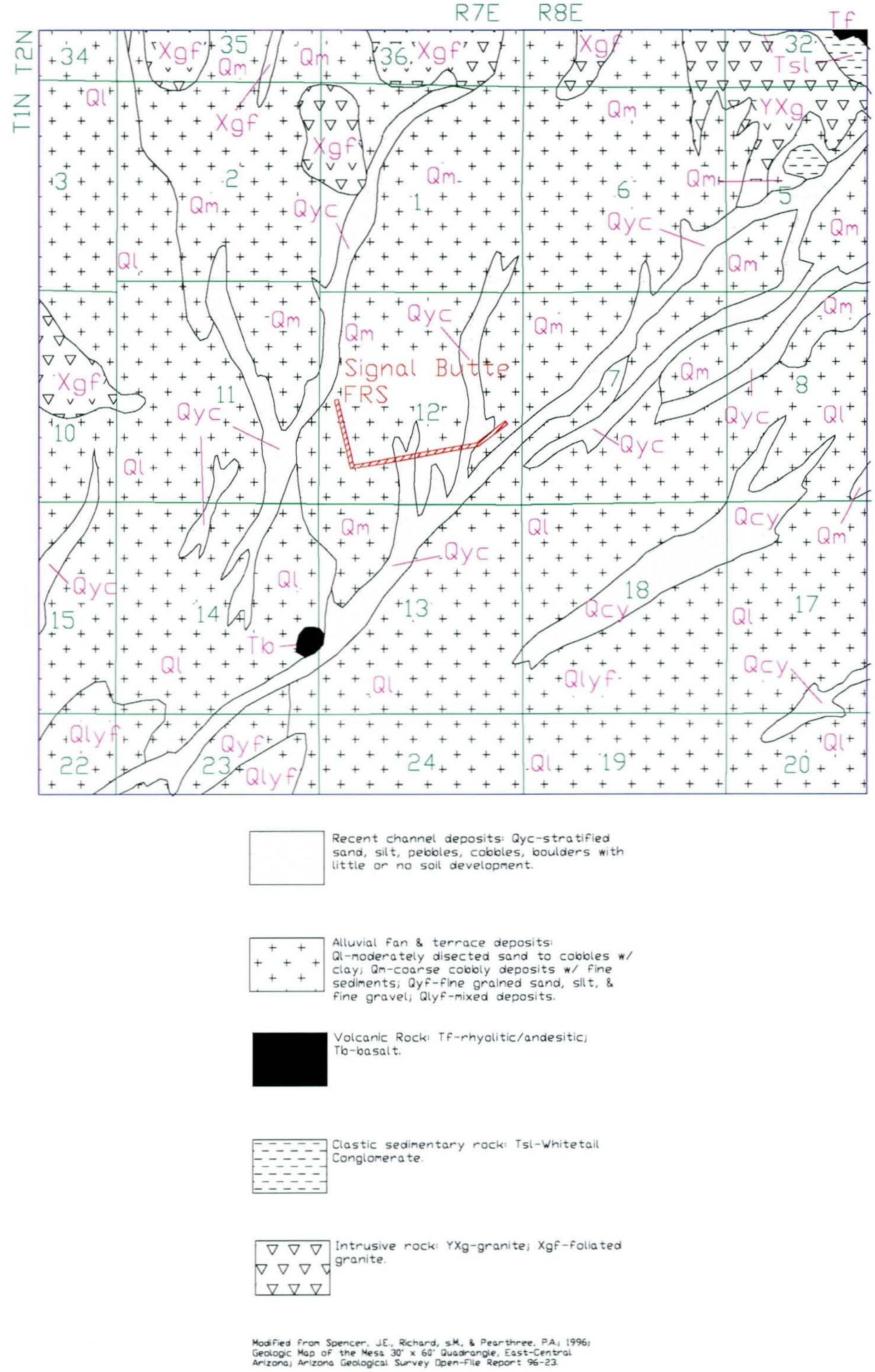


Figure 2-1. Signal Butte FRS Regional Geology.

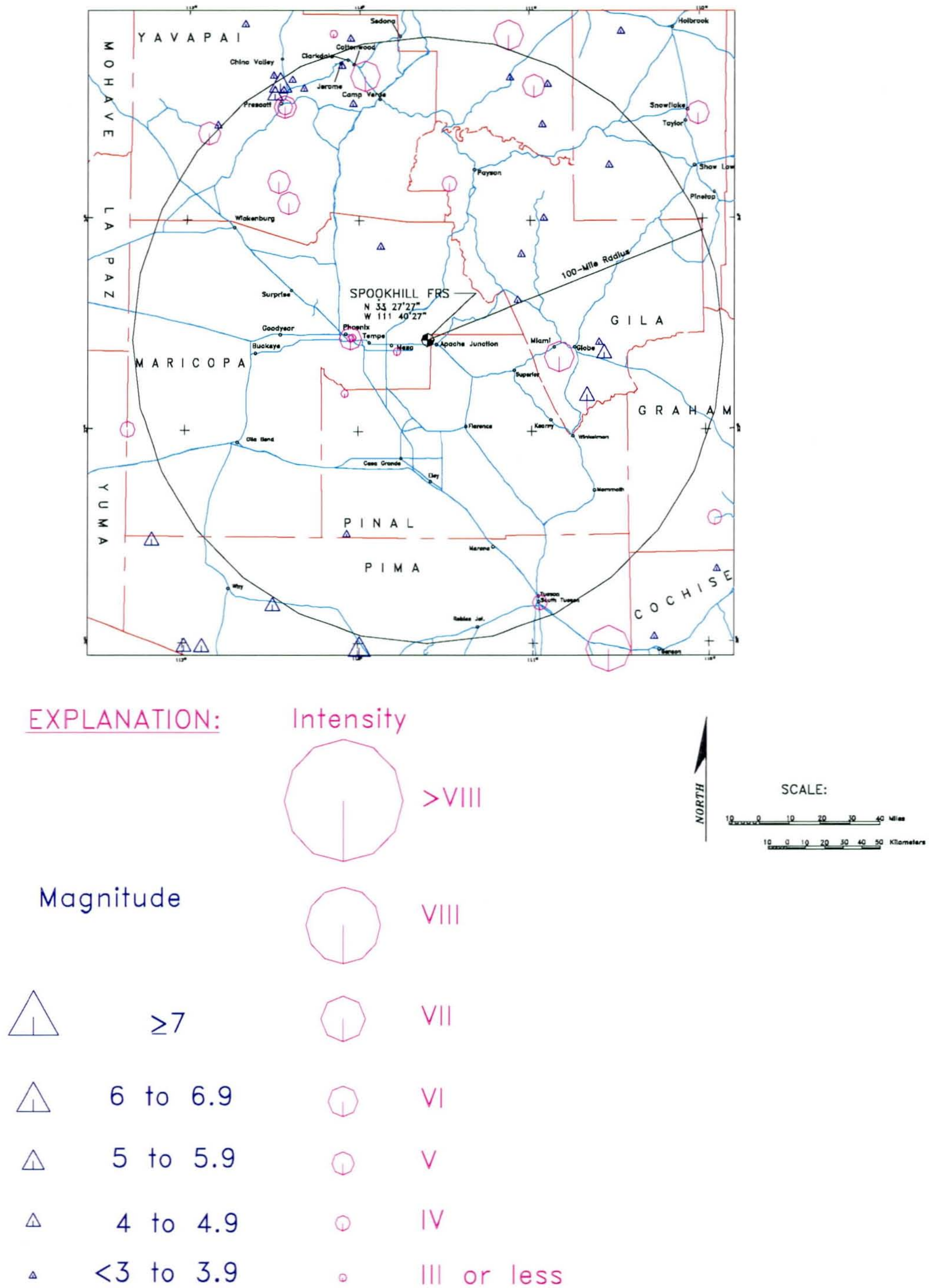


Figure 2-2. Earthquake Epicenter Map: Signal Butte FRS and Vicinity.

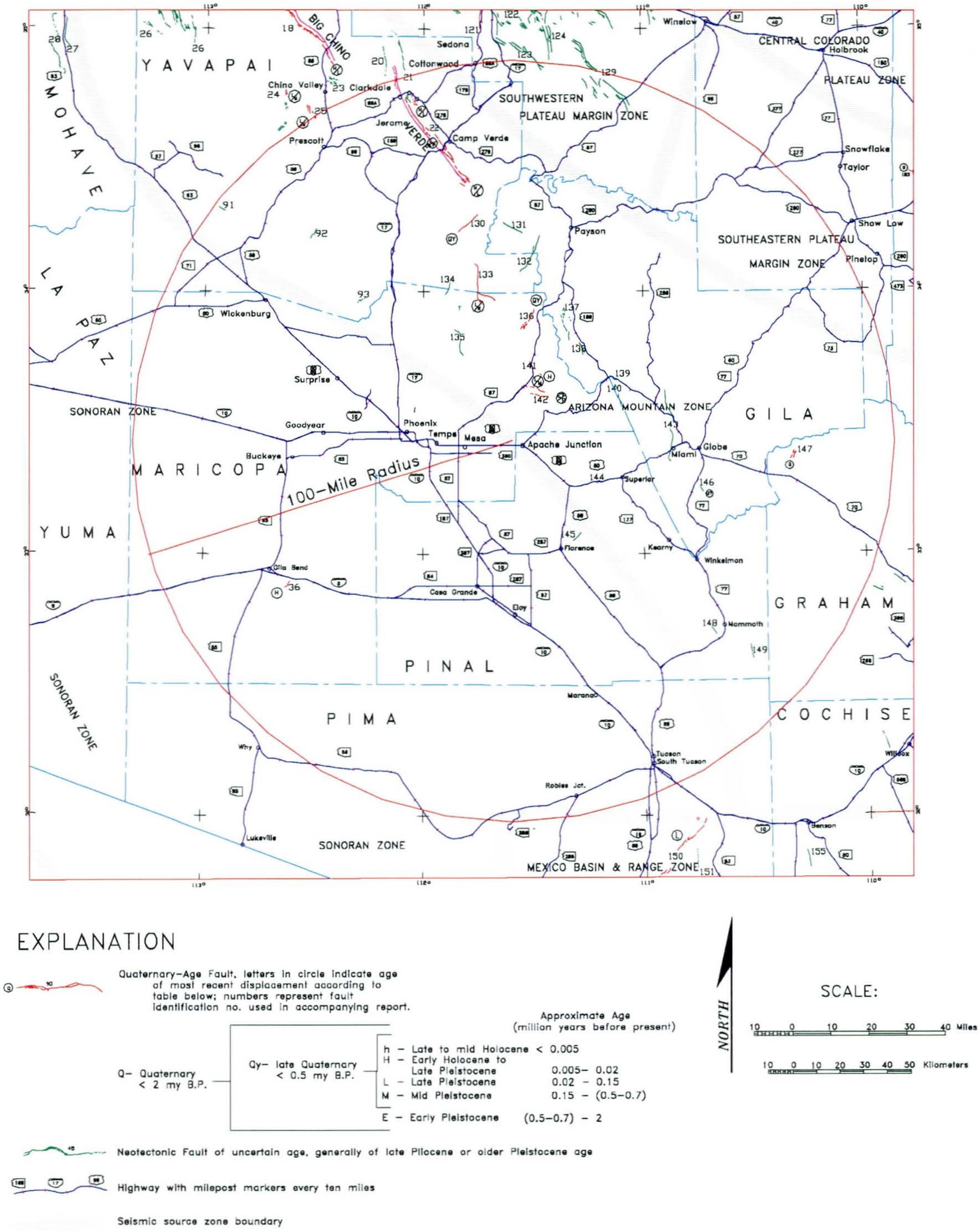
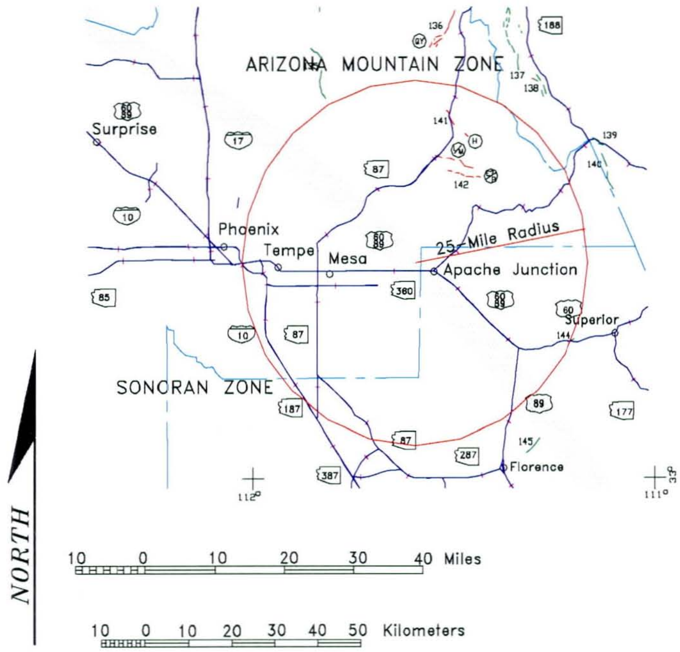


Figure 2-3. Regional Fault Map 100-Mile Radius.



EXPLANATION

Development of Seismic Maps for Arizona
Report Number: FHWA-AZ92-344
ADOT Contract No: HPR-PL-1(37)344

Quaternary-Age Fault, letters in circle indicate age of most recent displacement according to table below; numbers represent fault identification no. used in accompanying report.

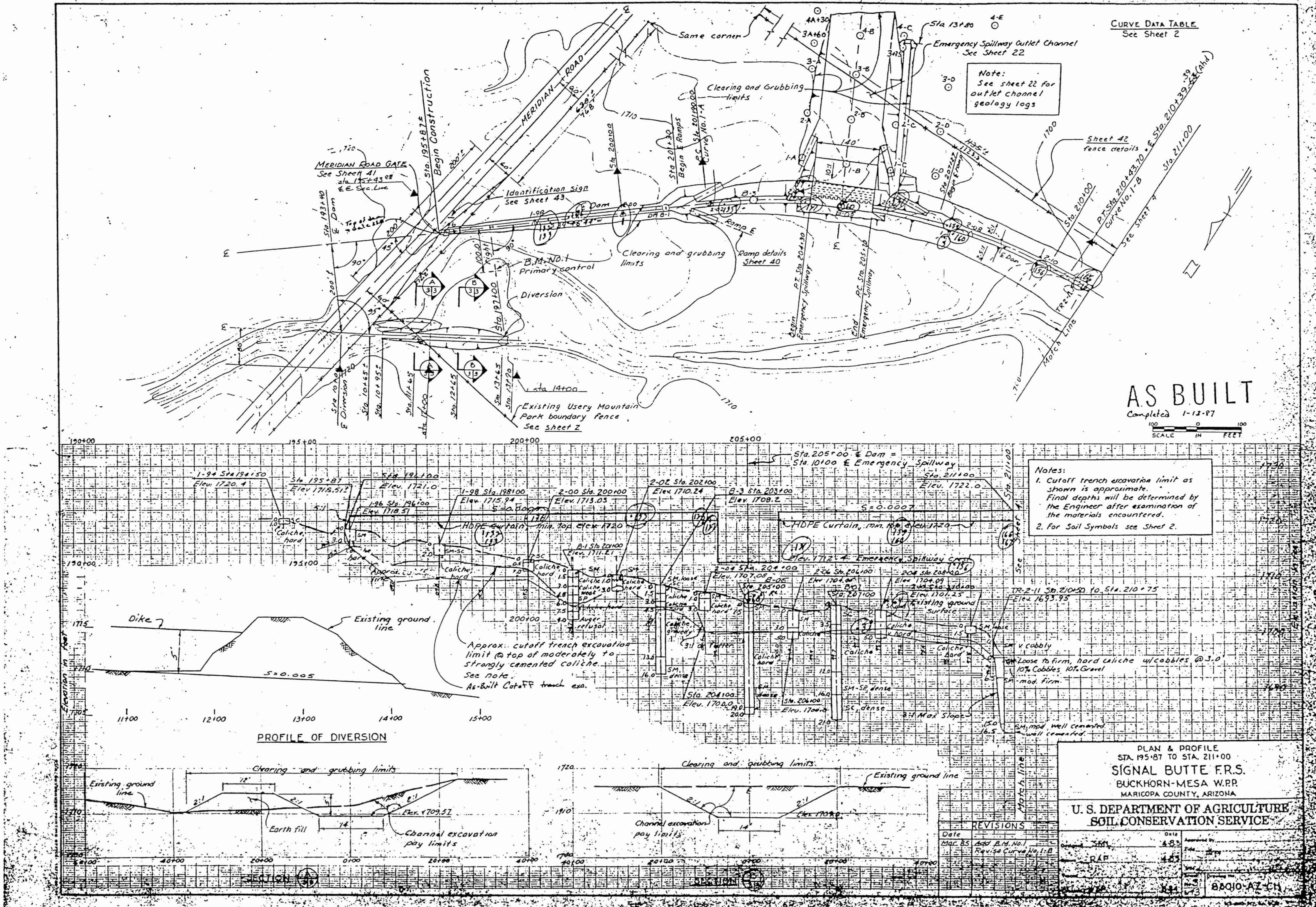
			Approximate Age (million years before present)
Q- Quaternary < 2 my B.P.	Qy- late Quaternary < 0.5 my B.P.	h - Late to mid Holocene	< 0.005
		H - Early Holocene to Late Pleistocene	0.005- 0.02
		L - Late Pleistocene	0.02 - 0.15
		M - Mid Pleistocene	0.15 - (0.5-0.7)
	E - Early Pleistocene		(0.5-0.7) - 2

Neotectonic Fault of uncertain age, generally of late Pliocene or older Pleistocene age

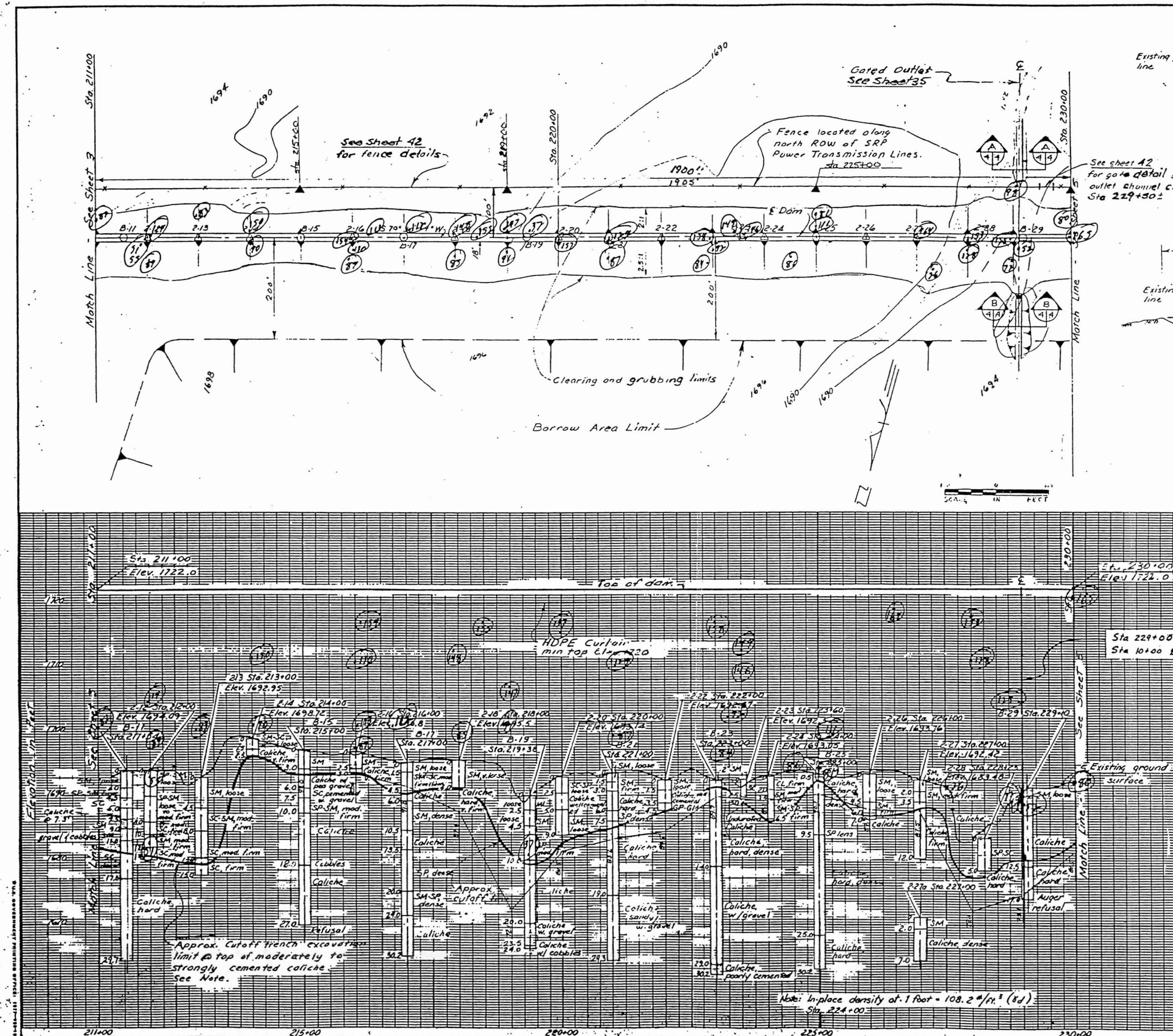
Highway with milepost markers every ten miles

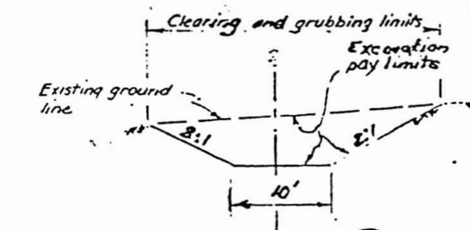
Seismic source zone boundary

Figure 2-4. Area Fault Map 25-Mile Radius.

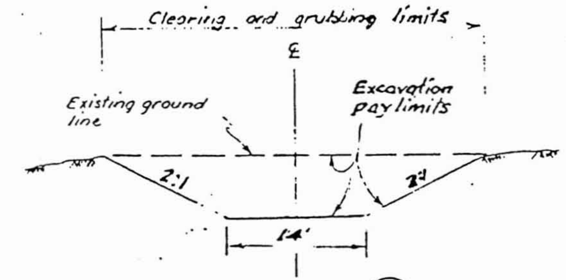

CURVE DATA TABLE
See Sheet 2
Note:
See sheet 22 for outlet channel geology logs
Same corner
Sta 13+80
Emergency Spillway Outlet Channel
See Sheet 22
Clearing and Grubbing limits
MERIDIAN ROAD
MERIDIAN ROAD GATE
See Sheet 41
Sta. 195+87±
Begin Construction
Identification sign
See Sheet 43
Sta. 201+30
Begin £ Ramps
P.C. Sta 201+90.00
Curve No. 1-A
Ramp £
Ramp details
Sheet 40
Clearing and grubbing limits
B.M. No. 1
Primary control
Diversion
P.T. Sta 204+30
Begin Emergency Spillway
P.C. Sta 205+70
End Emergency Spillway
Sheet 42
fence details
Sta. 210+00
Sta. 211+00
P.T. Sta. 210+43.70
Curve No. 1-B
See Sheet 4
Match Line
Sta. 14+00
Existing Usery Mountain Park boundary fence
See Sheet 2
AS BUILT
Completed 1-13-87
SCALE IN FEET
Sta. 205+00 £ Dam = Sta. 10+00 £ Emergency Spillway
1-94 Sta 194+50
Elev. 1720.4
Sta. 195+87
Elev. 1718.51
Sta. 196+00
Elev. 1721.0
1-98 Sta. 198+00
Elev. 1715.94
1-96 Sta. 196+00
Elev. 1718.51
2-00 Sta. 200+00
Elev. 1713.03
2-02 Sta. 202+00
Elev. 1710.24
B-3 Sta. 203+00
Elev. 1708.2
Sta. 211+00
Elev. 1722.0
S=0.0007
HDPE Curtain, min. top elev. 1720
Elev. 1712 £ Emergency Spillway Crest
B-1 Sta 201+00
Elev. 1711.21
2-04 Sta. 204+00
Elev. 1707.08
2-06 Sta. 206+00
Elev. 1704.61
2-08 Sta. 208+00
Elev. 1704.09
Elev. 1701.25
Existing ground surface
TR-2-11 Sta. 210+50 to Sta. 210+75
Elev. 1693.95
Caliche hard
Approx. cutoff trench excavation limit @ top of moderately to strongly cemented caliche. See note.
As-Built Cutoff trench exc.
Sta. 204+00
Elev. 1700.0
Sta. 206+00
Elev. 1700.0
SC, dense
3:1 Max Slope
SM-SP, dense
Loose to firm, hard caliche w/cobbles @ 3.0
10% Cobbles 10% Gravel
SM-mod. firm
SM, mod. well cemented
Notes:
1. Cutoff trench excavation limit as shown is approximate. Final depths will be determined by the Engineer after examination of the materials encountered.
2. For Soil Symbols see Sheet 2.
Dike
Existing ground line
S=0.005
Elevation in Feet
PROFILE OF DIVERSION
Clearing and grubbing limits
Existing ground line
Earth fill
Elev. 1709.57
Channel excavation pay limits
SECTION A
SECTION B
PLAN & PROFILE
STA. 195+87 TO STA. 211+00
SIGNAL BUTTE F.R.S.
BUCKHORN-MESA W.P.P.
MARICOPA COUNTY, ARIZONA
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
REVISIONS
Date
Mar. 85
Add B.M. No. 1
Revise Curve No. 1-B
8-Q-10-AZ-CH

SB Sheet 1





SECTION A/4 (Not to scale)
OUTLET CHANNEL



SECTION B/4 (Not to scale)
INLET CHANNEL

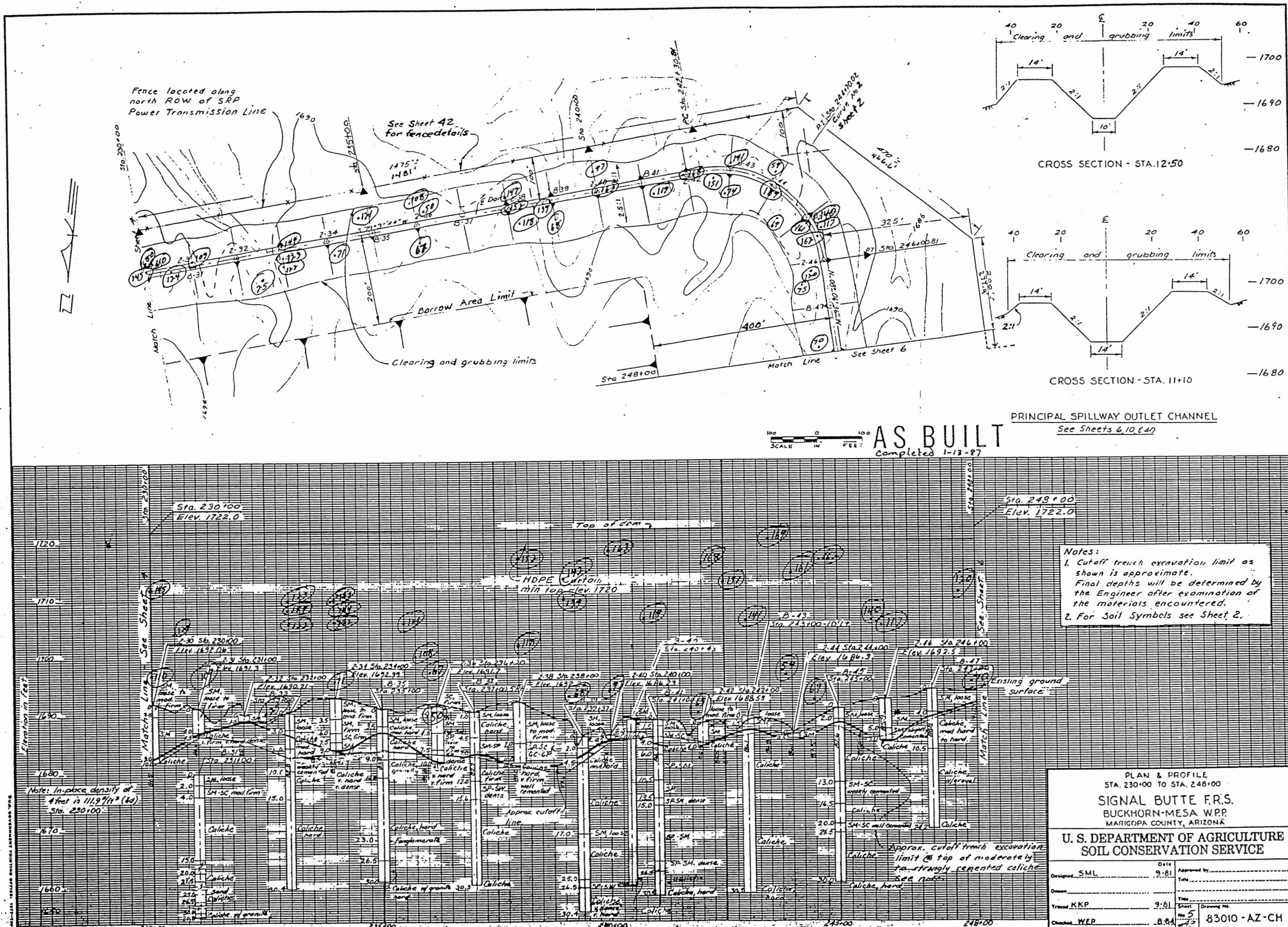
AS BUILT
Completed 1-13-87

Notes:
1. Cutoff trench excavation limit as shown is approximate. Final depths will be determined by the Engineer after examination of the materials encountered.
2. For Soil Symbols see Sheet 2.

PLAN & PROFILE
STA. 211+00 TO STA. 230+00
SIGNAL BUTTE F.R.S.
BUCKHORN-MESA W.P.P.
MARICOPA COUNTY, ARIZONA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed SML	Date 3-81	Approved by	
Drawn EFS	3-81	Title	
Traced		Title	
Checked WEP	8-84	Sheet No. 4 of 43	Drawing No. 83010-AZ-CH

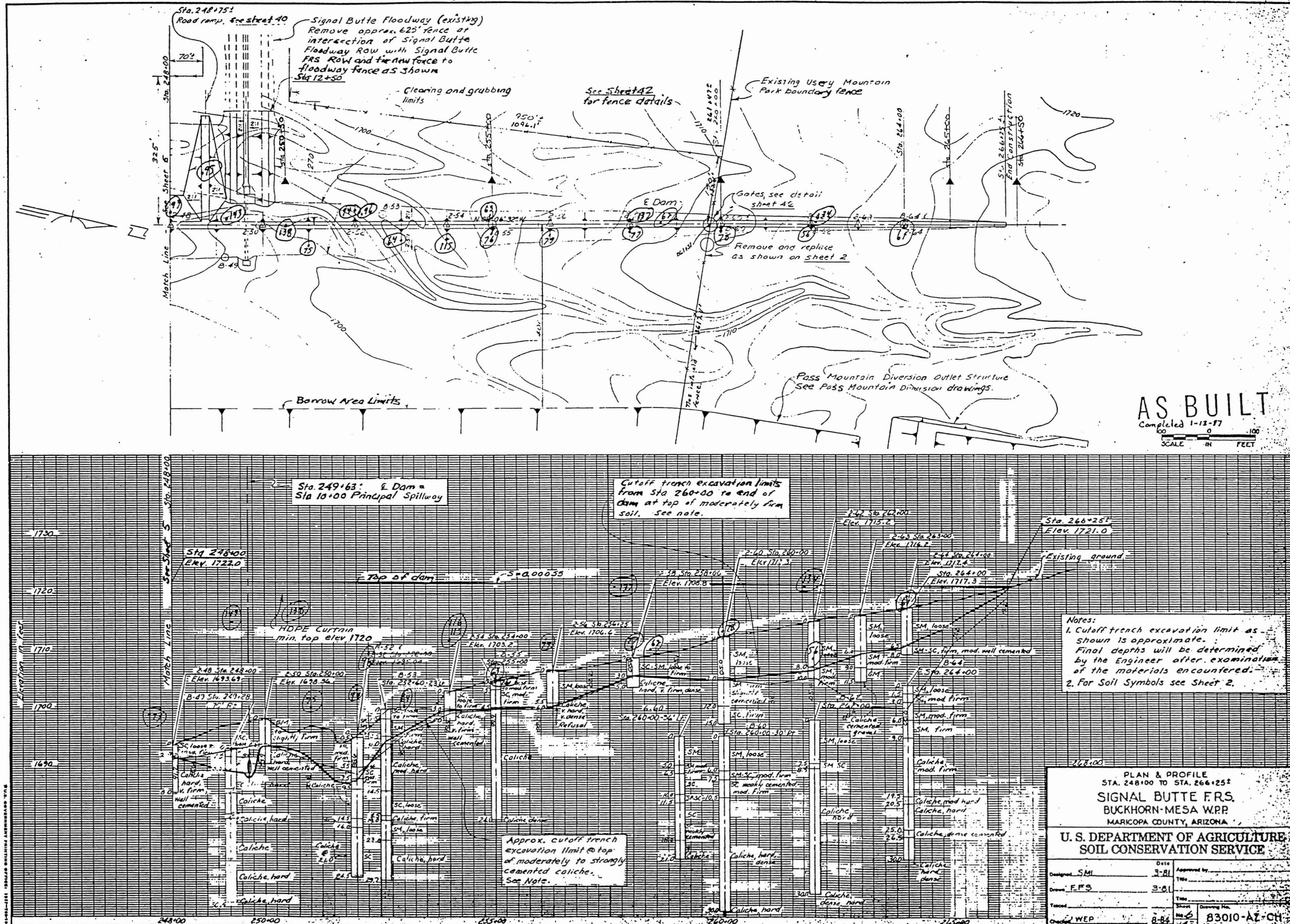


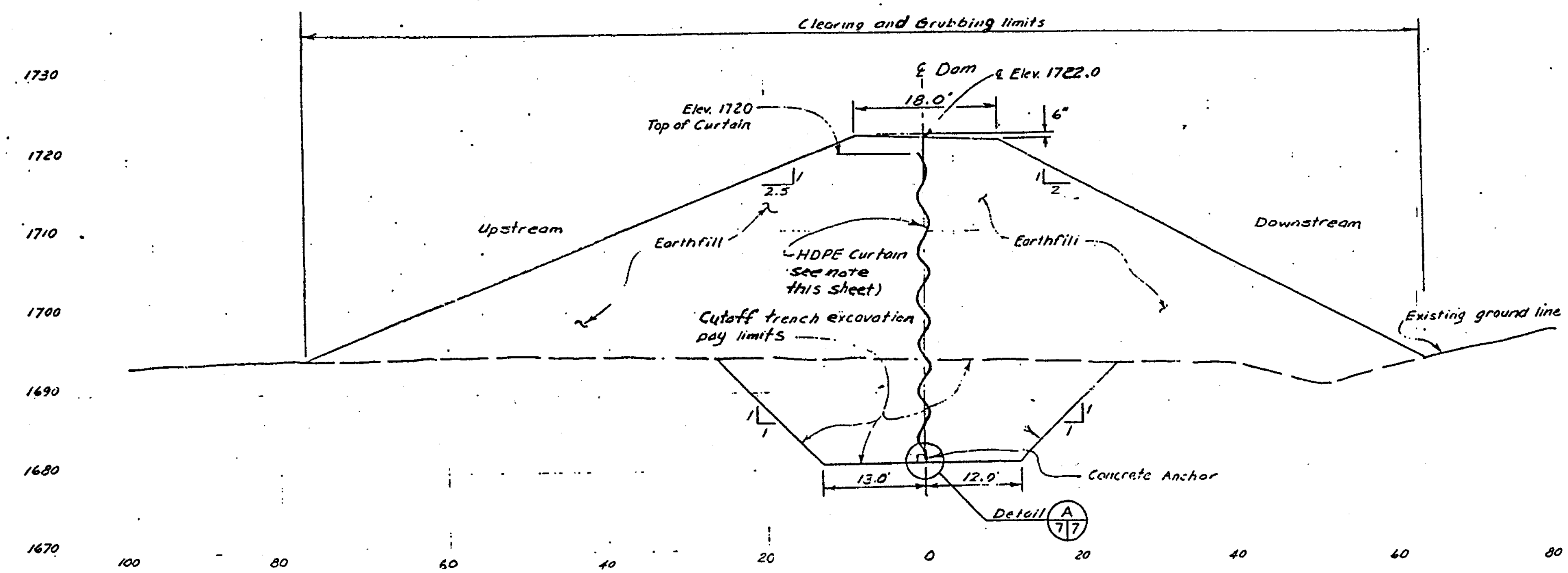
Notes:
1. Cutoff trench excavation limit as shown is approximate. Final depths will be determined by the Engineer after examination of the materials encountered.
2. For Soil Symbols see Sheet 2.

PLAN & PROFILE
STA. 230+00 TO STA. 248+00
SIGNAL BUTTE F.R.S.
BUCKHORN-MESA W.P.P.
MARICOPA COUNTY, ARIZONA

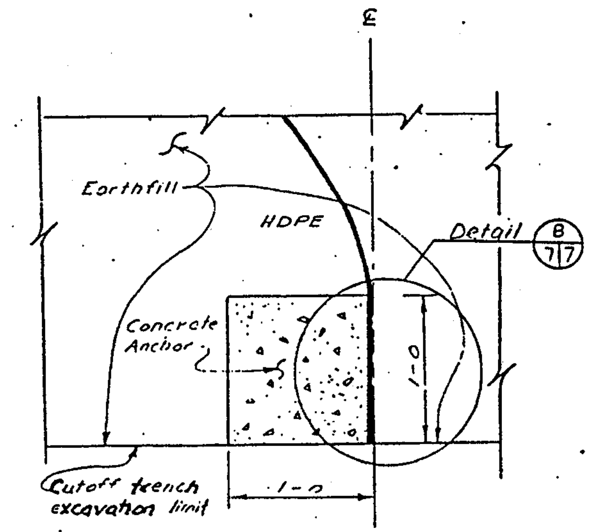
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

		Date	
Designed	SML	9-81	Approved by
Drawn			Title
Traced	KKP	9-81	Sheet No. 5 of 43
Checked	WEP	8-84	Drawing No. 83010-AZ-CH


Sta. 248+75±
Road ramp. See sheet 40
Signal Butte Floodway (existing)
Remove approx. 625' fence at intersection of Signal Butte Floodway Row with Signal Butte FRS Row and tie new fence to floodway fence as shown
Sta 12+50
Clearing and grubbing limits
See Sheet 42 for fence details
Existing Usery Mountain Park boundary fence
Gates, see detail sheet 46
Remove and replace as shown on sheet 2
Pass Mountain Diversion Outlet Structure
See Pass Mountain Diversion drawings.
Borrow Area Limits
Match Line
Sheet 5
AS BUILT
Completed 1-13-87
SCALE IN FEET
Sta. 249+63: ℄ Dam = Sta 10+00 Principal Spillway
Cutoff trench excavation limits from Sta 260+00 to end of dam at top of moderately firm soil. See note.
Sta 248+00
Elev. 1722.0
Top of dam
S=0.00035
HDPE Curtain
min. top elev 1720
Sta. 266+25±
Elev. 1721.0
Existing ground
Approx. cutoff trench excavation limit @ top of moderately to strongly cemented caliche. See Note.
Elevation in feet
Notes:
1. Cutoff trench excavation limit as shown is approximate. Final depths will be determined by the Engineer after examination of the materials encountered.
2. For Soil Symbols see Sheet 2.
PLAN & PROFILE
STA. 248+00 TO STA. 266+25±
SIGNAL BUTTE F.R.S.
BUCKHORN-MESA W.P.P.
MARICOPA COUNTY, ARIZONA
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed SMI 3-81
Drawn FFS 3-81
Checked WEP 8-84
Sheet 6 of 43
83010-AZ-CH
SB Sheet 4

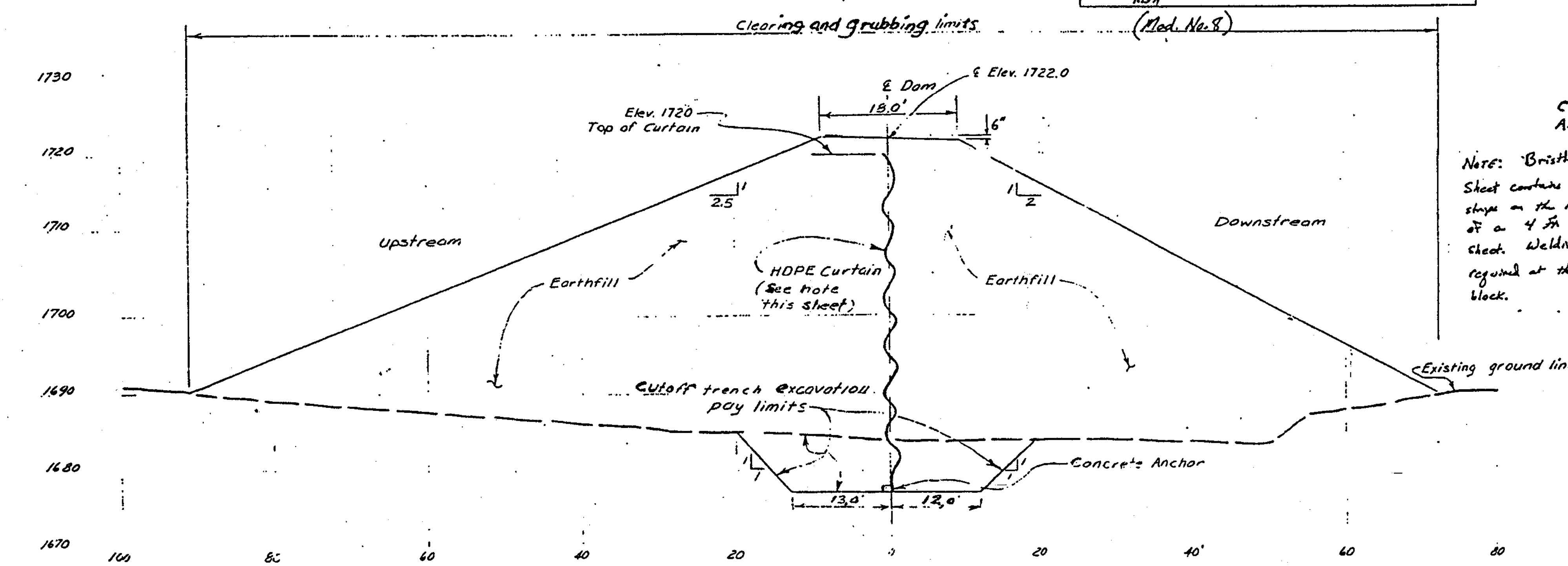


STA 212-00

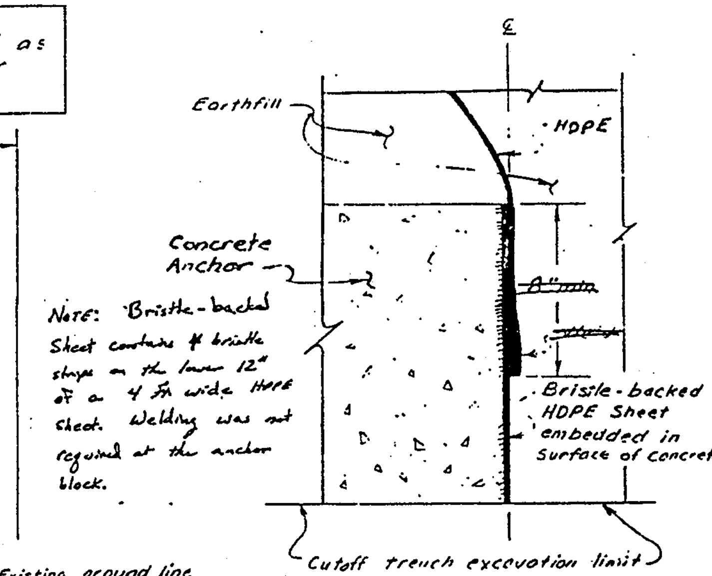


DETAIL A 7/7 (Not to scale)

Note: Install HDPE curtain as vertical as conditions permit and no flatter than 1.25:1 at any location.
(Mod. No. 8)



STA. 227+85



DETAIL B 7/7 (Not to scale)

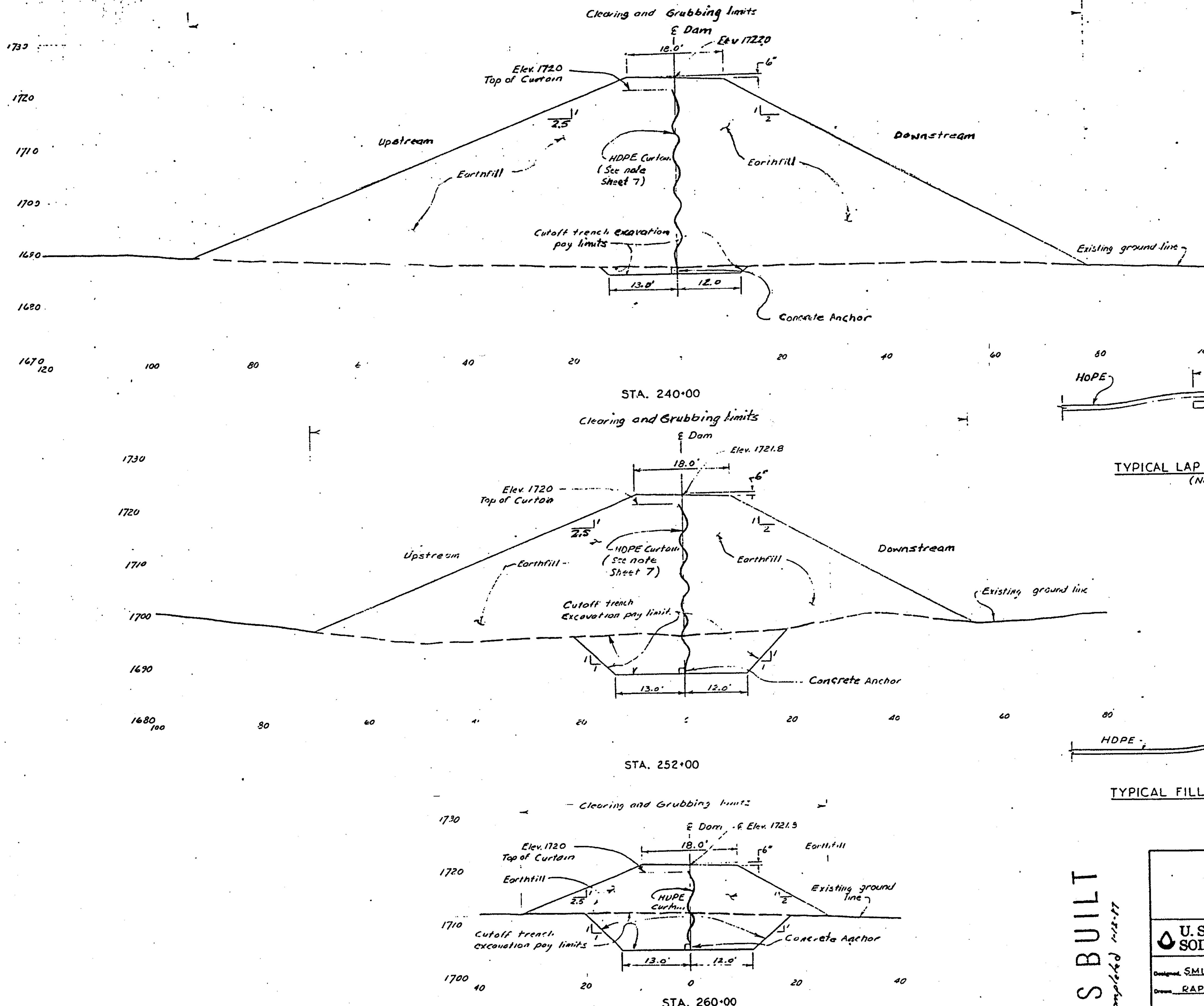
AS BUILT
Completed 1-13-87

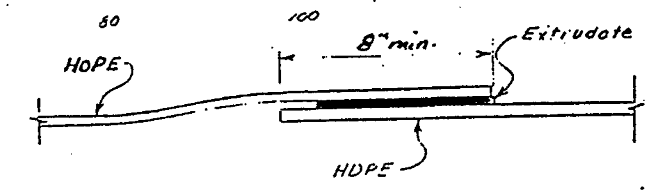
CROSS SECTIONS OF DAM
STA 212+00 & STA. 227+85

SIGNAL BUTTE F.R.S.
BUCKHORN-MESA WATERSHED
MARICOPA COUNTY, ARIZONA

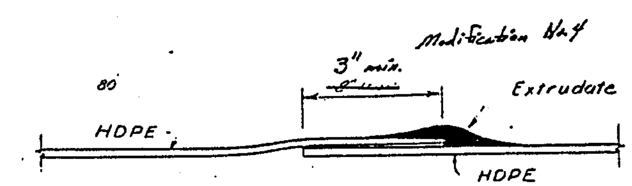
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

	Date	
Designed SML	10-83	Approved by
Drawn RAP	10-83	Title
Traced EFS	10-83	Title
Checked WEP	8-84	Sheet No. 7 of 43 — Drawing No. 83010-AZ-CH





TYPICAL LAP WELD SHEET JOINT
(Not to Scale)



TYPICAL FILLET WELD SHEET JOINT
(Not to scale)

AS BUILT
Completed 11-12-87

CROSS SECTIONS OF DAM
STA. 240+00, STA 252+00 & STA 260+00

SIGNAL BUTTE F.R.S.
BUCKHORN-MFSA WATERSHED
MARICOPA COUNTY, ARIZONA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed SML	10-83	Approved by
Drawn RAP	10-83	Title
Traced		Title
Checked WEP	8-84	Sheet No. 8 of 43 — Drawing No. 83010-AZ-CH

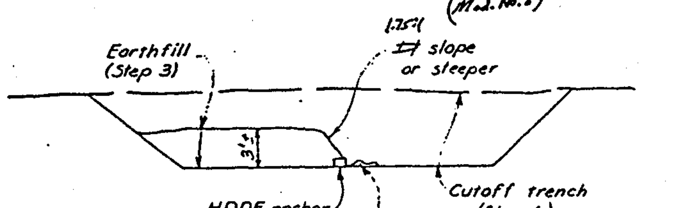
1. *Excavate cutoff trench.*

2. *Form concrete anchor for HDPE.*

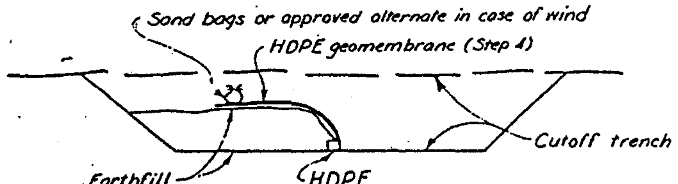
   The "form" may be a trench in the caliche, or formed on the surface of the cutoff trench excavation. The difficulty of trenching varies with particle size and amount of natural cementation.

   Polygrip filaments will not bond well without vibration of the concrete next to the filaments. If another bonding method is used, it must be an industry standard (water tight) or a demonstration of bond shall be required.

3. *Begin placement of Earthfill on upstream side of concrete anchor. Complete fill to an approximate depth of 3 feet. The depth of lift will vary with irregular depth of the cutoff trench. Slope the Earthfill adjacent to the HDPE anchor no flatter than 1.75:1. The slope will be determined by the stability of the freshly-placed Earthfill and the Contractor's procedures, as approved by the Engineer.* (Mod. No. 8)

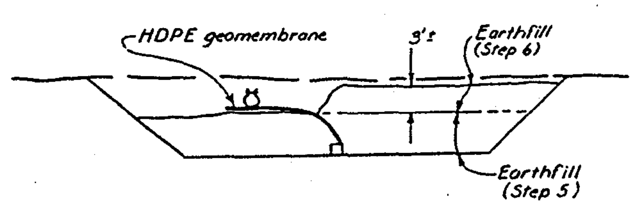


4. *Weld strip of HDPE geomembrane to polygrip (or equal) on concrete anchor and lay the HDPE on the Earthfill constructed in Step 3. The width of HDPE laid will vary with manufacturer and contractor's operation. An approximate width of 10 feet is used for example. This width, 500 feet long, would weigh about 2450 #.*

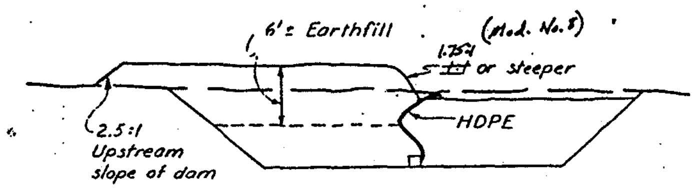


5. *Place Earthfill on downstream side of HDPE anchor and on top of HDPE geomembrane until even with elevation of the first lift (Step 3).*

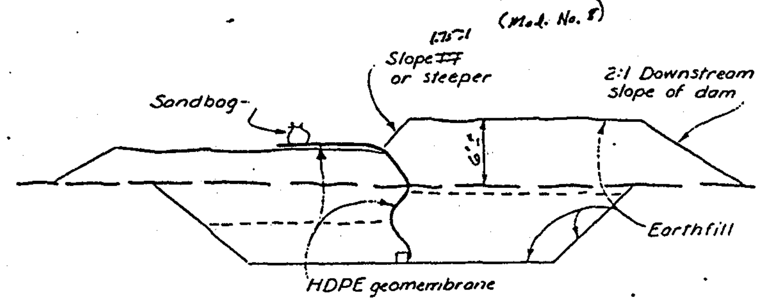
6. *Continue placing Earthfill to an additional depth of 3 feet ± with an upstream slope no flatter than 1.75:1*



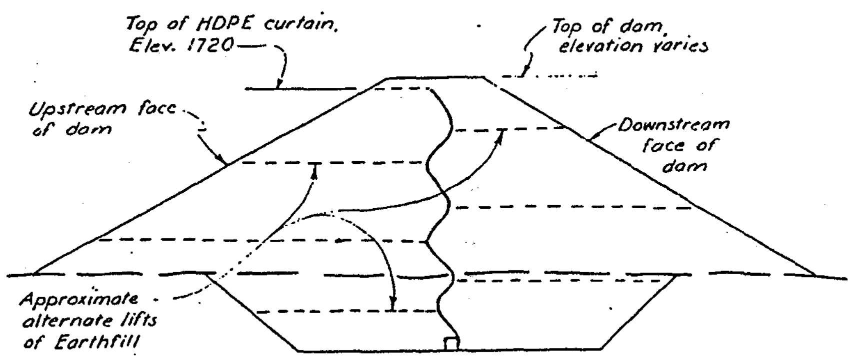
7. *Lay HDPE geomembrane on new slope and place Earthfill on upstream side.*



8. *Weld next width of HDPE geomembrane on to first and lay it on finished Earthfill (like Step 4). Continue placing Earthfill.*



9. *Continue alternating lifts and welds until Elevation 1720 is reached. Place Earthfill over top of HDPE curtain to final design elevation.*

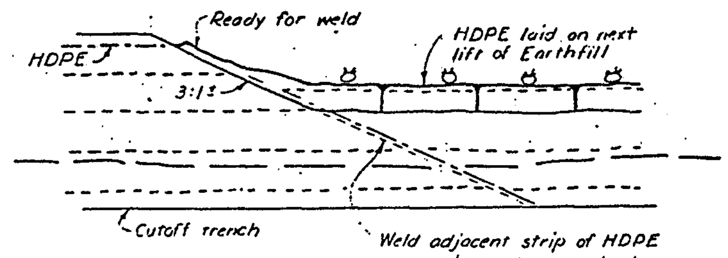


10. *The length of dam to be constructed at one time may vary. Welds may be constructed at any angle within the plane of the geomembrane. The material shall not at any time be folded back on itself so that a crease is pressed. This condition will cause a split or weakness in the material.*

    Patches and seams will be permitted at any reasonable location or angle necessary to complete the work. All tears and visible punctures will be patched in a manner approved by the manufacturer.

    Any part of the HDPE geomembrane that is driven over shall be inspected for damage and repaired or replaced as determined by the Engineer. This may require excavation if the Contractor's operation has caused the geomembrane to be covered, such as for an equipment crossing.

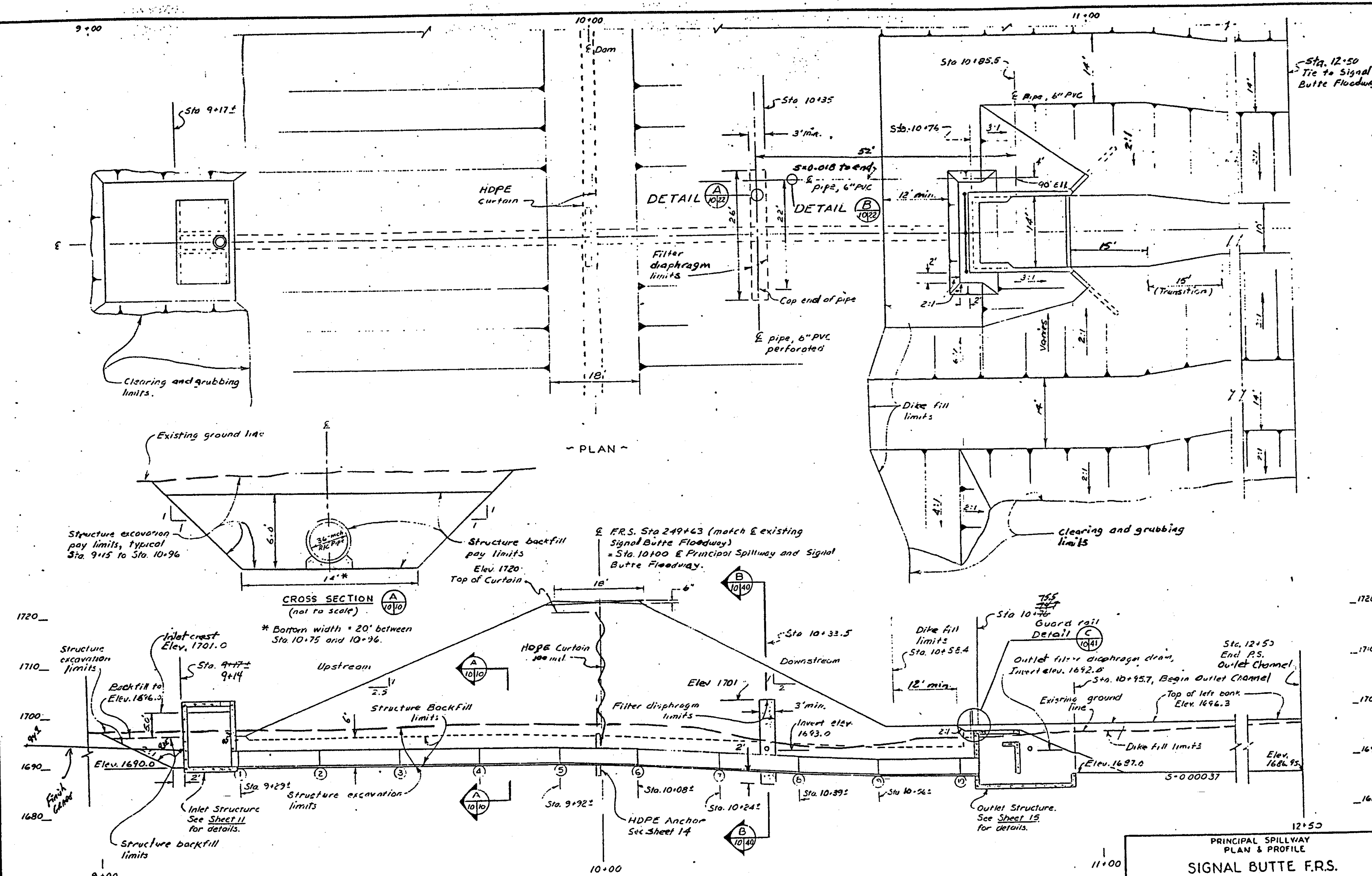
11. *The following intersection of completed embankment with section under construction is suggested:*



PROFILE ALONG ℄ DAM

AS BUILT
Completed 1-13-87

HDPE CURTAIN INSTALLATION	
SIGNAL BUTTE F.R.S. BUCKHORN-MESA W.P.P. MARICOPA COUNTY, ARIZONA	
U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE	
Designed SML — Date 12-84	Approved by
Drawn EFS — 12-84	Title
Traced	Title
Checked WEP — 12-84	Sheet No. 9 of 43 — Drawing No. 83010-AZ-CH



PROFILE ℄ PRINCIPAL SPILLWAY

SCALE IN FEET (10 0 10 20)

PIPE JOINT INVERT ELEVATIONS			
①	1690.0	⑥	1689.5
②	1690.0	⑦	1688.5
③	1690.0	⑧	1687.5
④	1690.0	⑨	1687.0
⑤	1690.0	⑩	1687.0

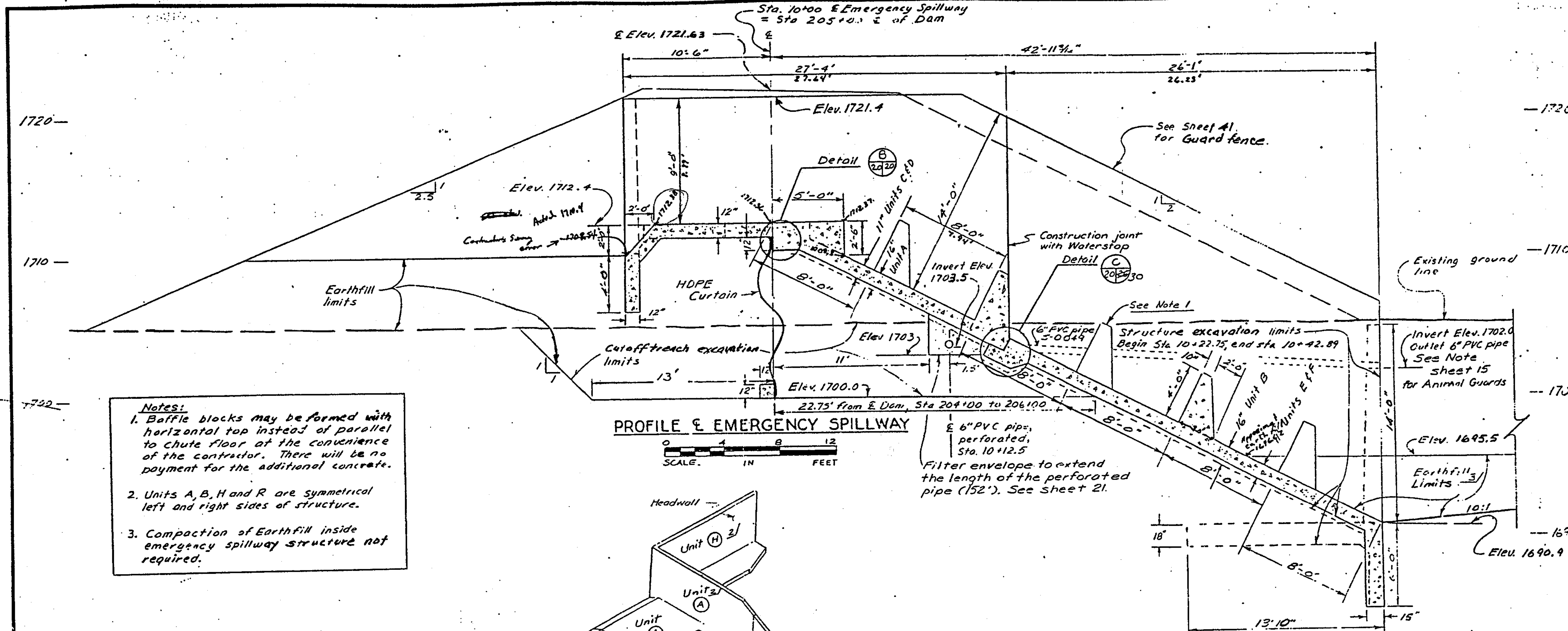
AS BUILT
Completed 1-13-87

PRINCIPAL SPILLWAY
PLAN & PROFILE

SIGNAL BUTTE F.R.S.
BUCKHORN-MESA W.P.P.
MARICOPA COUNTY, ARIZONA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

		Date	
Designed	SML	11-81	Approved by
Drawn	RAP	11-81	Title
Traced	FFS	12-81	Title
Checked	WEP	8-84	Sheet No. 10 of 43 — Drawing No. 83010-AZ-CH

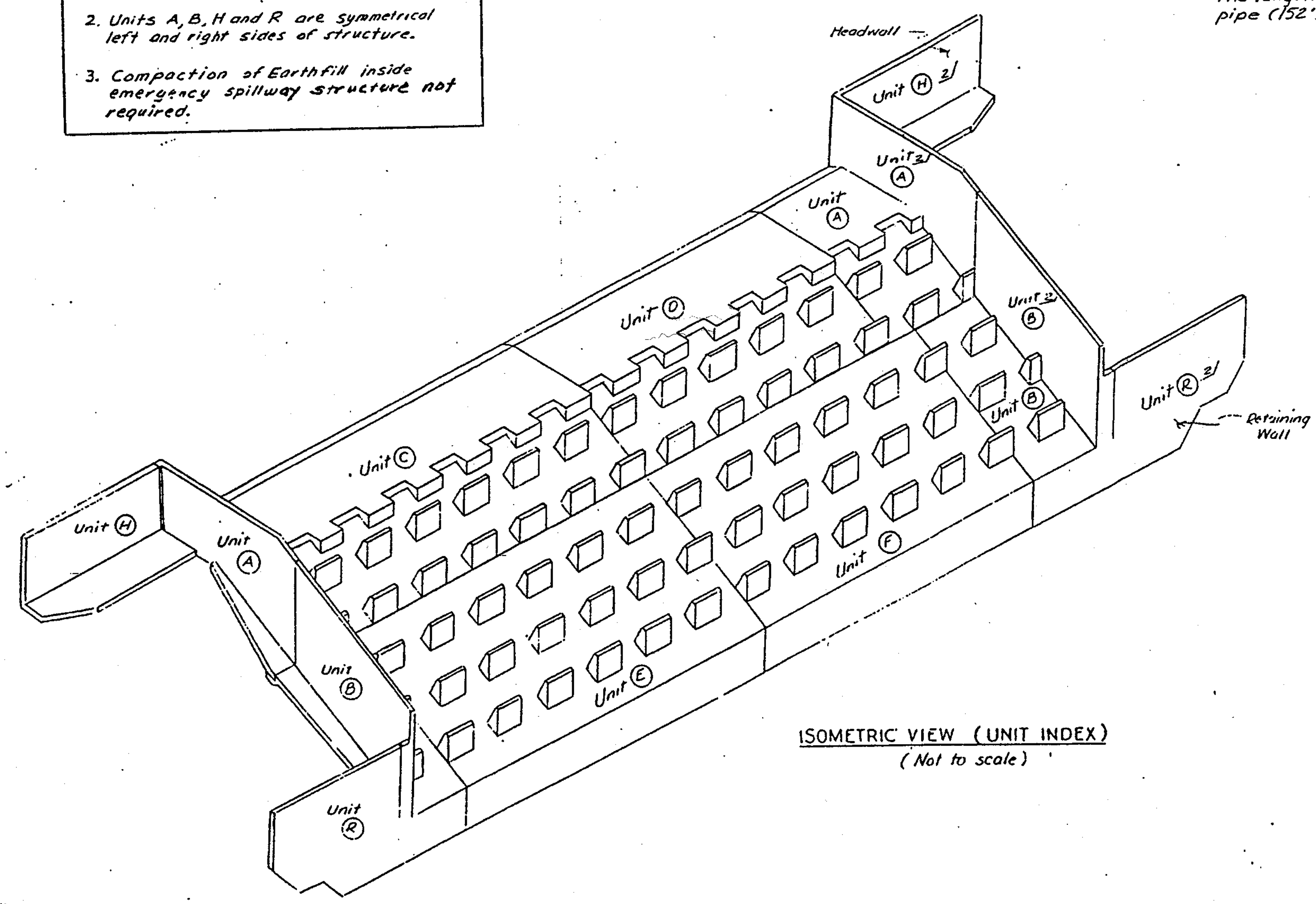


PROFILE ℄ EMERGENCY SPILLWAY

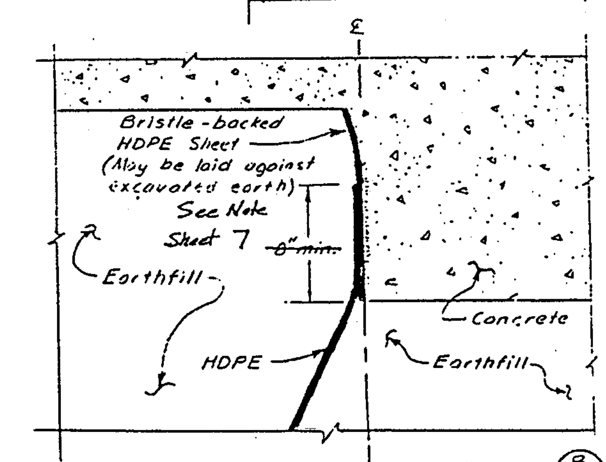
SCALE. 0 4 8 12 IN FEET

Notes:

1. Baffle blocks may be formed with horizontal top instead of parallel to chute floor at the convenience of the contractor. There will be no payment for the additional concrete.
2. Units A, B, H and R are symmetrical left and right sides of structure.
3. Compaction of Earthfill inside emergency spillway structure not required.



ISOMETRIC VIEW (UNIT INDEX)
(Not to scale)



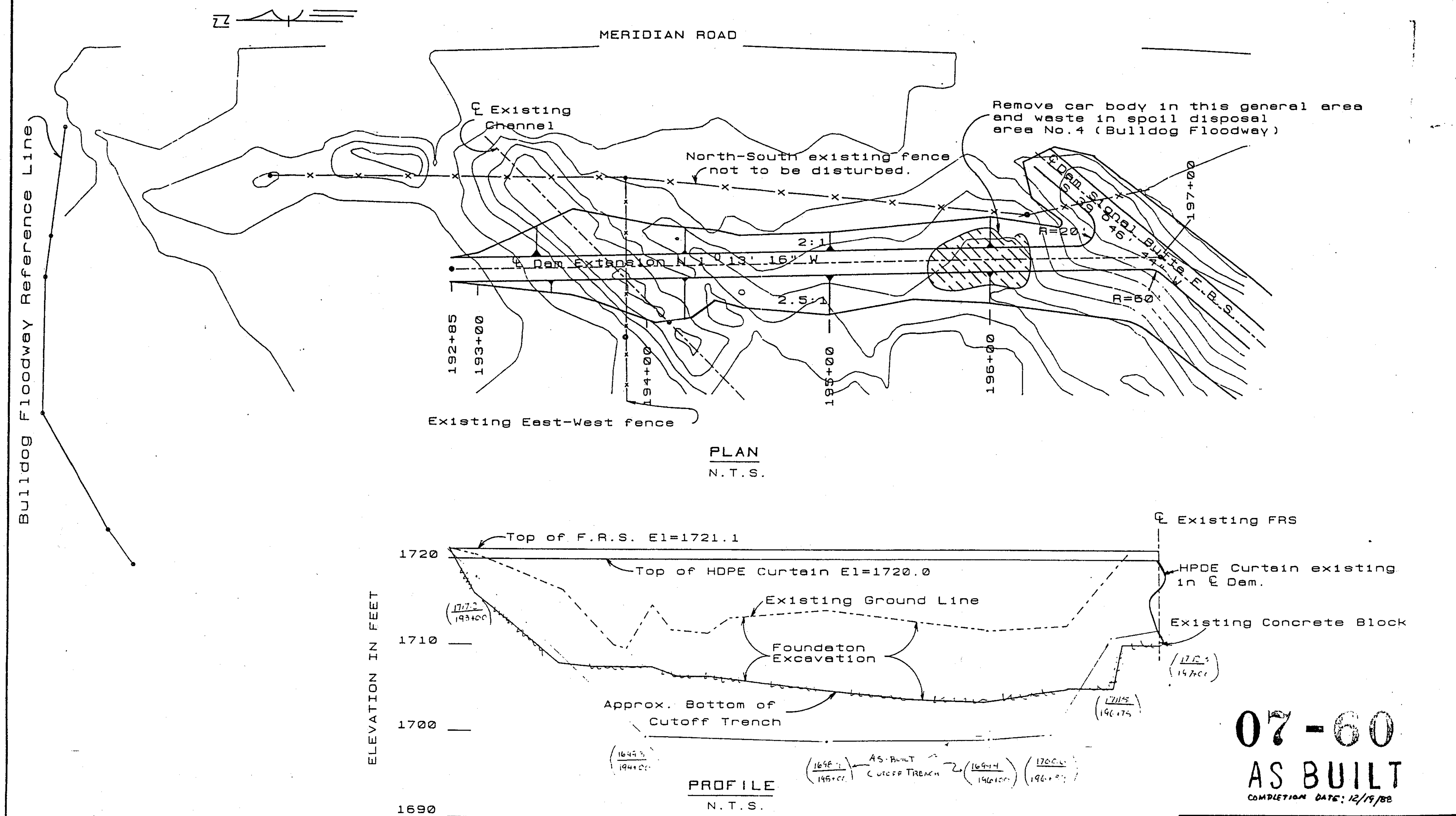
DETAIL B 20/20
(not to scale)

AS BUILT
Completed 1-13-87

EMERGENCY SPILLWAY
PROFILE & UNIT INDEX
SIGNAL BUTTE F.R.S.
BUCKHORN-MESA W.P.P.
MARICOPA COUNTY, ARIZONA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

	Date	
Designed SM	11-83	Approved by
Drawn RAP	11-83	Title
Traced		Title
Checked WEP	2-84	Sheet 20 of 72 — Drawing No. 83010-AZ-CH



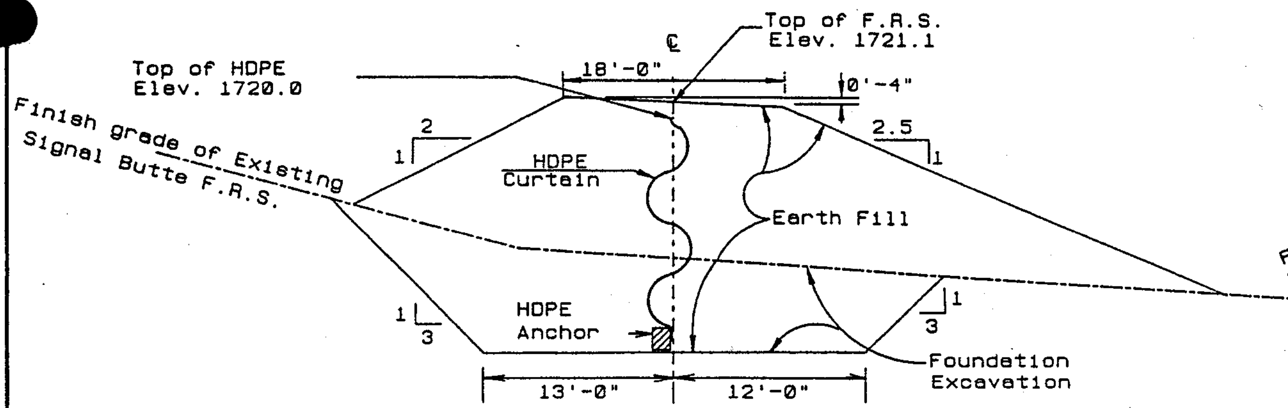
07-60
AS BUILT
COMPLETION DATE: 12/15/88

SIGNAL BUTTE F.R.S. EXTENSION
PLAN & PROFILE
Buckhorn-Mesa W.P.P.
Pinal County, Arizona

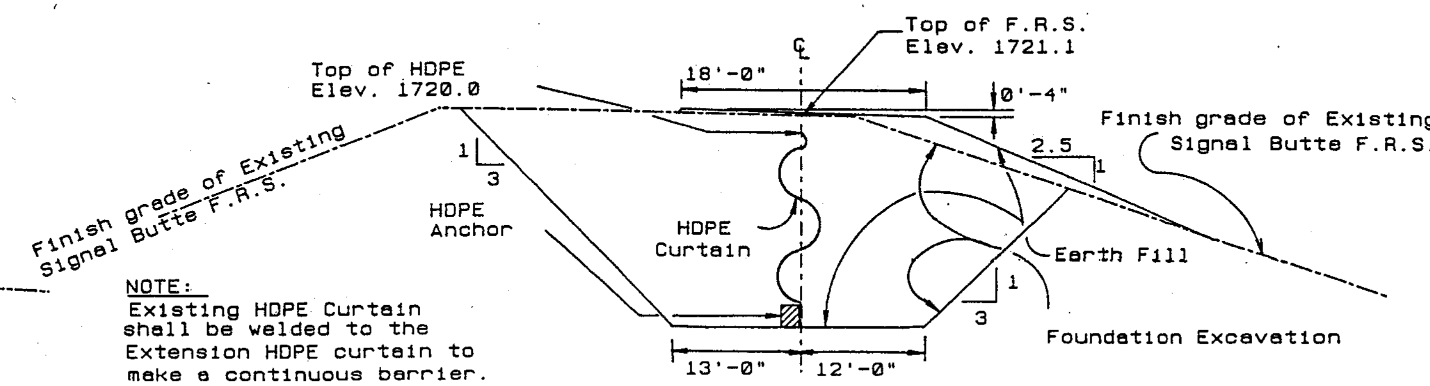
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

		Date	
Designed	T.S.J.	6/87	Approved By
Drawn	R.H.C.	6/87	Title
Traced	A.D.M.	12/87	Title
Sheet 60 A			Drawing No.

48



STA 196+26 to 196+90
(N.T.S.)

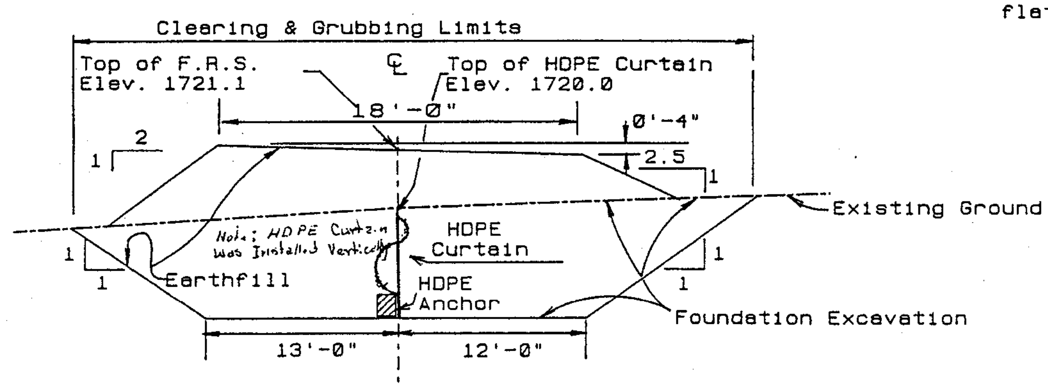


NOTE:
Existing HDPE Curtain shall be welded to the Extension HDPE curtain to make a continuous barrier.

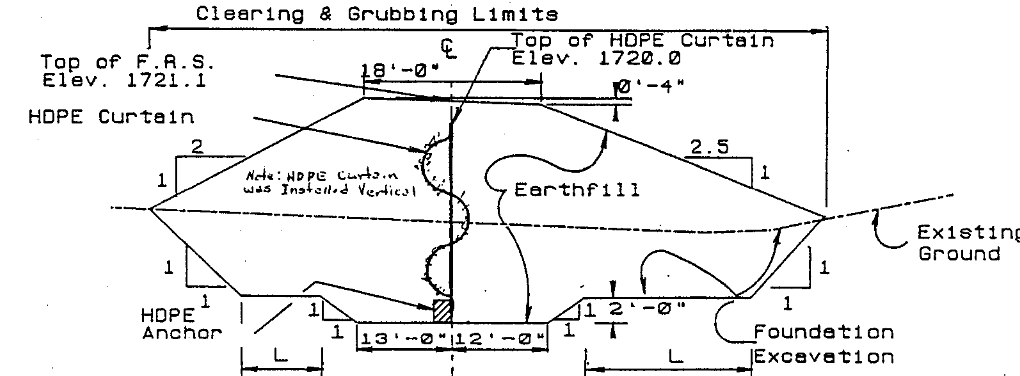
STA 196+90 to 197+00
(N.T.S.)

TYPICAL SECTIONS INSIDE EXISTING EMBANKMENT

NOTE:
Install HDPE curtain as vertical as conditions permit, no flatter then 1.75:1 at any location.



STA 192+85 to 193+53
(N.T.S.)

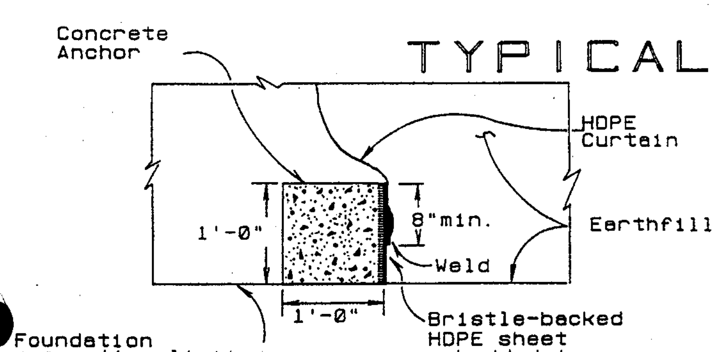


NOTE:
1. "L" will vary such that the foundation excavation limit matches the toe of the earthfill embankment. The bench 2' above the approved cutoff level may be eliminated where the foundation excavation falls outside the toe of the embankment.

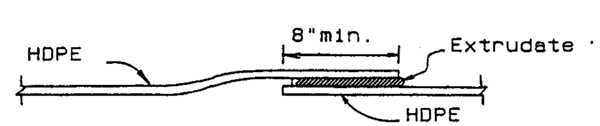
STA 193+53 to STA 196+26
(N.T.S.)

07-60
AS BUILT
COMPLETION DATE: 12/19/88

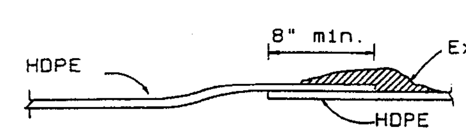
TYPICAL SECTIONS OUTSIDE EXISTING EMBANKMENT



ANCHOR BLOCK DETAIL



TYPICAL LAP WELD SHEET JOINT



TYPICAL FILLET WELD SHEET JOINT

SIGNAL BUTTE F.R.S. EXTENSION
CROSS SECTIONS
Buckhorn-Mesa W.P.P.
Pinal County, Arizona

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

		Date	
Designed	T.S.J.	6/87	Approved By
Drawn	A.D.M.	12/87	Title
Traced			Title
Checked	D.E.P.	12/87	Sheet No. 60 of / Drawing No.

45

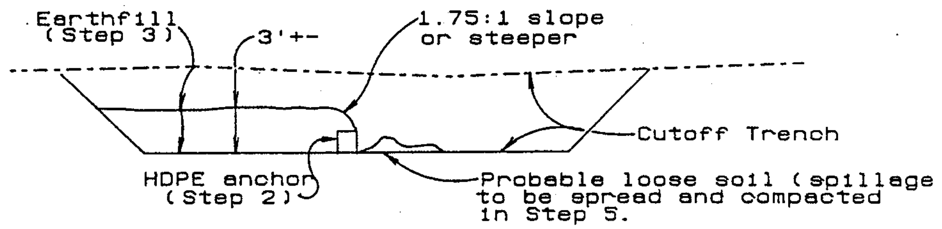
SB Sheet 12

1. Excavate cutoff trench.
2. Form concrete anchor for HDPE.

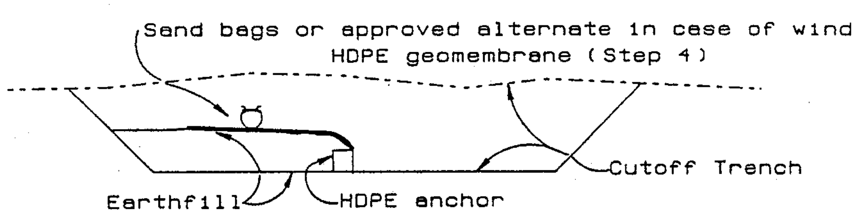
The "form" may be a trench in the caliche or formed on the surface of the cutoff trench excavation. The diffculty of trenching varies with particle size and amount of natural cementation.

Polygrip filaments will not bond well without vibration of the concrete next to the filaments. If another bondiing method is used,it must be an industry standard (water tight) or a demonstration of bond shall be required.

3. Begin placement of Earthfill on upstream side of concrete anchor. Complete fill to an approximate depth of 3'-0". The depth of lift will vary with irregular depth of the cutoff trench. Slope the Earthfill adjacent to the HDPE anchor no flatter than 1.75:1. The slope will be determined by the stability of the freshly-placed earthfill and the Contractor's procedures, as approved by the Engineer.

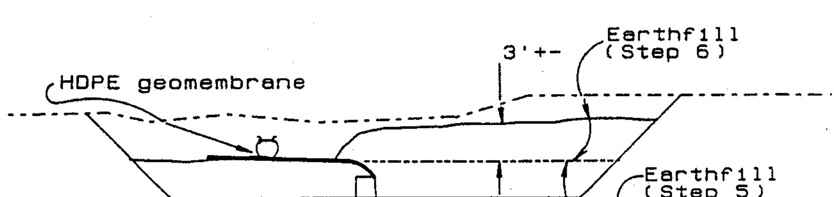


4. Weld strip of HDPE geomembrane to polygrip (or equal) on concrete anchor and lay the HDPE on the Earthfill constructed in step 3. The width of HDPE laid will vary with manufacturer and contractor's operation. An approximate width of 10 feet is used for example. This width, 500 feet long, would weigh about 2450#.

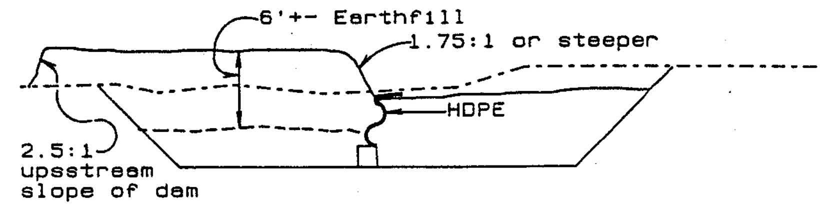


5. Place Earthfill on downstream side of HDPE anchor and on top of HDPE geomembrane until even with elevation of the first lift (Step 3).

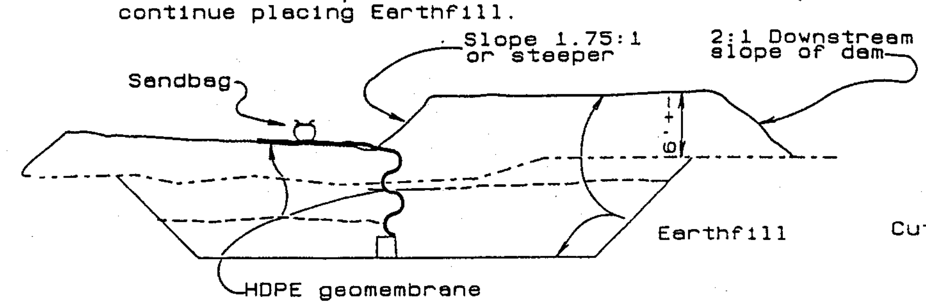
6. Continue placing Earthfill to an additional depth of 3 feet+- with an upstream slope no flatter than 1.75:1.



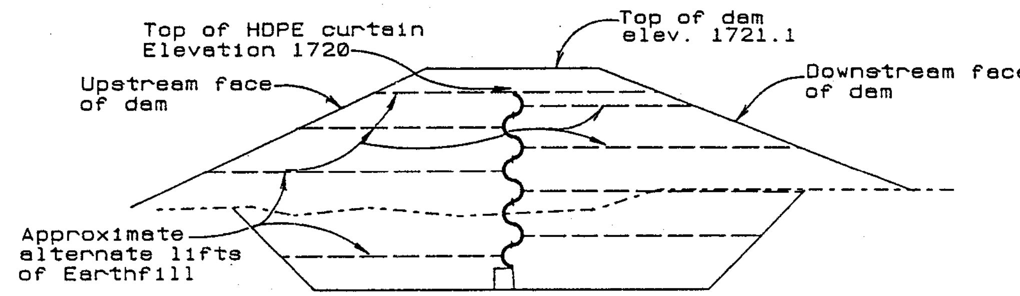
7. Lay HDPE geomembrane on new slope and place Earthfill on upstream side.



8. Weld next width of HDPE geomembrane on to first and lay it on finished Earthfill (Step 4) continue placing Earthfill.



9. Continue alternatng lifts and welds until Elevaton 1720 is reached. Place Earthfill over top of HDPE curtain to final design elevation.

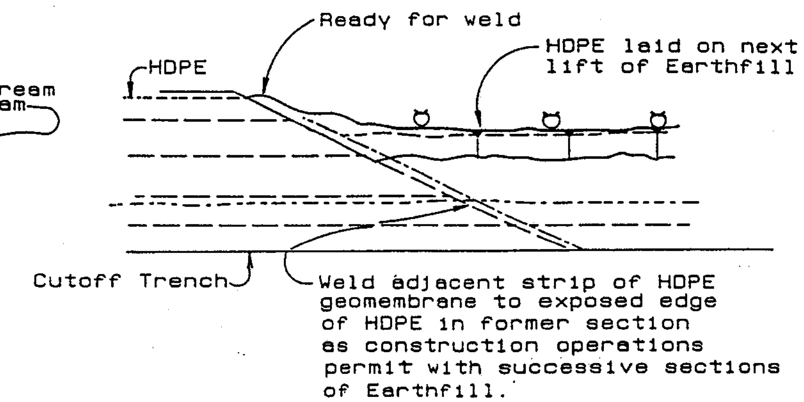


10. The length of dam to be constructed at one time may very. Welds may be constructed at any angle within the plane of the geomembrane. The material shall not at any time be folded back on itself so that a crease is pressed. This condition will cause a split or weakness in the material.

Patches and seams will be permitted at any reasonable location or angle necessary to complete the work. All tears and visible punctures will be patched in a manner approved by the manufacturer.

Any part of the HDPE geomembrane that is driven over shall be inspected for damage and repaired or replaced as determined by the Engineer. This may require excavation if the Contractor's operation has caused the geomembrane to be covered, such as for an equipment crossing.

11. The following intersection of completed embankment with section under construction is suggested:



PROFILE ALONG ℄ DAM

(Note: HDPE Curtain Was Installed Vertical By Hanging It On Square Steel Posts)

07-60

AS BUILT

COMPLETION DATE: 12/19/88

SIGNAL BUTTE F.R.S. EXTENSION	
HDPE CURTAIN INSTALLATION	
Buckhorn-Mesa W.P.P.	
Pinal County, Arizona	
U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE	
Designed D.E.P. S.M.L. Date 12/87	Approved By
Drawn A.D.M. 12/87	Title
Traced	Title
Checked	Sheet No. 60 D / Drawing No.

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART III SIGNAL BUTTE FRS

<u>Section 3.0 Field Examination</u>

Section 3.0 Field Examination

3.1 Purpose

The purpose of the field examination is to provide a systematic visual field technical investigation in which the structural stability and operational adequacy of the FRS project features are analyzed and evaluated to determine if deficiencies exist at the FRS and associated project features. The examination was conducted by walking the length of the structure and visually examining the crest, upstream and downstream slopes, upstream and downstream toes, and appurtenant structures. Comments are recorded on an inspection log and photographs taken of pertinent observations. Cracks, holes, and burrows were probed with a hand-held 3-foot stainless steel metal rod to examine depth, extent, and resistance to probing. No other intrusive/internal examination method was used during this examination.

The field examination of the structure is accomplished to provide a basis for timely initiation of corrective measures to be taken where necessary. This examination was conducted on July 10 and 11, 2000 by the following technical examination team:

3.2 Technical Examination Team

Robert Eichinger, P.E.	Project Manager, Kimley-Horn and Associates
John Sikora, P.E.	Dam Safety Engineer, URS Corp.
Ken Euge, P.G.	Principal Geologist, Geological Consultants
Diana Davisson, EIT	Civil Analyst, Kimley-Horn and Associates

<u>Other Participants:</u>

Tom Renckly, P.E.	Project Manager, Civil Engineer, Flood Control District of Maricopa County

3.3 Project Summary

Inspection Frequency
Signal Butte FRS is inspected on an annual basis jointly by the Flood Control District and the Arizona Department of Water Resources. The next joint District/ADWR inspection is scheduled for December 2001.

Maximum Water Surface Elevations
The District maintains a historic log of maximum water surface elevations for Signal Butte FRS. The maximum recorded impoundment for Signal Butte reservoir is 166 acre-feet with a stage of 13.7 feet at the FRS (January 11, 1993).

Spillway Erodibility
Based on District records, there has been no recorded emergency spillway flows at Signal Butte FRS. The spillway is a reinforced concrete baffle block chute structure.

Distress Observations Corrected or Operation and Maintenance Conducted Since Last Inspection
Embankment slope erosion repair is an on-going O&M item.

Past Distress Observations Not Yet Corrected
Noted past erosion on the upstream and downstream slope. This is an on-going maintenance issue.

Flood Control District Operation and Maintenance Responsibilities
The District is responsible for total operation and maintenance of Signal Butte FRS and associated appurtenances.

3.4 Field Examination Results Summary

Embankment
The crest of the FRS is gravel plated. Most crest settlement monuments were found. Station markers were located. The crest is clear of vegetation. The access gates and fences located off and adjacent to Meridian Road are operational. No longitudinal or transverse cracks were observed. The embankment slopes have intermittent rilling.

Abutments
The left and right abutment terminus contacts appear in satisfactory operational condition. No slides, sign of instability or erosion of the abutment surfaces were observed.

Upstream Slope
The upstream slope shows erosion rills. There are very few animal burrows on the slope face. The upstream toe shows very minor signs of erosion. There was no evidence of seepage, undermining, settlement or sloughing. There is rock mulch protection on the slope.

Downstream Slope
Animal burrows are evident on this slope face. These burrows range from small reptile burrows (lizards) to ground squirrel activity. The slope has a medium density of small shrubs and grasses. There are erosion rills on the face of the downstream slope. There was no evidence of seepage, undermining, settlement or sloughing.

Principal Spillway
The approach channel was clear of debris and obstructions. The reservoir pool has a medium density stand of mesquite, acacias, and palo verdes.

The exterior of the inlet structure was clean. The inlet is a "T" shaped riser typical of NRCS designs. The concrete for the inlet structure showed no signs of structural distress. The trash rack was clear of debris and obstructions. The interior of the conduit was inspected visually by shining sunlight reflected from a hand mirror from the outlet end. The walls of the conduit appeared clean and there were no apparent signs of seepage.

The discharge outlet of the principal spillway was clear of debris. The joints of the outlet structure were straight and tight. The outlet channel was clear of debris. The outlet structure is a standard impact basin typical of Bureau of Reclamation designs for energy dissipators used on the outlets of culverts.

Low-level Outlet Station 229+00

The inlet of the low-level outlet at Station 229+00 appeared clear of debris and sediment. The trash rack was clear of debris. The gate was not operated during this inspection. The outlet of the low-level outlet was clear of debris.

Emergency Spillway
The emergency spillway is located at Station 204+29 and downstation from the left abutment. The FRS emergency spillway is a reinforced concrete baffle block chute spillway structure. The approach channel to the spillway was clear of debris and obstructions. The control sill appeared in satisfactory condition. The emergency spillway is a reinforced concrete baffle block structure. At the upstream side where the wingwall meets the side wall there is a repaired 1/2-inch gap at the top of the joint while the base of the joint looks tight. There are minor vertical cracks on the walls of the spillway channel. These cracks are most likely shrinkage cracks that occur during curing of the concrete. The spillway was constructed with a riprap stilling basin downstream of the baffle blocks. The stilling basin was clear of debris and vegetation.

Instrumentation
Signal Butte FRS has a series of settlement monuments. The "A"-series are located every 500-feet along the downstream crest of the structure. The "B"-series are located approximately every 500-feet along the downstream toe of the dam in combination with the corresponding "A"-series monuments. The "B"-series monuments are offset from the downstream toe. Not all monuments from the "A" or "B" series were located during the inspection. Monuments not readily located are most likely buried in shallow embankment fill.

A staff gauge located on the upstream slope at the principal spillway is used to indicate the level of water impounded in the reservoir. A pressure transducer is located at the inlet structure of the principal spillway. The transducer works in combination with a flood warning telemetry system, which allows signals to be sent to a centralized receiver at the District indicating water levels at the reservoir.

3.5 Conclusions

The overall conclusion of the field examination is that the FRS and appurtenant structures are in satisfactory operational condition.

3.6 Recommendations

The following is a list of recommended corrective actions resulting from this field examination:

a. Continuing observation should be made of the above mentioned items (erosion of slopes).
b. Station posts need to have signs on both sides of post facing both directions of travel.
c. Monitor and repair when necessary erosion gullies on the upstream and downstream face.
d. Video and photograph log the interior of the principal spillway conduit.
e. Monitor for transverse and longitudinal cracks. Establish crack monitoring program.

3.7 Future Inspections

The next annual inspection by FCD is scheduled for December 2001.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
EMBANKMENT DAM INSPECTION REPORT

Each item of the checklist should be completed. Repair is required when obvious problems are observed. Monitoring is recommended if there is a potential for a problem to occur in the future. Investigation is necessary if the reason for the observed problem is not obvious.

Brief description should be made of any noted irregularities, needed maintenance, or problems. Abbreviations and short descriptions are recommended. Additional sheet(s) may be used for any items not listed and additional comments.

DAM NO.: **07.60**	DAM NAME: **SIGNAL BUTTE FRS**	TYPE: EARTH EMBANK
CONTACTS: Tom Renckly FCD		REPORT DATE: August 15, 2000
INSPECTED BY: Bob Eichinger-KHA, Ken Euge-Geological Consultants, John Sikora-URS Corp		INSPECTION DATE: July 10, 2000
REVIEWED BY: Doug Plasencia, KHA	DATE: August 16, 2000	PAGE 1 of _6_
STORAGE LEVEL: Reservoir Empty	TOTAL FREEBOARD: 8.6 ft.	PHOTOS? YES

Item	Comments	NOT APPLIC.	NO	YES	MONITOR	REPAIR	INVESTIGATE
1. CREST	**18 ft. wide**						
a. Settlements, slides, depressions?			X				
b. Misalignment?			X				
c. Longitudinal/Transverse cracking?			X				
d. Animal burrows?			X				
e. Adverse Vegetation?			X				
f. Erosion?			X				
2. UPSTREAM SLOPE	**2.5.:1**						
a. Erosion?	**Minor rills throughout.**			X	X		
b. Inadequate ground cover?			X				
c. Adverse vegetation?			X				
d. Longitudinal/Transverse cracking?			X				
e. Inadequate riprap?	**Place stone mulch to assist in erosion protection.**			X			X
f. Stone deterioration?		X					
g. Settlements, slides, depressions, bulges?			X				
h. Animal burrows?	**Minor burrows scattered intermittently.**			X	X		
3. DOWNSTREAM SLOPE 2:1							
a. Erosion?	**Minor rills throughout.**			X	X		
b. Inadequate ground cover?			X				
c. Adverse vegetation?			X				
d. Longitudinal/Transverse cracking?			X				
e. Inadequate riprap?			X				
f. Settlements, slides, depressions, bulges?			X				
g. Soft spots or boggy areas?			X				
h. Movement at or beyond toe?			X				
j. Animal burrows?	**Minor burrows scattered intermittently.**			X	X		
4. DRAINAGE-SEEPAGE CONTROL	**Longitudinal HDPE curtain – crest to foundation.**						
a. Internal drains flowing?	**Reservoir empty.**		X				
b. Boils at or beyond toe?	**Reservoir empty.**		X				
c. Seepage at or beyond toe?	**Reservoir empty.**		X				

Item	Comments	N/A	NO	YES	MON	REP	INV
d. Does seepage contain fines?		X					
5. ABUTMENT CONTACTS							
a. Erosion?			X				
b. Differential movement?			X				
c. Cracks?			X				
d. Settlements, slides, depressions, bulges?			X				
e. Seepage?	**Reservoir empty.**		X				
f. Animal burrows?			X				
6. OUTLET WORKS-APPROACH CHANNEL	Unlined.						
a. Eroding or backcutting?			X				
b. Sloughing?			X				
c. Restricted by vegetation?			X				
d. Obstructed with debris?			X				
e. Silted in?			X				
7. OUTLET WORKS-INLET STRUCTURE							
a. Seepage into structure?	**Reservoir empty.**		X				
b. Debris or obstructions?			X				
c. If concrete, do surfaces show:							
1. Spalling or Scaling?			X				
2. Cracking?			X				
3. Erosion?			X				
4. Exposed reinforcement?			X				
d. If metal, do surfaces show:							
1. Corrosion?			X				
2. Protective coating deficient?			X				
3. Misalignment or spilt seams?			X				
e. Do the joints show:							
1. Displacement or offset?			X				
2. Loss of joint material?			X				
3. Leakage?	**Reservoir empty.**		X				
f. Are the trash racks:							
1. Broken or bent?			X				
2. Corroded or rusted?			X				
3. Obstructed?			X				
g. Sluice/Drain gates:	**Grates on vegetative outlet at Sta. 229+50.**						

Item	Comments	N/A	NO	YES	MON	REP	INV
1. Broken or bent?			X				
2. Corroded or rusted?			X				
3. Leaking?	**Reservoir empty.**		X				
4. Not seated properly?			X				
5. Not operational?			X				
6. Not periodically maintained?			X				
7. Date last operated?	**Operated annually.**						
8. OUTLET WORKS-CONDUIT	**Concrete.**						
a. Seepage into conduit?	**Reservoir empty.**		X				
b. Debris present?			X				
c. If concrete, do surfaces show:	**Did not inspect interior.**						
1. Spalling or scaling?			X				X
2. Cracking?			X				X
3. Erosion?			X				X
4. Exposed reinforcement?			X				X
5. Other?	**Recommend video inspection of interior.**		X				X
d. If Metal, do surfaces show:							
1. Corrosion?		X					
2. Protective coating deficient?		X					
3. Misalignment or spilt seams?		X					
e. Do the joints show:							
1. Displacement or offset?			X				X
2. Loss of joint material?			X				X
3. Leakage?	**Reservoir empty.**		X				X
9. OUTLET WORKS-STILLING BASIN/POOL	**Principal spillway only.**						
a. If concrete, do surfaces show:							
1. Spalling or Scaling?	**Minor spalling.**			X	X		
2. Cracking?	**Minor vertical crack.**			X	X		
3. Erosion?			X				
4. Exposed reinforcement?			X				
b. If concrete, do joints show:							
1. Displacement?			X				
2. Loss of joint material?			X				
3. Leakage?	**Reservoir empty.**		X				
c. Do the energy dissipators show:							
1. Signs of deterioration?			X				

Item	Comments	N/A	NO	YES	MON	REP	INV
2. Covered with debris?			X				
3. Signs of inadequacy?			X				
10. OUTLET WORKS-OUTLET CHANNEL	Unlined, Concrete, Riprap or Other						
a. Eroding or backcutting?			X				
b. Sloughing?			X				
c. Obstructed?			X				
d. Poorly riprapped?			X				
e. Tailwater elevation and flow condition:							
11. EMERGENCY SPILLWAY-APPROACH CHANNEL	**Unlined**						
a. Eroding or backcutting?			X				
b. Sloughing?			X				
c. Restricted by vegetation?			X				
d. Obstructed with debris?			X				
e. Silted in?			X				
12. EMERGENCY SPILLWAY-CONTROL STRUCTURE							
a. If concrete, do surfaces show:							
1. Spalling or scaling?			X				
2. Cracking?				X	X		
3. Erosion?			X				
4. Exposed reinforcement?			X				
b. If concrete, do joints show:							
1. Displacement or offset?	**At upstream side where the wing wall meets the side walls there is a repaired ½-inch gap at the top of the joint while the joint is tight at the base.**			X	X		
2. Loss of joint material?							
3. Leakage?	**Reservoir empty.**						
c. If spillway is unlined:							
1. Are slopes eroding?		X					
2. Are slopes sloughing?		X					
3. Is crest eroding?		X					
d. Is weir in poor condition?			X				
e. Where is control structure?	**St. 202+50.**						
13. EMERGENCY SPILLWAY - CHANNEL	**Reinforced concrete baffle block spillway.**						
a. Obstructions or restrictions?			X				
b. If concrete, do surfaces show:							
1. Spalling or scaling?			X				
2. Cracking?	**Minor vertical cracks (shrinkage?).**			X	X		
3. Erosion?			X				

Item	Comments	N/A	NO	YES	MON	REP	INV
4. Exposed reinforcement?			X				
c. If concrete, do joints show:							
1. Displacement or offset?			X				
2. Loss of joint material?			X				
3. Leakage?	**Reservoir empty.**		X				
d. If an unlined channel, does it show:							
1. Erosion?		X					
2. Slopes sloughing?		X					
3. Poorly protected w/ vegetation/riprap?		X					
14. EMERGENCY SPILLWAY-TERMINAL STRUCTURE	**Riprap stilling basin.**						
a. If concrete, do surfaces show:							
1. Spalling or scaling?		X					
2. Cracking?		X					
3. Erosion?		X					
4. Exposed reinforcement?		X					
. If concrete, do joints show:							
1. Displacement or offset?		X					
2. Loss of joint material?		X					
3. Leakage?		X					
c. Do the energy dissipators show:							
1. Signs of deterioration?			X				
2. Covered with debris?			X				
3. Signs of inadequacy?			X				
15. EMERGENCY SPILLWAY - OUTLET CHANNEL	**Unlined.**						
a. Eroding or backcutting?			X				
b. Sloughing?			X				
c. Obstructed or restricted?			X				
16. RESERVOIR	**Did not walk reservoir perimeter or pool area.**						
a. High water marks?			X				
b. Erosion/Slides into pool area?			X				
c. Sediment accumulation/Vegetation growth?			X				
d. Floating debris present?			X				
e. Depressions, sinkholes or vortices?			X				
f. Low ridges/saddles allowing overflow?			X				
g. Structures below dam crest elevation?		X					
17. INSTRUMENTATION							

Item	Comments	N/A	NO	YES	MON	REP	INV
a. List type(s) of instrumentation: Staff gages, ALERT gage-water pressure transducer, settlement monuments, station markers at downstream edge of crest of dam							
b. In poor condition?			X				
c. Not read or analyzed regularly?			X				
d. Is data available?				X			
18. CONDITION SUMMARY / LICENSE / EAP / NEXT INSPECTION							
a. Dam condition: **No Safety Deficiencies**							
b. Safe storage Level: **Permanent storage is restricted to elevation 1701 ft. principal spillway elevation. Temporary storage above this level.**							
c. List date of current License: **January 9, 1991.**							
d. Should new License be issued?		X					
e. In compliance with License?				X			
f. In compliance with Statute and Rules?				X			
g. In compliance with ADWR/District Actions?				X			
i. List current size; accurate? **Small.**				X			
j. List current downstream hazard; accurate? **High.**				X			
k. Is there a current EAP? If so, list latest revision date:	**An EAP needs to be prepared according to FEMA 64 guidelines.**		X				
l. List normal inspection frequency: **Annual.**							
m. Recommend date for next inspection: **November 2000.**							

Notes/Sketches

Signal Butte FRS

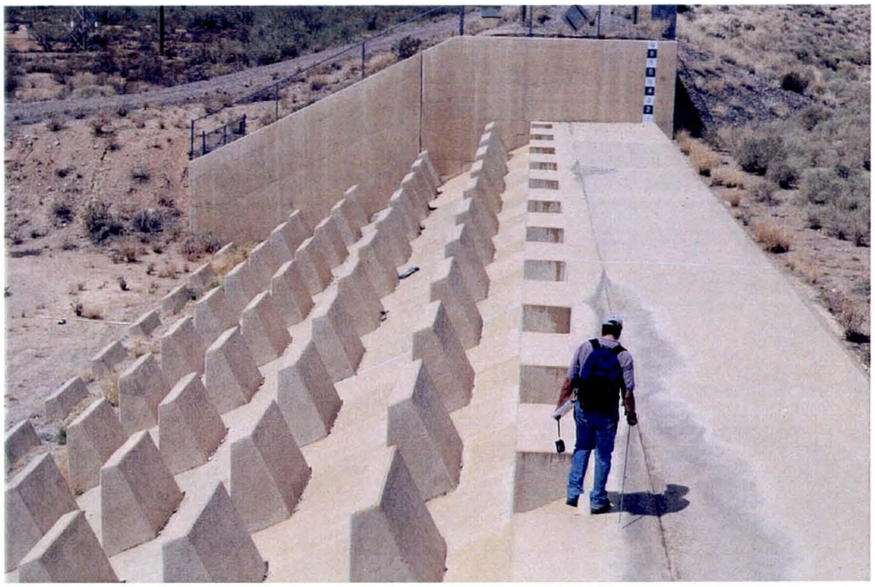
Station	U/S	D/S	Crest	Observation	Detailed Description	Photo	Stake	Inspector
Start 7/10/00 10:30 AM								
194+00		X		Slope vegetation	View of vegetation on DS slope face; slope plated with rock mulch	R2-4		KE
195+00			X	Station Marker				DD
195+00		X		Survey monument	No survey monuments off DS embankment slope			KE
				Sign	Signal Butte FRS and Watershed sign	R2-5		KE
195+00	X			Photo	Photo on left abutment looking right	1285		JHS
195+00---204+29				Gravel Mulch	Crest to toe, start to emergency spillway			RAE
200+00		X	X	Station Marker & Settlement Monument	Crest: A-1 Settlement Monument, Toe: B-1 Settlement Monument, & Offset Monument			DD
204+20			X	Observation	Emergency spillway in good shape no deformation in concrete wingwalls. Concrete in good shape no spalling			JHS
204+29				Emergency Spillway	Separation at emergency spillway wall, Probe 18 inches	R1P8		RAE
					Middle of emergency spillway looking downstream	R1P9		RAE
					Middle of emergency spillway looking downstream	R1P10		RAE
					Middle of emergency spillway looking upstream	D4		DD
204+29		X		Emergency Spillway	View of emergency spillway; spillway structure in good condition	R2-6		KE
204+29			X	Photo	Photo taken on crest looking downstream	1286		JHS
204+29			X	Photo	Photo on the left side of the spillway looking right	1287		JHS
204+52		X		Emergency Spillway	Exposure of caliche cemented breccia in ES outlet channel	R2-7		KE
210+00		X	X	Station Marker & Settlement Monument	Crest: A-3 Settlement Monument, Toe: B-3 Settlement Monument, & Offset Monument			RAE
215+00		X	X	Station Marker & Settlement Monument	Crest: A-4 Settlement Monument, Toe: B-4 Settlement Monument, & Offset Monument			DD
216+00	X			Photo	Upstream face looking right	1288		JHS
		X		Vegetation	View of saguaro growing insite lattice powerline structure	R2-8		KE
220+00		X	X	Station Marker & Settlement Monument	Crest: A-5 Settlement Monument, Toe: B-5 Settlement Monument, & Offset Monument			DD
220+00		X		Rock mulch	Rock mulch plating on upper one-quarter of DS slope face w/ minor rills & rodent activity			KE
225+00		X	X	Station Marker & Settlement Monument	Crest: A-6 Settlement Monument, Toe: B-6 Settlement Monument, & Offset Monument			DD
				Gravel Mulch	Crest to midway to toe			RAE
226+50			X	Gravel Mulch	Gravel mulch thinned out from crest to toe, 20 ft wide, possible tire tracks, fence looks new			RAE
227+00		X		Erosion	Tire tracks up DS slope face; loss of rock mulch plating from upper portion of slope	R2-9		KE
229+00	X			Gated (vegetative) outlet	Gaged, trash rack, photo looking downstream of outlet channel	R1P11		RAE
229+00	X			Photo	Photo of the upstream gated outlet	1289		JHS
229+00	X			Observation	15-inch gated outlet in good shape no deflection in wingwalls, concrete in good shape no spalling. Three pipes, air vent, pressure transducer and stem.			JHS
		X		outlet	pipe & wing wall			DD
229+50				ATV ruts	Crest to slope ATV ruts			RAE
230+00		X	X	Station Marker & Settlement Monument	Crest: A-7 Settlement Monument, Toe: B-7 Settlement Monument, & Offset Monument			RAE
230+00		X		Survey monument	Unmarked survey monument offset from embankment toe			KE
235+00		X		Erosion/Borrows	Minor gulleys and rodent activity			KE
235+00		X	X	Station Marker & Settlement Monument	Crest: A-8 Settlement Monument, Toe: B-8 Settlement Monument, & Offset Monument			RAE

Signal Butte FRS

Station	U/S	D/S	Crest	Observation	Detailed Description	Photo	Stake	Inspector
237+50	X			Diversion Structure Steps	Pass Mountain	R1P12		RAE
240+00		X	X	Station Marker & Settlement Monument	Crest: A-9 Settlement Monument, Toe: B-9 Settlement Monument, & Offset Monument			DD
240+00		X		Erosion/Borrows	Minor gulleys and rodent activity			KE
241+00	X	X		Gravel Mulch	crest to toe			DD
242+00		X		Rock mulch	Rock mulch plating top to toe of DS slope face			KE
242+30		X	X	Station Marker & Settlement Monument	Crest: A-10 Settlement Monument, Toe:No B Monument (disturbed or removed), & Offset Monument			RAE
245+00			X	Station Marker & Settlement Monument	Crest: A-10 Settlement Monument, Toe:No B Monument (disturbed or removed), & Offset Monument			RAE
246+00		X	X	Station Marker & Settlement Monument	Crest: A-11 Settlement Monument, Toe: B-11 Settlement Monument, & Offset Monument			DD
246+00	X	X		Gravel Mulch	Crest to midway to toe			RAE
249+63	X			Principle Spillway	Tower structure, trash rack			RAE
				Outlet Structure	To Signal Butte Floodway			RAE
249+63		X		Principle Spillway	View of principal spillway inlet structure	R2-10		KE
249+63		X		Principle Spillway	View of principal spillway outlet structure and channel	R2-11		KE
249+63		X		Principle Spillway	View of outlet channel and floodway	R2-12		KE
249+63		X		Principle Spillway	View of principal spillway outlet structure and channel	R2-13		KE
249+63		X		Principle Spillway	View looking upstream at principal spillway outlet	R2-14		KE
249+63	X			Photo	Photo of the inlet structure	1290		JHS
249+63	X			Photo	Photo of the inlet structure	1291		JHS
249+63	X			Observation	Inlet structure in good shape, no deformation of concrete walls and no spalling of concrete.			JHS
250+00		X	X	Station Marker & Settlement Monument	Crest: A-12 Settlement Monument, Toe: B-12 Settlement Monument, & Offset Monument			RAE
252+00		X		Rock mulch	Rock mulch plating terminates at this station			KE
255+00		X	X	Station Marker & Settlement Monument	Crest: A-13 Settlement Monument, Toe: B-13 Settlement Monument, & Offset Monument			RAE
255+00		X		Erosion/Borrows	Minor rill erosion and rodent activity			KE
260+00		X	X	Station Marker & Settlement Monument	Crest: A-14 Settlement Monument, Toe: B-14 Settlement Monument, & Offset Monument			RAE
260+50	X	X		Gravel Mulch	Disturbed gravel, ATV tracks			RAE
265+00			X	Station Marker	& Offset Stake			RAE
265+00		X		Survey monument	No survey monuments off DS embankment slope; view to southeast along Signal Butte FRS structure	R2-15		KE
END								
	Inspector Initials							
	RAE		Bob Eichinger		Kimley-Horn and Associates			
	DD		Diana Davisson		Kimley-Horn and Associates			
	KE		Ken Euge		Geological Consultants			
	TR		Tom Renckly		Flood Control District			
	JS		John Sikora		URS-Grenier Woodward-Clyde			

Signal Butte FRS. Left abutment looking right Station 195+00 near Signal Butte extension.

Signal Butte FRS. Looking downstream from emergency spillway Station 205+00. Note horse corral and homes.



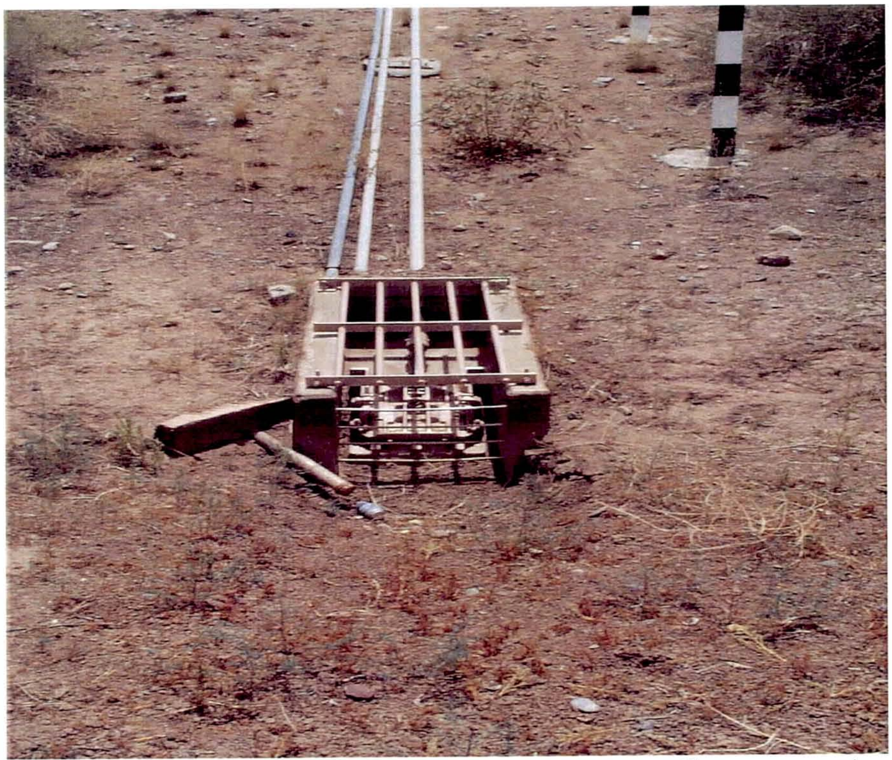
Signal Butte FRS. Emergency Spillway. Baffle block chute spillway with concrete control sill.

Signal Butte FRS. Left wing contact with embankment. Slight separation from embankment on crest.

Signal Butte FRS. Exposure of caliche cemented breccia in emergency spillway channel.

Signal Butte FRS. Station 226+00. Tire tracks up downstream slope. Loss of gravel mulch plating from upper slope.

Signal Butte FRS. Station 237+50. Looking north from crest toward Pass Mountain. Note drop structures from Pass Mountain diversion into Signal Butte reservoir.



Signal Butte FRS. Station 229+00. Low level outlet. Note staff gages, stem, air pipe, and alert conduits.

Signal Butte FRS. Principal Spillway inlet structure. Station 249+63.

Signal Butte FRS. Principal Spillway outlet structure into Signal Butte floodway.

Signal Butte FRS. Principal Spillway outlet structure with energy dissipator.

Signal Butte FRS. Looking downstream from top of crest at Station 249+63 at upstream end of Signal Butte floodway.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
EMBANKMENT DAM INSPECTION CHECKLIST

Each item of the checklist should be completed. Repair is required when obvious problems are observed. Monitoring is recommended if there is a potential for a problem to occur in the future. Investigation is necessary if the reason for the observed problem is not obvious.

Brief description should be made of any noted irregularities, needed maintenance, or problems. Abbreviations and short descriptions are recommended. Additional sheet(s) may be used for any items not listed and additional comments.

			NOT APPLIC.	NO	YES	MONITOR	REPAIR	INVESTIGATE
DAM NO.: **07.60**	DAM NAME: **SIGNAL BUTTE FRS**	TYPE: EARTH EMBANK						
CONTACTS:		REPORT DATE:						
INSPECTED BY:		INSPECTION DATE:						
REVIEWED BY:	DATE:	PAGE 1 of __						
STORAGE LEVEL: ft. Above/below Spillway Crest	TOTAL FREEBOARD:	PHOTOS? YES/NO						
Item	Comments							

Item	NOT APPLIC.	NO	YES	MONITOR	REPAIR	INVESTIGATE
1. CREST						
a. Settlements, slides, depressions?						
b. Misalignment?						
c. Longitudinal/Transverse cracking?						
d. Animal burrows?						
e. Adverse Vegetation?						
f. Erosion?						
2. UPSTREAM SLOPE						
a. Erosion?						
b. Inadequate ground cover?						
c. Adverse vegetation?						
d. Longitudinal/Transverse cracking?						
e. Inadequate riprap?						
f. Stone deterioration?						
g. Settlements, slides, depressions, bulges?						
h. Animal burrows?						
3. DOWNSTREAM SLOPE						
a. Erosion?						
b. Inadequate ground cover?						
c. Adverse vegetation?						
d. Longitudinal/Transverse cracking?						
e. Inadequate riprap?						
f. Settlements, slides, depressions, bulges?						
g. Soft spots or boggy areas?						
h. Movement at or beyond toe?						
j. Animal burrows?						
4. DRAINAGE-SEEPAGE CONTROL						
a. Internal drains flowing? Est. Left ___ gpm; Est. Right ___ gpm						
b. Boils at or beyond toe?						
c. Seepage at or beyond toe? Estimated ___ gpm						

Item	Comments	N/A	NO	YES	MON	REP	INV
d. Does seepage contain fines?							
5. ABUTMENT CONTACTS							
a. Erosion?							
b. Differential movement?							
c. Cracks?							
d. Settlements, slides, depressions, bulges?							
e. Seepage? Est. Left __ gpm; Est. Right __ gpm							
f. Animal burrows?							
6. OUTLET WORKS-APPROACH CHANNEL Unlined, Concrete, Riprap, or Other?							
a. Eroding or backcutting?							
b. Sloughing?							
c. Restricted by vegetation?							
d. Obstructed with debris?							
e. Silted in?							
7. OUTLET WORKS-INLET STRUCTURE							
a. Seepage into structure?							
b. Debris or obstructions?							
c. If concrete, do surfaces show:							
1. Spalling or Scaling?							
2. Cracking?							
3. Erosion?							
4. Exposed reinforcement?							
d. If metal, do surfaces show:							
1. Corrosion?							
2. Protective coating deficient?							
3. Misalignment or spilt seams?							
e. Do the joints show:							
1. Displacement or offset?							
2. Loss of joint material?							
3. Leakage?							
f. Are the trash racks:							
1. Broken or bent?							
2. Corroded or rusted?							
3. Obstructed?							
g. Sluice/Drain gates:							
1. Broken or bent?							

INSPECTED BY: | DATE:

Item	Comments	N/A	NO	YES	MON	REP	INV
2. Corroded or rusted?							
3. Leaking?							
4. Not seated properly?							
5. Not operational?							
6. Not periodically maintained?							
7. Date last operated?							
8. OUTLET WORKS-CONDUIT Concrete, Metal, or Plastic							
a. Seepage into conduit?							
b. Debris present?							
c. If concrete, do surfaces show:							
1. Spalling or scaling?							
2. Cracking?							
3. Erosion?							
4. Exposed reinforcement?							
5. Other?							
. If Metal, do surfaces show:							
1. Corrosion?							
2. Protective coating deficient?							
3. Misalignment or spilt seams?							
e. Do the joints show:							
1. Displacement or offset?							
2. Loss of joint material?							
3. Leakage?							
9. OUTLET WORKS-STILLING BASIN/POOL							
a. If concrete, do surfaces show:							
1. Spalling or Scaling?							
2. Cracking?							
3. Erosion?							
4. Exposed reinforcement?							
b. If concrete, do joints show:							
1. Displacement?							
2. Loss of joint material?							
3. Leakage?							
c. Do the energy dissipators show:							
1. Signs of deterioration?							
2. Covered with debris?							

EMB. DAM INSP. CHECKLIST	PAGE 4 of	DAM NO.: **07.60**						
INSPECTED BY:		DATE:						
Item	Comments		N/A	NO	YES	MON	REP	INV
3. Signs of inadequacy?								
10. OUTLET WORKS-OUTLET CHANNEL Unlined, Concrete, Riprap or Other								
a. Eroding or backcutting?								
b. Sloughing?								
c. Obstructed?								
d. Poorly riprapped?								
e. Tailwater elevation and flow condition:								
11. EMERGENCY SPILLWAY-APPROACH CHANNEL Unlined, Concrete, Riprap or Other								
a. Eroding or backcutting?								
b. Sloughing?								
c. Restricted by vegetation?								
d. Obstructed with debris?								
e. Silted in?								
12. EMERGENCY SPILLWAY-CONTROL STRUCTURE								
a. If concrete, do surfaces show:								
1. Spalling or scaling?								
2. Cracking?								
3. Erosion?								
4. Exposed reinforcement?								
b. If concrete, do joints show:								
1. Displacement or offset?								
2. Loss of joint material?								
3. Leakage?								
c. If spillway is unlined:								
1. Are slopes eroding?								
2. Are slopes sloughing?								
3. Is crest eroding?								
d. Is weir in poor condition?								
e. Where is control structure?								
13. EMERGENCY SPILLWAY - CHANNEL Unlined, Concrete, Riprap or Other								
a. Obstructions or restrictions?								
b. If concrete, do surfaces show:								
1. Spalling or scaling?								
2. Cracking?								
3. Erosion?								
4. Exposed reinforcement?								

Item	Comments	N/A	NO	YES	MON	REP	INV
c. If concrete, do joints show:							
1. Displacement or offset?							
2. Loss of joint material?							
3. Leakage?							
d. If an unlined channel, does it show:							
1. Erosion?							
2. Slopes sloughing?							
3. Poorly protected w/ vegetation/riprap?							
14. EMERGENCY SPILLWAY-TERMINAL STRUCTURE							
a. If concrete, do surfaces show:							
1. Spalling or scaling?							
2. Cracking?							
3. Erosion?							
4. Exposed reinforcement?							
b. If concrete, do joints show:							
1. Displacement or offset?							
2. Loss of joint material?							
3. Leakage?							
c. Do the energy dissipators show:							
1. Signs of deteriation?							
2. Covered with debris?							
3. Signs of inadequacy?							
15. EMERGENCY SPILLWAY - OUTLET CHANNEL	Unlined, Concrete, Riprap or Other?						
a. Eroding or backcutting?							
b. Sloughing?							
c. Obstructed or restricted?							
16. RESERVOIR							
a. High water marks?							
b. Erosion/Slides into pool area?							
c. Sediment accumulation/Vegetation growth?							
d. Floating debris present?							
e. Depressions, sinkholes or vortices?							
f. Low ridges/saddles allowing overflow?							
g. Structures below dam crest elevation?							
17. INSTRUMENTATION							

a. List type(s) of instrumentation: Staff gages, ALERT gage-water pressure transducer, settlement monuments, station markers at downstream edge of crest of

EMB. DAM INSP. CHECKLIST	PAGE 6 of	DAM NO.: **07.60**						
INSPECTED BY:		DATE:						
Item	Comments		N / A	N O	Y E S	M O N	R E P	I N V

dam						
b. In poor condition?						
c. Not read or analyzed regularly?						
d. Is data available?						
18. CONDITION SUMMARY / LICENSE / EAP / NEXT INSPECTION						
a. Dam condition: Unsafe Nonemergency / Safety Deficiencies / No Safety Deficiencies						
b. Safe storage Level:						
c. List date of current License: June 22, 1993						
d. Should new License be issued?						
e. In compliance with License?						
f. In compliance with Statute and Rules?						
g. In compliance with ADWR/District Actions?						
i. List current size; accurate? Medium						
j. List current ds hazard; accurate? Significant						
k. Is there a current EAP? If so, list latest revision date:						
l. List normal inspection frequency: Triennial						
m. Recommend date for next inspection:						

Notes/Sketchs

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART III SIGNAL BUTTE FRS

Section 4.0 Recommendations for Further Actions/Investigations

Section 4.0 Recommendations for Further Actions/Investigations

This Section of Part III provides recommendations for further actions, work plans, and recommended investigations to be accomplished to remediate, repair, or modify, if necessary and required, the dam embankment, reservoir, and/or appurtenant structures. These recommendations are based on the technical review of historic documents (designs, reports, construction plans, as-builts, specifications, etc), review and evaluation of District procedures regarding operation and maintenance and inspection of dams, and from the field examinations of the structures. Structure specific recommendations and work plans are developed for each of the Work Assignment No. 3 dams as well as general operation and maintenance recommendations. The recommendations are in response to District and ADWR concerns and questions on methods and procedures to monitor, investigate, evaluate, repair, or modify a structure showing signs of distress or evaluate previous dam repairs or modifications.

4.1 Detailed Dam Safety Inspections – A procedure for detailed dam safety inspections was provided in the companion report "Policy & Program Report". The report provided in Appendix H detailed inspection guidelines, inspection checklists, and an inspection equipment checklist.

4.2 Phase II Engineering and Geotechnical Investigations – Phase II engineering and geotechnical investigations for the Signal Butte FRS should include the following:

Risk Assessment - A risk assessment of Signal Butte FRS should be conducted. It is recommended that the initial level for the risk assessment be conducted to evaluate the failure modes and effects analysis. Failure modes will need to be identified for Signal Butte FRS and may consist of failures due to transverse cracks, piping, or changes in upstream hydrology. Failure modes and effects analysis should be conducted through the use of an outside facilitator.

Geotechnical -Although the SCS has conducted a slope stability analysis for the Signal Butte FRS, it is recommended that a slope stability analysis of the exiting dam embankment under various loading conditions be conducted. KHA provides this recommendation because the original analysis is dated as being conducted in 1984, approximately, and that there was limited back-up documentation to review the previous analysis. The stability analysis can be conducted using UTEXAS3. The results of the study will provide factors of safety for the embankment given the loading conditions anticipated and can be compared against ADWR rules and factors of safety for embankment dams.

No evaluation of settlement or foundation collapse potential was conducted as part of the Signal Butte FRS design investigation. It is recommended that an assessment be made of existing geotechnical data to determine if an adequate database is available to evaluate embankment settlement and collapse potential. The results of this assessment should demonstrate if additional Phase II work is required in this regard.

Hydrology/Hydraulics - It is recommended that the District develop an updated hydrologic model of the Signal Butte FRS watershed to include recent watershed improvements. The updated model should be based on District methodology and the HEC-1 computer program. The rating curve developed by the District in 1997 and the 1993 mapping should be used to develop new outflow discharges from the principal spillway and emergency spillways. The full PMF should be routed through the dam, reservoir, and emergency spillway and examine the impacts of the PMF on freeboard for the dam and spillway. The results should be compared with ADWR dam safety requirements. A consideration as part of this study would be how to handle possible concurrent Bulldog floodway flows from the Apache Junction FRS and watershed upstream from the floodway since the watersheds are adjacent to one another, are of similar hydrologic characteristics, and are hydrologically and hydraulically interconnected.

A future watershed conditions land use hydrologic model should also be prepared and evaluated. This model should incorporate the impacts of the Pinal County drainage criteria on the upstream system elements (Apache Junction FRS). It is recommended that the District review any requests for drainage clearances submitted to Pinal County or the City of Apache Junction that are within the contributing watersheds.

An evaluation of upstream and downstream watershed conditions should be conducted during every other inspection of this structure. The purpose for conducting an examination of the upstream and downstream watershed conditions is to evaluate changes within the watershed such as urbanization which may affect in the inflow design flood (IDF).

Current techniques for calculating the IDF involve using HMR-49 to estimate the Probable Maximum Precipitation (PMP). HMR-49 is generally considered to be conservative, especially for large watersheds over 50 square miles. A recommendation is to conduct a site specific PMP for this watershed prior to reevaluating the hydrology and hydraulics of the dam. A site specific PMP will evaluate storm centering on the watershed and storm distribution. A typical PMF evaluation will assume uniform rainfall and a storm distribution such as the SCS. This design storm approach while it may be valid for small watershed and lower frequency events it may be unrealistic for major storm events on large watersheds.

An Incremental Damage Analysis (IDA) could also be performed on this structure. The purpose of an IDA analysis is to estimate if there would be additional damage to downstream structures if the dam were to fail during a large storm event over no structure in place and a large flood event occurring within the watershed. If the analysis demonstrates that for a lesser flood event than the full PMF there would be an insignificant difference in damage with or without the dam in place, the dam would only have to be upgraded to that ratio of the IDF.

Sediment Yield – An updated sediment yield study should be undertaken to estimate the sediment yield from the upstream watershed. The original methods undertaken by the NCRS for the design of the sediment reservoir were based on USGS topographic mapping with 4-foot contours. With new aerial mapping and updated sediment yield methodologies the results may indicate that there is less sediment contribution to the reservoir that originally designed.

Capacity Analysis - Recent aerial topographic mapping was prepared for the District in 1993. The District conducted a capacity analysis of the Signal Butte FRS in 1997. The results of this study indicate that the dam may have more than 100-year capacity and provides a higher level of flood protection. The dam may have a greater capacity than the design capacity, especially if the 100-year sediment volume is reduced depending upon the above suggested reanalysis. The District should re-survey the elevation of the emergency spillway crest elevation. The benchmark and the results of the survey should be compared against the District study conducted previously in 1997.

The 1993 mapping and the new mapping prepared as part of the Signal Butte ADMS can subsequently be used for future settlement/subsidence surveys, used as base mapping for crack location and monitoring, and used as base sheets for future alterations or modifications of the dam.

Utility Database - A utility database should be prepared. The database would consist of utility records that cross over, under, or through the dam embankment and/or ancillary features (such as the emergency spillway or outlet channels), or within the FCD right-of-way or easements. The database would track as a minimum: the type of utility crossing, location of crossing, skew to centerline of dam, depth of bury, type of encasement, provisions for piping and seepage control, utility owner (name, address, phone, contact person), location of as-built drawings, utility monumentation on dam, and method of construction (trenching, bore and jack).

Operation and Maintenance Plan - An operation and maintenance plan was located for Signal Butte FRS. The plan is minimal and includes discussions regarding inspections and emergency actions. It is recommended that a more complete O&M plan be prepared according to the minimum guidelines provided in the "Policy and Program" report (KHA, April 2000).

Emergency Action Plan - It is recommended that an emergency action plan be prepared according to the minimum guidelines as published by FEMA in their report titled "Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners" (FEMA 64, October 1998). A peacetime disaster plan was prepared for Signal Butte FRS by the Maricopa County Department of Emergency Affairs. However, this plan does not include all the requirements listed in the FEMA 64 guidelines and the ADWR rules for dam safety.

4.3 Crack Monitoring Program

It is recommended that the District monitor the location and size of surface expressed transverse and longitudinal cracks. This effort goes beyond just documenting the observations of cracks in inspection reports. A crack location plan needs to be prepared using the dam construction plans or the previously discussed topographic mapping as a base. It is recommended that the plan be developed in AutoCad or some other electronic plan retrieval system (HIS for example). Observed crack locations can be plotted on the crack plan and coded by type. A database of transverse and longitudinal cracks needs to be prepared. The input to the database includes location of crack (station: location on upstream slope, downstream slope, or crest), width of crack, depth of crack, and any other distinguishing characteristics. A photograph should be taken and labeled for each crack. Follow-up observations and notations can then be compared to previous observations and conclusions drawn regarding crack propagation. The long-term benefit of the crack monitoring plan is to evaluate if particular segments of the embankment are more predominant in showing signs of cracking than other segments. In this fashion the District can evaluate future requirements for rebuilding a particular segment of the dam embankment or other repair methods.

4.4 Operations and Maintenance

Landscaping: Where the safety of the structure is not compromised and effective flood-fighting and maintenance of the structure is not seriously affected, appropriate landscape plantings can be incorporated into the design of dam embankments (Corps of Engineers, "Guideline for Landscape Plant and Vegetation Management at Floodwalls, Levees, and Embankment Dams", January, 2000).

The primary objectives of plantings at dam embankments are to harmonize the development with the surrounding natural and human environment, enhance structures, control dust and slope erosion, provide privacy or screen out undesirable features, provide incidental habitat for wildlife, and create a pleasant environment for recreation. Plantings should be naturalistic and should avoid "arboretum-type" plantings.

Landscape plantings (aside from slope protection for erosion control) for <u>flood control</u> embankment dams should be confined to areas adjacent to the dam embankment. Because of the need for access at the upstream and downstream toe area by maintenance and construction equipment during periods of flooding, a minimum 50-foot vegetation-free zone should be maintained immediately downstream and upstream of the toes of the dam in the floodplain and on the abutments.

One method of establishing landscape plantings on embankment slopes is to provide for overbuilt areas on the dam faces. After establishing the minimum embankment section required to satisfy stability requirements, additional material could be added to the basic section to provide an area to support plantings. Overbuilt areas must include adequate consideration of the internal drainage system for the main structure. In no case should trees be directly planted on embankment slopes or crest.

Overbuilt areas require a root-free zone, which provides a margin of safety between the greatest extent of plant roots and the beginning of the basic structure. The basic structure is the engineered feature required for human safety. The bottom of the root-free zone will be the external limits of the cross section of the embankment established by the engineer for stability and/or seepage control.

Vegetation Management: Vegetation management at an earthen dam takes the form trimming of overgrown vegetation and the clearing of unwanted growth (large shrubs and trees). Trimming is conducted so that inspection of the slopes can be conducted without hindrance from vegetation. Locally, grasses and small shrubs are ideal for embankment dams along with rock mulch for slope protection against erosion. Vegetation should be trimmed on an ongoing basis and not be allowed to grow any higher than two to three feet. Trimming methods are labor intensive, usually involving gas powered weed trimmers or boom mowers.

Removal of dead trees and debris is recommended within the approach channels to principal spillways. This will reduce the chance that the inlet to the principal spillway would become clogged with debris. Typically, District dams have trash racks and/or a multiple-staged or tiered inlet for the principal spillways. In the event debris accumulates at a lower level on the inlet/trash rack, floodwater can still overtop the debris and flow into the principal spillway conduit. This type of inlet structure is recommended for all District dams where debris might be a concern.

Debris blockage of the principal spillway can cause operational constraints on the performance of the spillway to evacuate floodwaters. Depending on the volume of inflow, a blocked principal spillway can become non-functional and cause flow to occur in the emergency spillway for storm events less that the inflow design flood. Several of the District dams have a pedestrian/maintenance bridge that connects to the crest of the dam and the inlet tower of the principal spillway. In the event that the principal spillway becomes clogged during an event, District forces have the capability to remove the debris by standing on the bridge and using rakes or other means to remove debris.

Sediment Management: Sediment markers should be installed within the reservoir impoundment area. The sediment markers will provide the District with an indication of the rate of sediment build-up as well as when sediment removal activities are required.

Generally, District forces remove sediment when sediment build-up becomes apparent at the inlet and outlet structures of the principal spillway. No sediment maintenance has been conducted for the sediment pool. This may be due to the fact that: 1) there is no method to determine the level of sediment buildup in the pool, and 2) sediment build-up has not been a problem.

The District should develop a sediment management plan for District dams. The plan elements would require identification of the equipment, manpower, and for the disposal of removed sediment.

Clean Water Act (CWA)– Section 404: Certain activities relating to excavation-only activities are exempt from Corps jurisdiction under Section 404 of the CWA. However, the Corps' definition of exempt excavation activity is based on 'incidental fallback" and is very restrictive. The generally accepted definition of "incidental fallback" allows only for the spillage of material from the actual excavation device. This prohibits the pushing, windrowing or stockpiling (even temporarily) of material during the excavation activity. Sediment must be lifted (as opposed to pushed) from the site and deposited outside of the jurisdictional boundary to be exempt from Section 404. Sediment cleaning operations conducted with a backhoe or front-end loader (bucket equipment) would likely be exempt, while sediment clearing conducted with a grader or other blade equipment would not be exempt.

Sediment removal activities may also be subject to Section 401 and Section 402 regulations regardless of their Section 404 status. Ground disturbance of greater than 5 acres is subject to authorization under Section 402 of the CWA and Section 401 authorization may be required if the site will have a surface water discharge to jurisdictional areas. The ESA and Migratory Bird Treaty Act regulations may apply to areas of potential inhabitation or suitable habitat particularly if the area is vegetated. .

Flood control structures may result in increased vegetation growth. Structures in ephemeral channels can impound water for short periods after flow events, therefore increasing the hydroperiod of the site. An increase in available moisture can result in increased vegetation density or enhanced vegetation species composition.

In general, the type of vegetation communities created or enhanced by flood control structures will benefit wildlife species associated with riparian habitat or those species requiring a more dense growth of vegetation. Such habitat is rare in most areas of Arizona. Therefore, the vegetation communities have a higher probability for providing habitat for several Endangered Species Act (ESA) listed species. Depending on the type of structure other habitat may be created or enhanced.

The ESA and the Migratory Bird Treaty Act provide protection to listed species and to the species habitat. Removal of this vegetation may be considered a violation of the ESA and/or the Migratory Bird Treaty Act. Restrictions on activity timing and the extent of the activity may be imposed under these regulations.

Further, the removal of the vegetation may require permit authorization under Section 404 of the CWA. The removal of vegetation by mechanized land clearing (grubbing) is not considered an exempt activity under the Clean Water Act. The Corps' believes that the soil clinging to the roots will be dislodged in the process and will fall into other areas thus creating a discharge or fill situation. Removal of vegetation by cutting is not considered a jurisdictional activity. If stump or whole vegetation is removed in such a manner that the stump/stem is lifted from the site (as opposed to pushed across the site) the activity is considered to be exempt from Section 404 jurisdiction.

Vegetation clearing activities may be subject to regulation under Section 402 of the CWA if more than five acres of ground is disturbed and may also be restricted under the ESA adherence clause of the NPDES permit. Vegetation clearing may be subject to Section 401 if the area may discharge to a jurisdictional area or require a Section 404 authorization.

Riprap Placement/Repair: The placement of riprap or other armoring material is a jurisdictional activity under Section 404 and is subject to Corps' approval. In most instances this includes the repair or replacement of previously installed materials (As noted in NWP#3). Riprap activities may be subject to regulation under Section 402 of the CWA if more than five acres of ground or vegetation will be disturbed. Riprap material may also be subject to Section 401 approval.

Recommendations for Section 404 Regulatory Compliance

Clean Water Act.

- Conduct Jurisdictional Determinations on areas subject to periodic maintenance.
- Train Maintenance Workers in the identification of potential CWA Section 404 jurisdictional areas and the restriction of activities within jurisdictional boundaries.
- Conduct an audit of existing facilities to determine which have been previously authorized under Section 404 or other applicable regulation.
- Develop a vegetation management program that monitors and controls growth of vegetation to prevent the establishment of wetlands. (By definition a wetland must be vegetated). Under the proposed regional conditions of the new Nationwide Permit Program impacts to wetlands are not allowed, with certain exemptions for NWP 3 and 31.
- Coordinate with the Corps to develop a standard procedure for sediment removal, which identifies the type of equipment and methodologies that will be exempt from Section 404 jurisdiction based on the incidental fallback rule.
- Develop Best Management Practices (BMPs) and standard procedure for earth disturbance activities associated with maintenance activity to satisfy Section 402.
- Design and permit new facilities to include the appropriate maintenance activity in the original Section 404/401 authorization.
- Establish baseline conditions for existing facilities (Required under Section404 NWP31)
- Coordinate with Corps to determine if a Regional or other General permit for all maintenance activity is appropriate.
- Coordinate with the ADEQ and/or EPA to determine if a Section 401 water quality certification is applicable.

Endangered Species Act/Migratory Bird Treaty Act

- Train Maintenance Workers to identify potential habitat and to be aware of seasonal nesting times.

- Obtain appropriate ESA permit to allow for field survey and possible incidental take of certain listed species.
- Coordinate with USFWS to determine appropriate habitat conditions and survey protocols for areas of potential ESA restrictions.
- Develop a Maintenance Schedule that avoids activity in suitable habitat during the breeding season.
- Coordinate with USFWS regarding the potential development of suitable habitat in or adjacent to flood control structures. This may include the establishment of a pseudo Safe Harbor agreement.
- Design new facilities to provide for enhanced habitat outside of the area of maintenance disturbance. Thus developing long-term enhanced habitat and mitigation areas.

Federally Managed Areas

- Identify responsible Management Agency.
- Determine Management requirements for specific area.
- Conduct necessary NEPA documentation to support a CATEX.
- Include an ongoing Maintenance Plan in required NEPA documentation for new projects.

State and Local Regulations

- Coordinate with SHPO regarding potential historical significance of older facilities and of potential eligibility of areas requiring periodic maintenance.
- Train Maintenance Workers in the identification of vegetation listed in the various Native Plant regulations.
- Develop potential donor sites and acceptable salvage protocol for native vegetation removed from maintenance areas.

4.5 Subsidence and Earth Fissure Monitoring Program

Although the Signal Butte FRS is believed to be outside the limits of active ground subsidence in the East Valley area, conducting a horizontal and position survey of established benchmarks in the area of the FRS should be used to verify this theory. The control benchmark for this survey must be a witnessed, established benchmark in bedrock that has been in place for at least 30 years.

Subsidence due to groundwater withdrawal is not expected to be a problem at the Signal Butte FRS due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment. Signal Butte FRS is located on the Usery Mountain granitic pediment with bedrock at a relatively shallow depth of less than 200 feet beneath the FRS structure.

Earth fissuring at the Signal Butte FRS site and local vicinity has a low degree of probablitity due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment on which the Signal Butte FRS is founded. The nearest ground subsidence-related earth fissure is about two and one-half miles south of the south end of the FRS.

The Signal Butte FRS is located near an area of active ground subsidence and earth fissures. However, due to the presence of shallow granite pediment in the FRS area and the FRS's proximity to the pediment edge, earth fissuring should have minimal impacts on the Signal Butte FRS. Ground subsidence at the FRS is expected to be negligible. However, the Signal Butte FRS should be included in an area-wide monitoring program because of its proximity to the ground subsidence area and known earth fissures.

General guidelines have been prepared and should be implemented if the physical regional characteristics change in the vicinity of the dam. The following presents recommended guidelines for subsidence and earth fissure monitoring.

General Guidelines for Recommended Subsidence and Earth Fissure Monitoring

Many embankment flood control dams under the jurisdiction of the District are located in areas of active ground subsidence and earth fissures. The prognosis for continued ground subsidence and earth fissure development is high for the foreseeable future. Therefore, the assessment of existing and future potential ground subsidence and earth fissures and their impact on the safety of existing District dams is a critical element of the dam safety evaluation process

KHA recommends that the District Subsidence monitoring program outlined by Staedicke (1995) be adopted. It should also be refined and modified or amended where appropriate for application to District dams and to satisfy other regulatory requirements. The following outline incorporates the salient items of the District program and lessons learned by the BuRec, NCRS, and consultants with professional experience dealing with ground subsidence and earth fissures.

Ground subsidence due to groundwater withdrawal from deep aquifers is known to impact alluvium-filled basins in central Arizona including the District. The surface manifestations of ground subsidence include lowering of the ground surface over time and the development of earth fissures (or ground cracks) due to induced tensile stresses within the alluvium-filled basins. The initial activity of the subsidence monitoring program will be an evaluation of known subsidence within the District. This evaluation will be performed to assess current ground subsidence conditions and characterize the earth fissures present. These results will help formulate the general parameters of the monitoring program and the specific details for monitoring at each of the District's embankment dams. Where critical subsidence and each fissure conditions exist that might jeopardize dam safety, the monitoring program results could be used to help develop mitigation measures to reduce potential ground subsidence impacts caused by regional groundwater withdrawal.

The recommended scope of activities to accomplish the subsidence evaluation is separated into three tasks. Task 1 would be directed to an overview assessment of the District using available geological and hydrogeological data and geological interpretation of available aerial photography. Output from Task 1 would be a preliminary map of the District area identifying potential and known subsidence areas and earth fissures. This information would be used to target sites for direct field examination during Task 2. Task 2 would verify the presence of the fissures close to District structures. Task 3 includes the preparation of comprehensive settlement/subsidence and earth fissure monitoring program tailored to each embankment dam structure. The monitoring program would be designed to incorporate trigger mechanisms that would be used when excessive subsidence or earth fissure emergency conditions are identified.

Task 1: Compile Preliminary Subsidence/Earth Fissure Map:

- Research and compile existing earth fissure and ground subsidence data pertaining to the District service area.
- Assess future potential ground subsidence induced by groundwater withdrawal at the site and in the site vicinity. Data to complete this assessment will be obtained from the Arizona Department of Water Resources, U.S. Geological Survey Water Resources Branch and private sector hydrogeological consultants familiar with the area.
- Acquire aerial photographs from available sources, such as Maricopa County, Arizona Department of Transportation, BuRec, NRCS, and private sector companies. Aerial photographic interpretation would be used to identify suspect ground subsidence areas and earth fissures.
- Compile and analyze the data gathered and prepare a preliminary subsidence/earth fissure map of the District area and target areas for the Task 2 field reconnaissance. Use available subsidence monitoring data to estimate past subsidence and calculate future potential ground subsidence estimates.
- Prepare summary report documenting the Task I study findings and conclusions.

Task 2: Subsidence/Earth Fissure Field Reconnaissance

- Conduct a ground-truth field reconnaissance within a 5-mile radius of flood control embankment dams, identified in Task 1, that are in a subsidence area to:

  (1) Verify, or refine, and update the earth fissure and ground subsidence data compiled during Task 1.

(2) Identify and map earth fissures or other related 'suspect' features that may be present and potentially affect District flood control dams.

(3) Determine the rate of earth fissure growth where feasible using Task 2 information and historical aerial photography or other documentation.

- Stake and survey the location of the earth fissures and identify exploration sites.

- Prepare a Task 2 summary report documenting the results of the field reconnaissance.

Task 3: Prepare Preliminary Subsidence and Earth Fissure Monitoring Program

- Locate, relocate, or reestablish settlement/subsidence monitoring monuments on crest and downstream toe of embankment dams. Establish new monuments where deemed necessary. Relocated, reestablished, or new monuments should be constructed in accordance with recognized plans and specifications (NRCS, BuRec, ADOT, District). The number of survey monuments should be determined considering the future potential subsidence in the dam area, the structure hazard classification, and other factors that may be deemed critical based on discussion with District staff.

- Locate, relocate, or reestablish monitoring benchmarks in rock tied to an established survey network such as the National Geodetic Survey. All benchmarks should be thoroughly documented and witnessed.

- Identify and find wells near each embankment dam that can be used to monitor changes in groundwater levels. This information would be used to refine estimates of future potential ground subsidence.

- Verify benchmark survey control and survey the elevation of all monitoring monuments. Using the new survey data, rectify all previously obtained subsidence monitoring data relative to an established survey datum.

- Based on the results of the new survey and the rectifying of past data, develop a resurvey schedule suited to each dam structure. The surveys should be rerun at yearly intervals for two or three years to see if any trends exist. The monitoring intervals could be changed to range from one year to four or five years depending upon trends established or the calculated estimates of future potential subsidence. A suggested monitoring schedule is provided in the following table.

Table 4-1. Recommended Subsidence & Earth Fissure Monitoring Schedule.

Dam Hazard Classification	Monitoring Schedule			
	Ground Subsidence	Earth Fissures		
		≤ ¼ mile	¼ mile < D < 1 mile	1 mile < D < 5 miles
High	Annual	Annual	Annual	Biennial
Significant	Biennial	Annual	Biennial	Biennial
Low	Triennial	Triennial	Triennial	Pentad
Very Low	Pentad	Pentad	Pentad	Pentad

The monitoring schedule should be reevaluated on a triennial basis and revised if deemed necessary.

- Earth fissure monitoring should be conducted concurrently with the subsidence monitoring program. In areas of known active earth fissures, the monitoring intervals may need to be more closely spaced especially where an earth fissure is located within one mile of an District structure. Earth fissure monitoring could be conducted using (1) direct examination on the ground by geologists or geotechnical engineers or (2) low-sun-angle aerial photography. The earth fissure survey should also include measurement of its surface expression (length, width, depth, orientation, differential displacement, evidence of activity or inactivity).

- Surveying of subsidence benchmark and structure monuments should be conducted using currently accepted surveying methods and standards of practice. Survey accuracy standards should be 0.05 feet (or about 2 centimeters).

- Data collected should be recorded in an easily used format such as Microsoft EXCEL. As a minimum, reporting should be done annually. The report should be distributed to other interested parties including BuRec, Corps, USGS, AGS, ADOT, ADWR, County highway departments, and local jurisdictions. Supplemental reports could be necessary where rapidly occurring subsidence is documented or when earth fissure growth or development is observed.

Subsidence Monitoring For Signal Butte FRS

Settlement monuments were established on the embankment crest (A-series) and along the downstream toe (B-series). Some of the monuments have been destroyed or damaged.

The monitoring program should consist of a series of elevation data measurements taken at both the "A"-series and "B"-series monuments located along the Dam. The A-series and B-series monuments are located approximately every 500 feet along the crest and toe of the embankment, respectively. A recent dam safety field investigation revealed that many of these benchmarks have either been removed or destroyed. Additional survey monuments should be installed on the upstream and downstream toe and the upstream and downstream crest of the dam. The District database needs to be updated to store and plot the new settlement data to detect trends or movements.

Once all survey monuments are in place, a survey of the elevation of each point should be conducted in accordance with the recommended schedule for high hazard potential dams. The survey method used should have a vertical accuracy to at least 0.057 feet (2 centimeters). The results of the surveys, over time, would give:

- Subsidence/settlement measurements
- Subsidence/settlement rates (increase/decrease)
- Data on differential subsidence/settlement.

Although ground subsidence and earth fissures are expected to have a negligible impact on the Signal Butte FRS, subsidence data gathered at the Signal Butte FRS should be obtained, compiled, analyzed, and reported (to ADWR) in accordance the general ground subsidence/earth fissure monitoring program guideline.

A summary of the Phase II recommendations is provided in Table 4-2 on the following page.

Table 4-2. Summary of Recommendations for Signal Butte FRS.

Recommendation		Remark
Dam Safety Program Elements	Dam Safety Inspections	See "Policy and Program" Report
	Develop Utility Database	See "Policy and Program" Report
	Update Operations and Maintenance Plan	See "Policy and Program" Report
	Prepare Emergency Action Plan to meet Minimum requirements of FEMA 64	See "Policy and Program" Report
	Develop/prepare Crack Monitoring Plan	
	Install Sediment Markers in Reservoir	
	Continue Settlement Surveys	See "Policy and Program" Report
	Prepare Subsidence and Earth Fissure Monitoring Plan	See "Policy and Program" Report
Phase II Analyses	Conduct Risk Assessment	See "Policy and Program" Report
	Conduct Slope Stability Analyses	Design vs Existing vs ADWR requirements
	Update Hydrologic Models (100-yr, PMF)	New methodology and changes in land use
	Prepare Future Conditions hydrologic model	Evaluate detention/retention
	Evaluate upstream/downstream land use and watershed conditions	Impact on IDF
	Conduct Incremental Damage Analysis	Impact on IDF
	Conduct updated Sediment Yield Analysis	Reservoir capacity and upstream development
	Install settlement monitoring monuments (total of 4 at each cross section)	See Part III, Section 2, Subsection 2.5
	Conduct updated Reservoir Capacity Analysis	

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART III SIGNAL BUTTE FRS

Appendix A – Summary of NRCS Design Criteria

Item	NRCS Criteria	ADWR Criteria	Comment/Remarks
Publications and References for Corps, NRCS, and ADWR Criteria	Technical Release No. 60 TR-60. Earth Dams and Reservoirs. Oct. 1985. Amended Jan 1991	Rules for Dam Safety Procedures	
Size	Maximum ht = 38.0 ft Floodwater storage = 1360 AF Sediment storage -- 175 AF	**Intermediate:** 40' <height< 100' and 1000 ac-ft < capacity< 50,000 ac-ft	Presently an intermediate dam.
Structure Classification (Hazard Classification)	**Class C**. Failure may cause loss of life, serious damage to homes, industrial and commercial buildings, important public utilities, major highways, or railroads	**High**: probably loss of life and low to high economic losses	Currently a high hazard dam;
Inflow Design Flood (IDF)	One-percent event (100-year)	**0.5PMF to PMF**: High hazard class with any size class will vary based on downstream population and potential economic losses (pg 26)	May be required to pass 0.5 PMF with change in classification
Total Freeboard	4.8 ft per design plans (between Emergency Spillway crest and the settled top of the dam crest)	ADWR definition: vertical distance between the emergency spillway crest and the top of the dam Shall be the largest of the following : (note: this is for new dams) a) the sum of the IDF max water depth above the spillway crest plus wave runup b) the sum of the IDF max water depth above the spillway crest plus 3 ft c) The minimum of 5 ft	
Residual Freeboard	between maximum water surface elevation to dam crest		
Principal Spillway Design Flood	100-year	N/A	100-year
Principal Spillway Capacity	(a) Discharge through the emergency spillway will not occur (b) Adequate to empty the retarding pool in 10 days or less. Or adequate to empty 80 percent or more of the maximum volume of retarding storage after 10 days. The 10-day is measured starting from the time the maximum water surface elevation is attained during the passage of the principal spillway flood	N/A	(a) Discharge through the emergency spillway will not occur (b) Adequate to empty the retarding pool in 10 days or less. Or adequate to empty 80 percent or more of the maximum volume of retarding storage after 10 days. The 10-day is measured starting from the time the maximum water surface elevation is attained during the passage of the principal spillway flood (
Initial Reservoir Stage for Principal Spillway Hydrograph Routing	Crest elevation of the lowest ungated principal spillway inlet or the anticipated elevation of the sediment storage, whichever is higher	N/A	Crest elevation of the lowest ungated principal spillway inlet or the anticipated elevation of the sediment storage, whichever is higher
Design Procedures for Principal Spillways	TR 60 Chapt 6 Principal Spillways	for high and significant hazard dams principal spillway shall be 36-inches or greater; all high and significant hazard dams shall have the capacity to evacuate 90% of storage capacity of reservoir within 30 days, excluding reservoir inflows; corrugated metal pipe not acceptable	
PMP Storm Types	General and local. HMR No. 49	N/A	N/A
Minimum Emergency Hydrologic Criteria	For Class C Structure 1: emergency spillway hydrograph P100 + .26(PMP - P100) 2: freeboard hydrograph = PMP	N/A	
Emergency Spillway Capacity	(a) Pass the emergency spillway hydrograph resulting from P100 at the safe velocity (b) Pass the freeboard hydrograph with the water surface elevation at or below the design top of the dam (c) Capacity must not be less than that determined from Figure 7-1 on Page 7-8 in TR-60	Spillways and outlets of flood control dams shall be able to pass all the flood water at a discharge rate as calculated on the basis of the spillway design flood.	

Item	NRCS Criteria	ADWR Criteria	Comment/Remarks
Emergency Spillway Crest Elevation	(a) Satisfy the 2500 ac-ft total capacity limit (PL 83-566, NWM 500.20) (b) The discharge through the emergency spillway will not occur during the routing of the principal spillway hydrograph (c) If the 10-day drawdown requirement is not met for principal spillway capacity design, then the crest elevation of the emergency spillway will be raised as noted on Page 6-1, Capacity of Principal Spillway.	N/A	(a) Satisfy the 2500 ac-ft total capacity limit (PL 83-566, NWM 500.20) (b) The discharge through the emergency spillway will not occur during the routing of the principal spillway hydrograph (c) If the 10-day drawdown requirement is not met for principal spillway capacity design, then the crest elevation of the emergency spillway will be raised as noted on Page 6-1, Capacity of Principal Spillway.
Initial Reservoir Stage for Emergency Spillway Hydrograph Routing	The highest value from the following elevations: (a) Elevation of the lowest ungated principal spillway inlet (b) The anticipated elevation of the sediment storage (c) The elevation of the water surface associated with significant base flow (d) The pool elevation after 10 days of drawdown from the maximum stage attained when routing the principal spillway hydrograph. (Page 7-2 in TR 60)	N/A	
Sedimentation	100-year sediment reservoir	N/A	
Dam Breach		Unless waived by the Director, owners of high and significant hazard potential dams shall prepare, maintain, and exercise Emergency Action Plans for immediate defensive action to prevent failure of the dam and minimize threat to downstrem development.	Develop EAP
Special Requirement for Storage	2500 ac-ft (total reservoir capacity = water volume plus the anticipated sediment volume) according to Table 500-2 in Public Law 83-566, National Watershed Manual-Part 500.20. Based on Table 500-2, any amount for construction costs and >4,000 ac-ft of total capacity require a committee on Environment and Public Works of the Senate and committee on Public Works and Transportation of the House of Representatives.	The temporary storage will be evacuated as soon as possible following such periods of flood.(from License)	
Seismic	See TR-60	There are no seismic design requirements for existing flood control dams.	See Appendix B in Engineering Pamphlet 1110-2-1155 US Army Corps of Engineers
Design for Vegetated and Earth Emergency Spillways	(a) From EM - 27 Pages Appendix F (b) Spillway will not breach during passage of the freeboard storm (f) Maximum permissible velocity in vegetated emergency spillways: Table 7-1 in TR-60 (g) Maximum permissible velocity in earth emergency spillways: Table 7-2 in TR-60(Fortier and Scobey's Study) (h) Manning's n = 0.02 for design velocity in earth spillways; Capacity of earth spillways will be based on a appraisal of the Manning's n at the site. (i) Manning's n = 0.04 for vegetated spillways	Criteria depends on whether earthen spillway is located on soils subject to liquefaction.	

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART III SIGNAL BUTTE FRS

Appendix B – Settlement Monitoring Records

SETTLEMENT MONITORING OF EARTHEN DAMS
OPERATED BY THE FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

DRAFT

Prepared by

Jan M. Staedicke
Civil Engineering Technician III
Flood Control District of Maricopa County

June 1, 1995

Purpose

The purpose of this report is to:

a) Compile settlement monitoring data that has been acquired to date.

b) Recommend refinements to the monitoring procedure.

c) Recommend a schedule of continued monitoring.

d) Recommend that the settlement monitoring procedure be supplemented with:

 a) earth fissure monitoring procedure

 b) Periodic inspection using a team of specialists (geologist, structural engineer, etc.)

Introduction

Beginning in 1977 survey monuments were installed on the crest and downstream toe of the Flood Control District's (FCD's) earthen dams to monitor the settlement of these structures. It is assumed that changing elevations of monuments at the downstream toe of the structures indicate subsidence, and changing elevations of the crest monuments are the sum of subsidence plus expansion/contraction of the embankment fill. The difference between these two is then the apparent expansion/contraction of the fill material.

Subsidence is the downward movement or sinking of the Earth's surface caused by removal of underlying support (typically the withdrawal of groundwater). The estimated groundwater pumpage in the Salt River Valley basin area peaked in the 1950's. Due to an abundance of rainfall and surface water supply between 1976 and 1982, pumpage was greatly reduced and water levels rose over much of the basin during that time.[1] The Phoenix Active Management Area (AMA) was created by the Groundwater Management Act of 1980. Although groundwater levels have stabilized throughout much of the valley, they continue to decline in the area of Luke Air Force Base, so structures in this vicinity warrant greatest concern (White Tanks and McMicken).

The crest monuments are typically placed about 6" below the crest. Since the distance from the crest to the monument isn't constant, variation from the design crest of less than 1 foot is probably not significant. A more telling number is the settlement between years surveyed. Because groundwater pumping peaked in the 1950's, and our earliest survey data is 1977, we lack data for the most critical time period. Structures which should have the highest priority for continued monitoring are those in which the minimum elevation is more than 1 foot below design crest, or those which show the greatest settlement in the years surveyed.

Data Analysis

Appendix A contains a summary table that lists each structure and shows the maximum settlement between years surveyed, and the difference between the design crest and the minimum crest elevation. The table appears twice, sorted first by greatest settlement, and then by greatest change from the design crest.

Appendix B contains detailed comments regarding each structure.

Appendix C contains the following detailed information for each structure:

 1) Data table showing survey elevations, incremental and total settlement

 2) Plot of the crest settlement monuments

 3) Plot of the change in crest over the years surveyed.

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[1]Arizona Department of Water Resources Hydrologic Map Series Report No. 12 Sheet 1 of 3 Depth to Water and Altitude of the Water Level. Dated 1983

In each data table anomalies have been shaded. These have been checked from the plans, but they should also be checked from the survey notes. In cases where the error is obvious, it has been corrected and noted.

In addition to the data gathered in the settlement surveys, the District is in the process of conducting GPS surveys of each dam, to verify their capacities. The first of these surveys (Buckeye Structures 1,2,&3) has been submitted to the District, and the remaining surveys are to be submitted in late June. This data should be analyzed before prioritizing and conducting future subsidence surveys. Although the GPS surveys don't have the same level of accuracy, and don't include elevations of the settlement monuments, they do include spot elevations on the dams, and provide ties to the benchmarks used in the subsidence surveys. This should help us confirm those locations where enough subsidence has occurred to cause concern and/or warrant increased monitoring.

Groundwater Withdrawal Induced Subsidence fissuring

An earth fissure is a crack at or near the Earth's surface that is caused by subsidence.[2] According to SH&B's study of McMicken Dam "This kind of crack would in all probability lead to very rapid failure of the unrepaired dam in the event of major runoff into the reservoir."[3] SH&B's 1983 study of McMicken Dam states "it is considered highly probable that at least several earth fissures will form through the dam in the next few decades. The central vertical drain concept of repair yields...the only positive defence against subsidence induced fissuring through the dam."[4] It is recommended that we supplement our program of settlement monitoring with a program of monitoring fissures near FCD Dams. Fissures are known to exist in the vicinity of McMicken and Powerline Dams, and we would be wise to determine if fissures are present near other dams, and monitor their progression. The SH&B report has numerous references to publications regarding fissures, and this would be a good place to start.

Recommendations:

Recommended refinements to the settlement monitoring procedure:

1) Surveys should be tied into a grid of USC&GS monuments established in rock.
2) Surveys should include elevations of the crest, if monuments are below the surface.
3) Surveys should include the elevation of the emergency spillway.
4) Water levels in the vicinity should be checked at timing close to that of the surveys.
5) Establish monuments at the downstream toe, if they don't exist (McMicken)

Recommended schedule of continued monitoring:

ADWR has stated that after several surveys have been completed, surveys can be delayed indefinitely unless a trend of settlement has been established. The recommended survey interval is approximately 5 years, but this varies depending on the sponsor of the project. Table 1 shows the survey record and proposed schedule (assumes 5 year interval)

Corps Structures

Corps regulation no. 1110-2-100 states that their structures should be monitored at a 5 year interval.

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[2]Steven Slaff, <u>Land Subsidence and Earth Fissures in Arizona</u>, Arizona Geological Survey, 1993, p.11.

[3]SH&B, p. 66.

[4]Sergent, Hauskins & Beckwith, Design Report, <u>McMicken Dam Restoration Study</u>, 1983, Pages 2 and 3.

Recommended Periodic inspection:

Although the dams are regularly inspected by FCD's maintenance division, the Corps has stated that for their own structures they normally conduct a more formal inspection (called Periodic) at five year intervals. The settlement surveys are completed about six months prior to the inspection, so their results can be studied by the inspection team. The inspection team consists of a geologist, a structural engineer, and other specialists. It may be worthwhile for us to use this procedure, especially for dams which are in areas of known subsidence and fissuring.

A center drain was added to the dam in 1991. It is unknown if the drain was added to correct a transverse cracking problem (similar to other structures) which may have been partially caused by settlement/subsidence. As part of the 1991 modification, the crest was restored approximately to the design crest. For unknown reasons the crest wasn't restored level, with the new minimum elevation being 1588.90 at station 89+00.

There is an earth fissure approximately 1/4 mile west of Powerline Dam. The fissure, if projected eastward would intersect Powerline FRS at approximate station 125+00. The fissure would intersect the CAP before reaching the Dam. In the late 1980's, the Bureau of Reclamation installed sheet piling around the CAP at the location where the fissure would intersect. It is recommended that FCD's Engineering Division contact the Bureau to see what data they have gathered regarding the fissure. The eastward progression of the fissure should be monitored as part of the regular dam inspections. The District also has a series of photos taken along the fissure between 1985 and 1987.

SH&B's Report on McMicken Dam references the fissure near Powerline Dam on pages 57, 63, and 64. It is recommended that FCD's engineering Division review this information more carefully and consider a program of monitoring similar to that recommended for McMicken. See the discussion on McMicken that follows.

The maximum subsidence in the area of Queen Creek is 4.5 feet[3]. "A study of earth fissures near Baseline and Meridian Roads by the U.S. Geological Survey (USGS) and the U.S. Bureau of Reclamation (BuRec) is ongoing. Geophysical data again indicates that a shallow bedrock irregularity has caused localized differential consolidation and subsequent fissuring (Carpenter, 1982) "[4]
"An indication of the subsurface extent and erosion potential of some fissures, introduction of water at a rate of 550 gpm into the Meridian and Baseline Roads fissure system resulted in no overflow after five days of continuous pumping (Raymond, 1982)[5]

Rittenhouse FRS
Two surveys were performed over a 4 year spacing. The maximum settlement was -0.20 feet. The minimum elevation is 1.52 feet below the design crest.

Saddleback FRS
Three surveys have been performed over a seven year period. The maximum settlement over 4 years is -0.15 feet. The minimum elevation is 1.11 feet below the design crest. The third data set (1990) is still being compiled by SCS.

Signal Butte FRS
Two surveys have been performed over a two year period. The maximum settlement was +0.07'. The minimum elevation was 0.15' below the design crest.

Spookhill FRS
Three surveys have been performed over an eight year period. The maximum settlement was -0.03 feet. The minimum elevation was 0.48' below the design crest.

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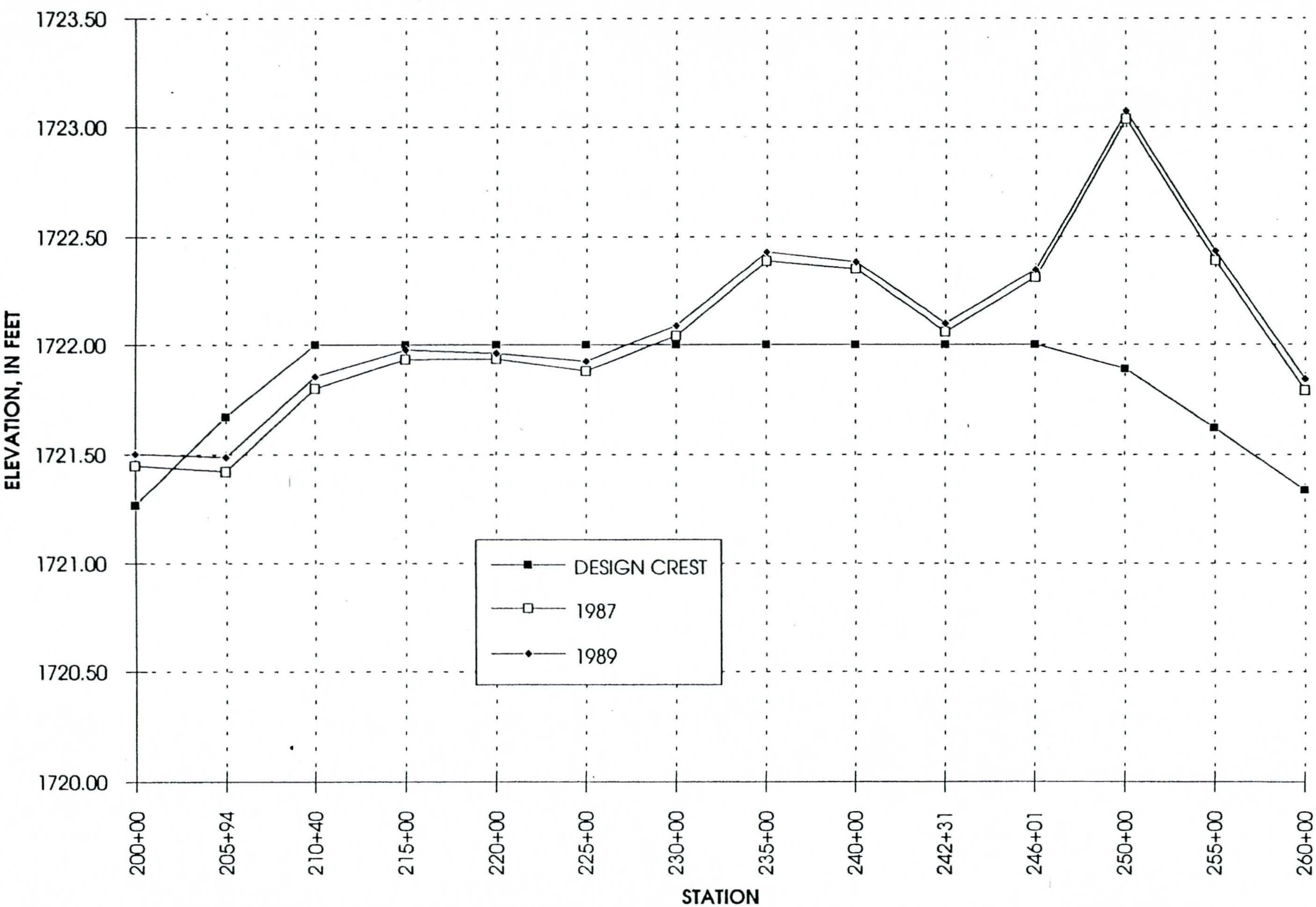
[3]Sergent, Hauskins & Beckwith, p. 57.

[4]SH&B, p. 63.

[5]SH&B, p. 64.

5/4/95

SIGNAL BUTTE FRS CREST SETTLEMENT MONUMENTS

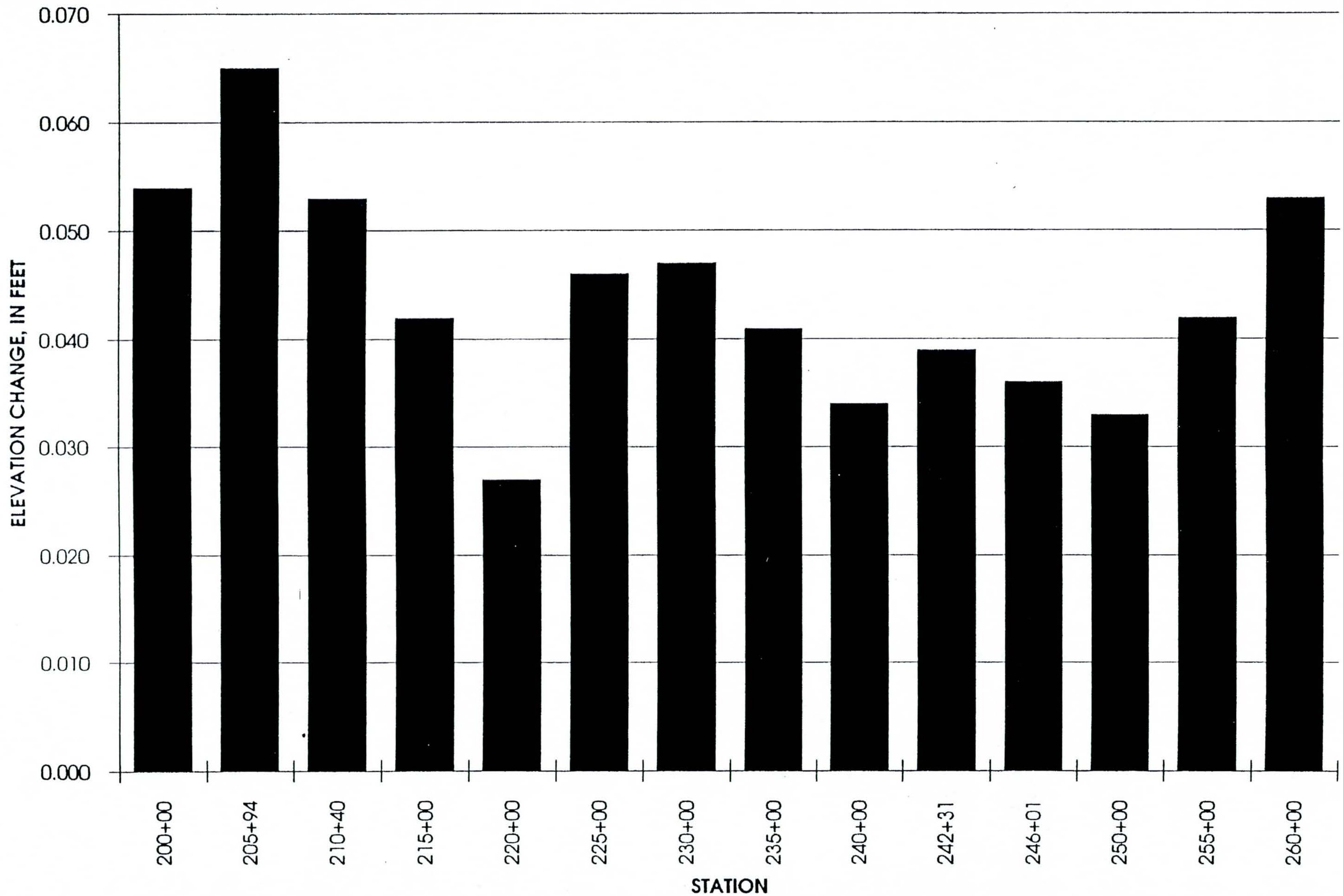


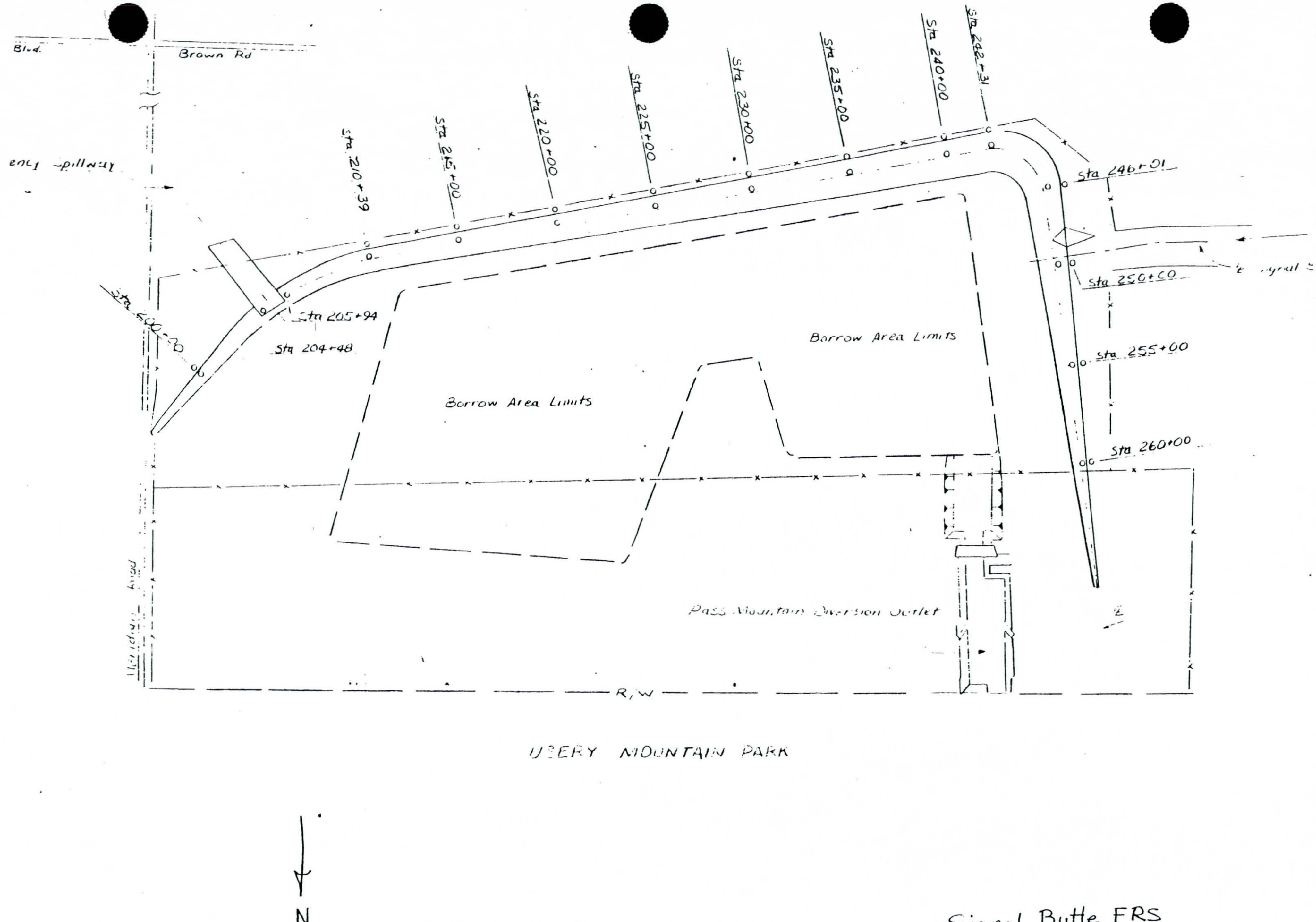
SIGNAL BUTTE FRS SUBSIDENCE MONITORING					
MARKER	**STATION**	**DESIGN**	**1987**	**1989**	**1987-1989**
SM-A1	200+00	1721.27	1721.448	1721.502	0.054
SM-A2	205+94	1721.67	1721.421	1721.486	0.065
SM-A3	210+40	1722.00	1721.799	1721.852	0.053
SM-A4	215+00	1722.00	1721.933	1721.975	0.042
SM-A5	220+00	1722.00	1721.935	1721.962	0.027
SM-A6	225+00	1722.00	1721.878	1721.924	0.046
SM-A7	230+00	1722.00	1722.041	1722.088	0.047
SM-A8	235+00	1722.00	1722.385	1722.426	0.041
SM-A9	240+00	1722.00	1722.348	1722.382	0.034
SM-A10	242+31	1722.00	1722.059	1722.098	0.039
SM-A11	246+01	1722.00	1722.308	1722.344	0.036
SM-A12	250+00	1721.89	1723.038	1723.071	0.033
SM-A13	255+00	1721.62	1722.388	1722.430	0.042
SM-A14	260+00	1721.34	1721.790	1721.843	0.053
AVERAGE CHANGE					**0.044**
MINIMUM			**1721.421**	**1721.486**	**0.027**
MAXIMUM			**1723.038**	**1723.071**	**0.065**
SM-B1	200+00		1712.521	1712.581	0.060
SM-B2	204+48		1712.435	1712.501	0.066
SM-B3	210+40		1699.839	1699.902	0.063
SM-B4	215+00		1698.076	1698.137	0.061
SM-B5	220+00		1692.797	1692.854	0.057
SM-B6	225+00		1693.107	1693.164	0.057
SM-B7	230+00		1691.986	1692.044	0.058
SM-B8	235+00		1692.091	1692.142	0.051
SM-B9	240+00		1686.281	1686.327	0.046
SM-B10	242+31		1687.144	1687.188	0.044
SM-B11	246+01		1693.304	1693.346	0.042
SM-B12	250+00		1699.200	1699.244	0.044
SM-B13	255+00		1705.116	1705.160	0.044
SM-B14	260+00		1710.680	1710.723	0.043
AVERAGE CHANGE					**0.053**
MINIMUM					**0.042**
MAXIMUM					**0.066**
CHANGE 1					-0.006
CHANGE 2					-0.001
CHANGE 3					-0.010
CHANGE 4					-0.019
CHANGE 5					-0.030

CHANGE 6					-0.011
CHANGE 7					-0.011
CHANGE 8					-0.010
CHANGE 9					-0.012
CHANGE 10					-0.005
CHANGE 11					-0.006
CHANGE 12					-0.011
CHANGE 13					-0.002
CHANGE 14					0.010
AVERAGE CHANGE					**-0.009**
MINIMUM					**-0.030**
MAXIMUM					**0.010**
NOTES:					
1) CONSTRUCTION COMPLETED 1987					
2) DESIGN CREST ELEVATION =					
3) DESIGN SPILLWAY CREST =					
4) MAXIMUM HEIGHT = 39'					

5/1/95

SIGNAL BUTTE FRS CHANGE IN CREST, 1987 TO 1989





Signal Butte FRS

SUBSIDENCE SURVEY DATA
SIGNAL BUTTE FRS

1987 SURVEY			
"A" SERIES		"B" SERIES	
STATION	ELEVATION (ft)	STATION	ELEVATION (ft)
200+00	1721.448	200+00	1712.521
205+94	1721.421	204+48	1712.435
210+40	1721.799	210+40	1699.839
215+00	1721.933	215+00	1698.076
220+00	1721.935	220+00	1692.797
225+00	1721.878	225+00	1693.107
230+00	1722.041	230+00	1691.986
235+00	1722.385	235+00	1692.091
240+00	1722.348	240+00	1686.281
242+31	1722.059	242+31	1687.144
246+01	1722.308	246+01	1693.304
250+00	1723.038	250+00	1699.200
255+00	1722.388	255+00	1705.116
260+00	1721.790	260+00	1710.680

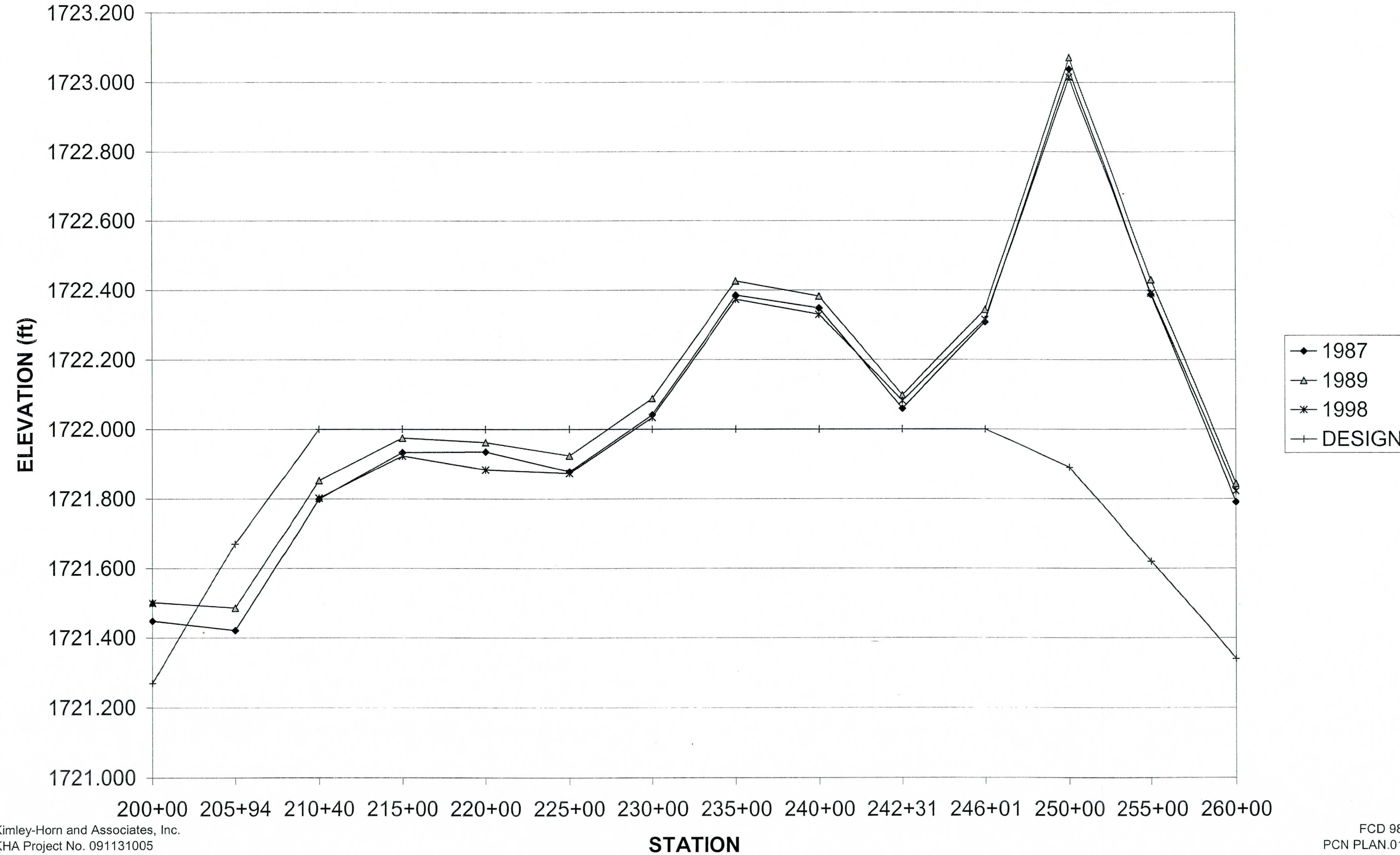
1989 SURVEY			
"A" SERIES		"B" SERIES	
STATION	ELEVATION (ft)	STATION	ELEVATION (ft)
200+00	1721.502	200+00	1712.581
205+94	1721.486	204+48	1712.501
210+39	1721.852	210+39	1699.902
215+00	1721.975	215+00	1698.137
220+00	1721.962	220+00	1692.854
225+00	1721.924	225+00	1693.164
230+00	1722.088	230+00	1692.044
235+00	1722.426	235+00	1692.142
240+00	1722.382	240+00	1686.327
242+31	1722.098	242+31	1687.188
246+01	1722.344	246+01	1693.346
250+00	1723.071	250+00	1699.244
255+00	1722.430	255+00	1705.160
260+00	1721.843	260+00	1710.723

1998 SURVEY			
"A" SERIES		"B" SERIES	
STATION	ELEVATION (ft)	STATION	ELEVATION (ft)
200+00	1721.4998	200+00	1712.5397
205+94		204+48	1712.4597
210+39	1721.8014	210+39	1699.8564
215+00	1721.9231	215+00	1698.0948
220+00	1721.8831	220+00	1692.7931
225+00	1721.8731	225+00	1693.0981
230+00	1722.0331	230+00	1691.9798
235+00	1722.3731	235+00	1692.0831
240+00	1722.3297	240+00	1686.2598
242+31	1722.0814	242+31	1686.6315
246+01	1722.3147	246+01	1693.2815
250+00	1723.0147	250+00	1699.1848
255+00	1722.3914	255+00	1705.1281
260+00	1721.8214	260+00	1710.7114

DESIGN CREST	
STATION	ELEVATION (ft)
200+00	1721.27
205+94	1721.67
210+40	1722.00
215+00	1722.00
220+00	1722.00
225+00	1722.00
230+00	1722.00
235+00	1722.00
240+00	1722.00
242+31	1722.00
246+01	1722.00
250+00	1721.89
255+00	1721.62
260+00	1721.34

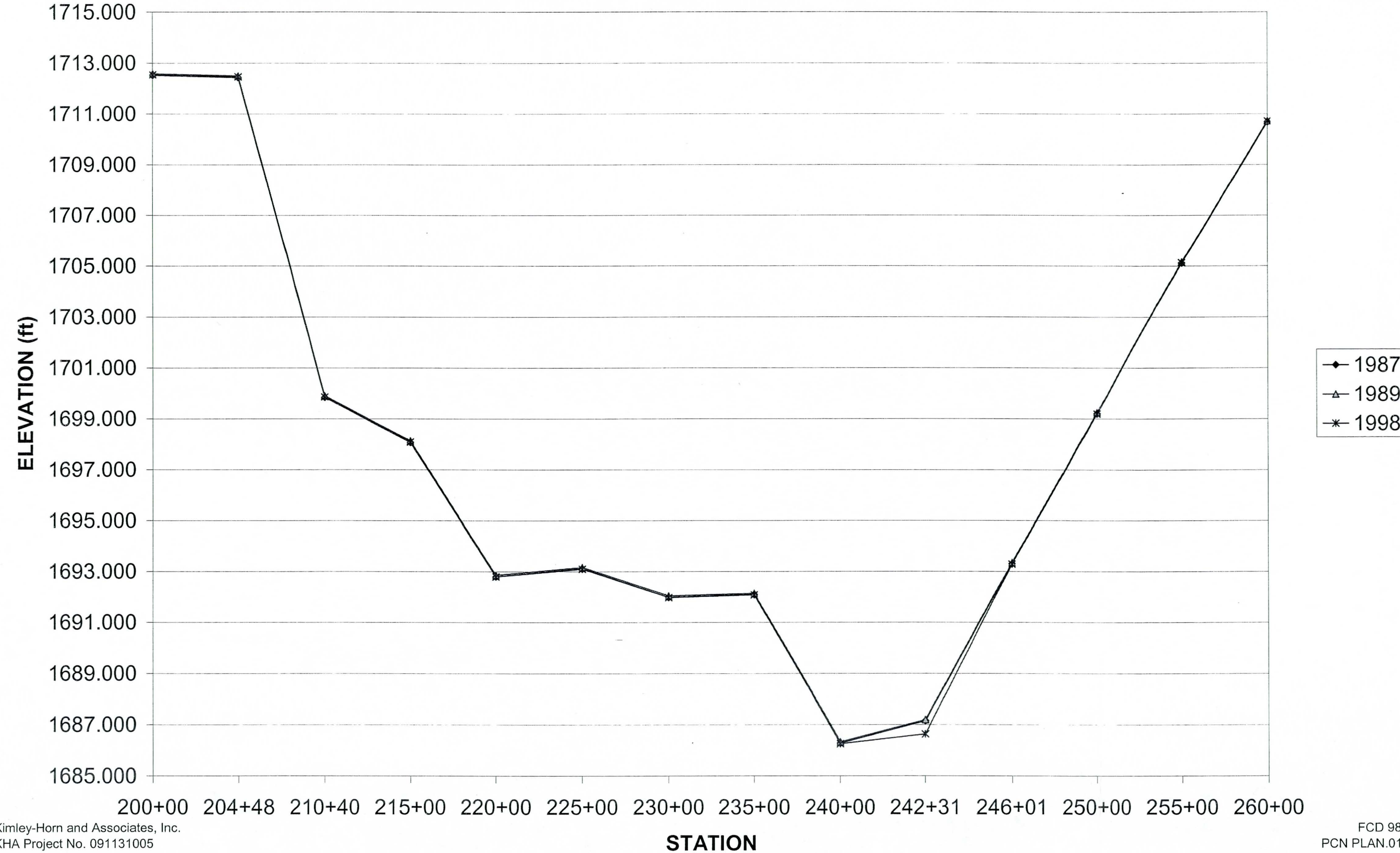
1987 SURVEY DRAWN BY D. CLOUGH OF THE USDA SCS., 3/87
1989 SURVEY DRAWN BY D. CLOUGH OF THE USDA SCS, 2/89
1998 SURVEY SEALED BY RICHARD D. TABOR OF GILBERTSON ASSOCIATES, INC., 10/2/98

SIGNAL BUTTE FRS CREST ("A" SERIES) ELEVATIONS



Printed 11/13/2000

SIGNAL BUTTE TOE ("B" SERIES) ELEVATIONS



Kimley-Horn and Associates, Inc.
KHA Project No. 091131005

FCD 98-41
PCN PLAN.01.00

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART IV APACHE JUNCTION FRS

Section 1.0 Description of Dam

Section 1.0 Description of Dam

The Apache Junction FRS is a structural plan element of the Watershed Work Plan for the Buckhorn-Mesa Watershed, Maricopa and Pinal Counties, Arizona. The Watershed Work Plan was prepared by the Natural Resources Conservation Service (NRCS; formerly the Soil Conservation Service, SCS) in January 1963. The watershed heads in the southwest-facing slopes of the Superstition Mountains and drains onto a wide alluvial fan on which valuable agricultural, urban and commercial developments have been constructed. The total original watershed area of Buckhorn-Mesa is 89,983 acres. The watershed is one of three for which concurrent planning efforts were conducted by the NRCS at the request of the District. The northernmost watershed is the "Buckhorn-Mesa", the central watershed is the "Apache Junction – Gilbert", and the southern watershed is the "Williams-Chandler".

1.1 Purpose of Dam

The Apache Junction FRS is one of three flood retarding structural measures designed and constructed under the watershed work plan. The other flood retarding structural measures are the Signal Butte FRS and the Spookhill FRS. The purpose of the Apache Junction FRS is to provide flood and erosion control benefits for downstream developments (agriculture, commercial and urban areas). The Apache Junction FRS was designed to control runoff from the 100-year flood event.

1.2 Dam Location and Features

Apache Junction FRS is located within the City of Apache Junction. The FRS begins 1,200 ft west of Apache Trail and ends at 1/4 mile south of McKellips Road and 1/4 mile west of Idaho Road. The FRS is about 30 miles east of downtown Phoenix and approximately one mile north of the City of Apache Junction. Figure 1-1 provides a location map of Apache Junction FRS. The project consists of the FRS structure and an emergency spillway. The project is part of the Buckhorn Mesa Watershed Protection and Flood Prevention Project, which includes the Signal Butte and Apache Junction flood retarding structures. The Flood Prevention Project was prepared, designed, and constructed by the U.S. Department of Agriculture, Natural Resources Conservation Service.

The reservoir behind the FRS is 98 acres with a capacity of 540 acre-feet. A permanent pool will not be retained in the reservoir, instead, the FRS and reservoir are designed to trap floodwater and store it only for as long as it takes to release it slowly and safely downstream. Reservoir capacity is then restored to handle a future flood.

The emergency spillway is located near the north (right) abutment of the FRS. Construction of the FRS and appurtenant structures was completed in December 1988.

1.3 Physical Features

Apache Junction FRS is a rolled earthfill structure. The length of the FRS is 8,764 feet with a maximum height of 22 feet and a crest width of 14 feet. The reservoir capacity is 540 acre-feet at a water surface elevation of 1799.77(emergency spillway crest elevation). The total capacity is approximately 2,000 acre-feet at a dam crest elevation of 1810.0 ft. The FRS was designed with 10 feet of freeboard and 95 acre-feet of sediment storage (100-year). Apache Junction FRS is accessible off Apache Trail by a padlocked gate. The maximum recorded impoundment for Apache Junction reservoir is 15 acre-feet with a stage of 4.76 feet at the FRS (July 23, 1993).

The principal spillway is an ungated 30-inch diameter concrete pipe approximately 137 feet long. The design outflow is 97 cfs from the principal spillway. The trash rack is located on the upstream inlet. The principal spillway discharges into a constructed channel (Bulldog floodway) through an outlet structure and then discharges into the Signal Butter FRS.

The emergency spillway is a reinforced concrete baffle block structure and is located adjacent to the north (left) abutment of the FRS. The spillway is approximately 100 feet wide with a capacity of 1875 cfs. The spillway crest elevation is 1799.77 feet.

The inflow design flood under proposed ADWR rules and regulations is the ½ PMF.

Station markers are located every 500-feet along the downstream crest of the FRS. A series of staff gages is located on the upstream slope adjacent to the principal spillway. Settlement monuments are located along the crest and downstream toe of the FRS.

A central filter drain was constructed in the Apache Junction FRS embankment as part of the original construction of the dam. Section 2.0 of this Part summarizes the purpose and construction of the filter drain.

Table 1-1 provides a summary of the physical structure data for Apache Junction FRS.

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART IV APACHE JUNCTION FRS

Section 2.0 Technical Review

Section 2.0 Technical Review

The purpose of the technical review is to review the engineering records related to the dam, it's construction, and through this review familiarize the project team with the structure, familiarize the team with the history of the structure, and acquaint the team with the basis of analysis and design. The review also provides for a review of original design criteria and design guidelines.

This section of the report presents a discussion of the dam design criteria under which the dam was originally constructed versus the ADWR dam safety rules and regulations for jurisdictional dams. This section also includes a discussion of the record modifications to the dam that were constructed as related to dam safety issues and modifications to the dam that are not directly dam safety related. A discussion is presented that focuses on past dam safety signs of distress.

This section of the report also presents a review of the technical documentation for the structure. The review of the technical documentation was limited to the available reports, studies, investigations, construction plans and as-builts, specifications, and office correspondence collected as part of this study. The purpose of the review of the technical documents is to assist in the engineering assessment of the structure. The technical document review, along with the field examinations, provided a basis to evaluate the structure regarding operational adequacy, structural stability, and dam safety rules and regulations.

2.1 Dam Design Criteria

Apache Junction FRS was originally analyzed by the NRCS in the early to mid-1960's. The hydrology for the structure has been modified several times in the mid-1970's and early-1980's by the NRCS to account for planning considerations for the Buckhorn-Mesa structures (flood retarding structures and floodways). The basis of design for the FRS was originally founded in the NRCS publication "Engineering Memorandum EM-27" which is the precursor manual to "Technical Release TR-60: Earth Dams and Reservoirs" the present NRCS design guideline for earth dams. The final analysis of the FRS has been in accordance with TR-60.

Appendix A (of this Part IV) provides a summary of the original NRCS design criteria (based on TR-60) for the dam and compares the criteria against ADWR dam safety rules and regulations for jurisdictional dams. Apache Junction FRS was designed to detain the 100-year event using NRCS criteria. This design event was used to size the principal spillway and reservoir volume. The hydrology for the emergency spillway design and freeboard design flood is discussed below in the Hydrology section following NRCS criteria. According to ADWR criteria, the Apache Junction FRS Inflow Design Flood (IDF) for emergency spillway capacity is the ½ PMF. Current (June 2000) ADWR regulations could change the size classification of the dam. The new size classification combined with the hazard classification could require that the IDF be changed. This IDF could be changed from between the ½ PMF and the full PMF. The NRCS, in their hydrologic study of Apache Junction FRS, has designed the dam not to overtop during the passage of the freeboard hydrograph, which was based on the full PMP/PMF (see below – Hydrology).

2.2 Dam Classification

The NRCS in their TR-60 manual uses a three-category "hazard" classification system. The three categories or classes are established to permit the association of criteria with the damage that might result from a sudden major breach of the earth dam embankment.

The NRCS classifies the Apache Junction FRS as a Class C structure. Class C structures are structures located where failure may cause loss of life, serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads.

The Arizona Department of Water Resources rules and regulations, in-place at the time of licensing, for jurisdictional dams classifies Apache Junction FRS as a high hazard, small size dam. Current ADWR regulations could change the size classification of the dam.

2.3 Structure Modifications Related to Dam Safety

The Ashton Company completed the original construction of the embankment in December 1988. The original construction of the embankment included the construction of a longitudinal centerline transition filter. The filter trench is 3.0-ft wide and extends from the bottom of the cut-off trench to 1.0-ft below the crest of the dam. The "as-built" filter trench was constructed deeper, approximately 2 to 4-ft deeper, from Stations 33+00 to 45+00, 55+00 to 60+00, and from 97+00 to 100+00. The transition filter was extended below the cut-off trench to the elevation of a communications conduit at Station 76+50. The filter was designed in response to embankment cracking at other NRCS structures located near the Apache Junction FRS. The NRCS and EBASCO, consultant to the NRCS, assumed that embankment cracking was going to occur and would be handled by the transition filter. The transition zone would be made of granular cohesionless material which will maintain a filter zone capable of preventing the migration of embankment materials. The NRCS estimated that the embankment transition zone can accommodate as much as approximately two feet of settlement in the twenty-foot high embankment. This, combined with the limited depth of the soil layer between the underlying caliche and the embankment, had led the NRCS to decide to make no provisions other than to apply extra compaction effort to the foundation materials under the embankment. No provision of embankment camber to allow for settlement was made or considered necessary by the NRCS.

Construction was also completed for installation of landscaping treatments for the Apache Junction FRS. The landscaping treatment included providing rock mulch and seed mixes on the embankment slopes and seed mixes in the upstream borrow areas (reservoir pool). The purpose of the landscaping treatment was to minimize construction impacts and restore disturbed areas to native flora.

2.4 Structure Modifications Non-Dam Safety Related

The as-built construction plans for the Apache Junction FRS show several utility crossings at the roadway crossing of Idaho Road and Lost Dutchman Road. An AT&T communications cable was constructed under the embankment at Station 76+25. A waterline is show in the roadway plan sheet of the as-builts. The waterline is shown to run east/west and is located on the northside of Lost Dutchman Boulevard. The waterline turns north at the intersection of Lost Dutchman and Idaho Road. The line continues north in Idaho Road on the westside of Idaho.

NRCS construction correspondence dated November 12, 1987 to the Flood Control District provides a discussion regarding a City of Apache Junction waterline. The letter states that:

> "The contract for the construction of the Bulldog Floodway and Apache Junction FRS requires the Contractor (Ashton) to keep the existing 4-inch diameter waterline that crosses the FRS at Station 84+25 active until a replacement line can be installed and made functional with the ramp for Idaho Road. The contractor is experiencing many problems in maintaining their construction activities in this area without disturbing this line and disrupting the water service. The contractor has submitted a proposal that will route the waterline below the foundation excavation. At the completion of the replacement line they will fill the existing line with an approved grout mixture".

Apparently this 4-inch waterline was abandoned and filled with grout according to the contractor plans. The approximate location of the abandoned 4-inch diameter waterline is at Station 84+25 and was placed under the FRS cut-off trench according to the contractor's submittals.

The as-built construction plans for Apache Junction FRS provided two roadways crossings of the embankment. These roadways are Idaho Road and Lost Dutchman Boulevard. The roadways were designed above the 25-year storm event as the roadways cross the impoundment area.

KHA recommends that an extended data research effort be conducted of all District dams for documented utility crossings. The database should include at a minimum the type of utility, utility owner, size of utility, depth of utility, encasement types, cross reference to dam, construction plans and specifications, and permits.

Other modifications or repairs to the structure included ongoing slope erosion repairs and hydroseeding. District records of these types of maintenance activities are not detailed sufficiently to indicate the limits and extent of hydroseeding and slope erosion repair.

2.5 Dam Safety Signs of Distress

Inspection reports for Apache Junction FRS were reviewed from the latest reports (including ADWR and District) of November 1999 back to October 1989. KHA also conducted an inspection of Apache Junction FRS in September 2000. District inspection reports are available at the District. ADWR has provided the District with recent ADWR dam safety inspection reports for Apache Junction FRS. The inspection log from the September 2000 inspection conducted by KHA is provided as part of Section 3.0 of this Part IV. Note that Apache Junction FRS was constructed with a central longitudinal transition filter as was done on several other NRCS structures in the vicinity of Apache Junction (e.g., Powerline FRS, Vineyard Road FRS, and Rittenhouse FRS).

Previous inspection reports have documented observations of longitudinal cracks on the dam crest along the dam centerline. The first reports of longitudinal cracks on the dam crest appear in the District's November 1996 inspection report. The cracks appear to be formed in association with the central transition filter. Recent longitudinal cracks were observed and noted in ADWR's November 1999 inspection of Apache Junction. These cracks were located at Stations 81+88, 84+85, 86+00, and 98+60. ADWR probed the cracks with a steel probe to try to get an indication of the depth of cracking. ADWR also photographed the cracks and provided the photos as part of their inspection report.

Kimley-Horn conducted an inspection of the dam in July 2000. The inspection included looking for past reported longitudinal cracks. Longitudinal cracks were located on the crest at centerline at Stations 81+00 to 82+50, 86+00, and 95+50. One old transverse crack was observed at Station 36+00 on the downstream and upstream slope. The transverse crack was probed but to no depth.

Minor erosion is evident on the downstream and upstream slopes of the embankment. The inspection log included as part of Section 3.0 of this Part documents the limits and magnitude of the slope erosion. The upstream and downstream slopes have rock mulch place on the slope from the top of the dam down to mid-slope. The areas where rock mulch has been placed do not show signs of any significant erosion.

Other observations were made that are minor in nature and can best be handled as part of the on-going maintenance of the dam.

2.6 Review of Technical Documentation

Hydrology- The Buckhorn-Mesa Watershed Project was outlined in Part I, Section 3.0. The structural elements of the watershed project include three flood retarding structures and several interconnecting floodways. The three flood retarding structures capture and impound stormwater from their respective upstream watersheds. The floodways

(Bulldog, Signal Butte, and Spook Hill) convey the discharges from the principal spillways of the dams and also serve to intercept stormwater from their respective upstream drainage areas. The interception of stormwater is accomplished through the use of side inlets into the floodways. Discharges from the principal spillway of Apache Junction FRS are conveyed into the Bulldog Floodway which then discharges into the impoundment for the Signal Butte FRS. Discharges from the principal spillway of Signal Butte FRS are conveyed into the Signal Butte Floodway which then discharges into the impoundment for the Spook Hill FRS. Discharges from the principal spillway of Spook Hill FRS are conveyed into the Spook Hill Floodway, which then ultimately discharges into the Salt River. Figure 1-1 located in Section 1.0 of this Part provides the layout of the Buckhorn-Mesa structures and floodways.

The NRCS designed the Apache Junction FRS to detain the 100-year storm event. NRCS's determination of the 100-year precipitation and runoff was based on the procedures in the NRCS "National Engineering Manual – Section 4 – Hydrology" and the requirements of TR-60 for a Class C hazard structure. The NRCS used three design hydrographs to size features of the dam. The principal spillway hydrograph (PSH) is the hydrograph used to determine the minimum crest elevation of the emergency spillway. It is used to establish the principal spillway capacity and determine the associated minimum floodwater retarding storage. For a Class C structure, the PSH is based on the one hundred-year precipitation (P_{100}). The principal spillway was sized for the P_{100} hydrograph storm routed through the spillway such that the maximum pool is drained in 10 days or less (at least 85 percent of the maximum storage is drained in 10 days or less). The principal spillway crest was set at the sediment pool elevation (per TR-60).

The emergency spillway hydrograph (ESH) is the hydrograph used to establish the dimensions of the emergency spillway. For a Class C hazard structure, the ESH is based on a watershed precipitation depth according to the following formula: $\{P_{100} + 0.26(PMP - P_{100})\}$. The freeboard hydrograph (FBH) is the hydrograph used to establish the minimum settled elevation of the top of the dam. It is also used to evaluate the structural integrity of the spillway system. For a Class C hazard structure, the FBH is based on a watershed precipitation depth for the probable maximum precipitation (PMP).

The original hydrologic analysis for Apache Junction FRS is summarized in NRCS's 1963 Watershed Work Plan report titled "Buckhorn-Mesa Watershed – Maricopa and Pinal Counties, Arizona". The hydrographs for the 1963 ESH and FBH were based on precipitation depths of 4.0-in and 10.0-in, respectively (6-hr) (NRCS, 1963: Table 3 - Structures Data). The hydrology for Apache Junction FRS was revised by the NRCS (and their consultant EBASCO) from the original hydrology during the time period from approximately the mid-1970's to the mid-1980's. NRCS used the TR-20 hydrograph computer program to develop the inflow to the dam from the contributing upstream watershed. The hydrology was revised due to changes in project structure elements and revised drainage subbasin limits. A review of the EBASCO documentation revealed that the design precipitation for the Apache Junction FRS for the 100-year, 24-hr storm is 4.1-in; for the ESH - a depth of 7.1-in; and for the FBH - a depth (6-hr PMP) of 13.7-in and a depth (24-hr PMP) of 15.8-in (for a drainage area of 5.79 square miles and an emergency baffle block spillway width of 100-ft).

The emergency spillway was designed by routing the emergency spillway hydrograph through the spillway. The starting water surface for routing the emergency spillway hydrograph through the reservoir is at the elevation of the sediment pool or at the water surface elevation after 10 days of drawdown, whichever is higher. According to TR-60, the emergency spillway for Class C structures is not to be used during the 100-year event. The freeboard hydrograph for Class C structures are routed through the reservoir starting at the same water surface elevation as for the emergency spillway hydrograph.

EBASCO provided final design reports of Apache Junction FRS that includes final design TR-20 and DAMS2 models and documentation of full input and output for the PSH, ESH, and FBH design hydrographs. Specific final analysis of watershed parameters such as subbasin delineations, curve number development, rainfall depth and rainfall distribution, and routing parameters are found in the reports.

The emergency spillway crest elevation used in the EBASCO DAMS2 model is 1799.7-ft, which is the same elevation depicted on the as-built construction plans and the elevation-discharge rating curve for Apache Junction FRS. The maximum water surface elevation for the ESH and FBH in the DAMS2 model was 1802.9-ft and 1809.4-ft, respectively. The peak discharges from the emergency spillway for the ESH and FBH are 1,875-cfs and 10,600-cfs, respectively (EBASCO, 1986).

The EBASCO peak inflow for the full PMP into Apache Junction FRS is approximately 37,362 cfs with a peak emergency spillway outflow discharge of 10,600 cfs. The PMF will not overtop the structure according to the EBASCO studies and NRCS criteria.

Inundation Studies and Breach Analysis – EBASCO Services conducted a spillway inundation and dam breach study for the NRCS in February 1986 (EBASCO, 1986). The purpose of the EBASCO study was to estimate the extent of downstream flooding/inundation from discharges from the emergency spillway resulting from the emergency spillway hydrograph, freeboard hydrograph, and several dam breach locations.

The study consisted of routing discharge hydrographs, computing flow depths and velocities, and delineation of inundated areas for the spillway flows and breach flows at two locations. EBASCO analyzed six events as provided in Table 2-1.

The Idaho Road breach location was selected as it was determined to be critical for the inundation of developed areas close to the dam. The breach at the southwest corner of the FRS would release water into a relatively confined channel, resulting in the minimum attenuation of the flood peak and maximum depth and velocity of flow (EBASCO, 1986). The downstream extent of the mapping was limited by the availability of detailed topography. The study also showed the sensitivity of the water level computations to the uncertainty of the Manning roughness coefficient.

Table 2-1. Downstream Inundation Events.

Event No.	Event Description
1	Spillway Discharge: Emergency Spillway Hydrograph
2	Spillway Discharge: Freeboard Hydrograph (FBH)
3	Dam Breach West of Idaho Road: At the peak reservoir level resulting from the PSH
4	Dam Breach West of Idaho Road: At the peak reservoir level resulting from the FBH
5	Dam Breach at the southwest corner of Apache Junction FRS: At the peak reservoir level resulting from the PSH
6	Dam Breach at the southwest corner of Apache Junction FRS: At the peak reservoir level resulting from the FBH

The gradually varied spillway discharge hydrographs corresponding to the ESH and FBH were routed downstream using the HEC-1 computer program "Flood Hydrograph Package". The Modified Puls routing option using normal depth storage and outflow was used. Four routing reaches were used, each represented by a typical cross-section.

The maximum potential for downstream flooding would occur if a breach in the dam were to form at the maximum reservoir level corresponding to the FBH, which is the level of the crest of the dam. The probability of this event is extremely small, because the probability of the FBH (i.e., PMP) itself is extremely small. An additional case considered is failure at the maximum level resulting from the PSH (P_{100}). In this case a breach would have to be formed by piping, because the water level is nearly 10 feet below the crest of the dam. Since the reservoir contains water only for a period of a few days, a piping failure is also extremely unlikely (EBASCO, 1986).

Peak discharges and the travel times of the peaks were determined as far downstream as the limits of the topographic mapping available to EBASCO. The HEC-1 was used for the spillway discharges and the TR-66 procedure for the Idaho Road and southeast corner breaches. The results of the study are provided in the EBASCO report as Figures 1, 2, and 3. From the peak discharge curves in Figures 1, 2, and 3, flows were interpolated for each of the cross-sections used in the water surface profile computations. For these flows, corresponding water surface elevations and mean channel velocities were interpolated from the data produced from the HEC-2 models.

Three inundation maps were prepared by EBASCO for the spillway and the two breach locations based on the water surface profile for the high n-values. The maps show the limits of inundation for the emergency spillway hydrograph and the freeboard hydrograph discharges from the emergency spillway. The mapping is somewhat outdated by standards and methodologies utilized at the present by the District. The EBASCO inundation mapping should be revised based on new downstream topographic mapping and changes in downstream development and drainage patterns.

Downstream inundation mapping for the Apache Junction FRS is also provided in the "Emergency Operations Plan" prepared by the Maricopa County Department of Emergency Management. Appendix G of the Plan specially provides emergency response to Storms and Floods within Maricopa County. Within this Appendix are subappendices for each of the County owned dams with County responses/actions as a result of a dam failure. Appendix 23 of General Appendix G provides specific information for Apache Junction FRS. Appendix 23 also provides a crude inundation map downstream of the dam. The map appears to be a compilation of the three inundation map limits prepared by EBASCO as part of their inundation study.

The District recently completed a restudy of the downstream inundation flooding limits from discharges from the emergency spillway. The study was completed in July 2000 and was conducted on behalf of the District by Michael Baker Jr. Inc. (FCD Contract No. 98-33). The study limits from upstream to downstream were from the emergency spillway to the Central Arizona Project canal (a distance of approximately 4.7 miles). The study examined the inundation limits for spillway discharges for the full PMF, the 2/3 PMF, and the 1/3 PMF. The full PMF emergency spillway discharge used in the study was 10,500 cfs which is relatively the same freeboard hydrograph emergency spillway discharge determined by EBASCO in 1986 (10,600 cfs).

The Baker study estimated, using the U.S. Army Corps of Engineers HEC-RAS model, for each discharge, downstream inundation limits, flood travel times, average flow velocities and flow depths, and computed water surface elevations. The flooding limits are depicted on aerial topographic mapping at a scale of 1-inch to 200-ft at a contour interval of 2-feet. The Baker study notes that there are potential flows discharging from the emergency spillway that could overtop the Central Arizona Project canal and continue to flow downstream (southwest) from the canal. This mapping should be used as part of the Apache Junction emergency action plan.

Sedimentation - The sediment storage requirements for the FRS is based on local stock pond surveys, studies of sediment sources, and factors that influence sediment yields. The major sources of sediment are from all areas above the dam site.

The NRCS report titled "Sedimentation Buckhorn-Mesa Watershed 1974 Supplement" provides the sediment storage requirements for Apache Junction FRS. The results of this report were used by EBASCO Services in their analysis and design of the dam. The sediment storage requirements for Apache Junction FRS was determined based on a sediment yield of 0.21 acre-feet per square mile per year and a trap efficiency of 70 percent. The 100-year period sediment volume required was calculate to be 95 acre-feet based on a (1974) drainage basin area for Apache Junction FRS of 6.30 square miles.

Capacity Analysis - In March 1997, the District reanalyzed the capacity for the Apache Junction FRS based on new aerial topographic mapping provided as part of FCD Contract 93-51. The District developed new stage-storage-area curves and computed the time to evacuate a full impoundment pool. The District study found the crest of the emergency spillway elevation to be 1801.92 ft (NAVD 1988) which is a gage height of 16.0 ft for a storage capacity of 676 ac-ft. The time to drawdown this volume of water was estimated at 4.6 days assuming no inflow into the impoundment or clogging of the principal spillway.

A District analysis conducted in July 1997 compared the design capacity versus the March 1997 computed capacity. The design emergency spillway crest elevation is 1799.75-ft while the FCD 93-51 study determined the crest elevation to be 1801.92 ft or a difference of 2.17 ft. The design capacity of Apache Junction FRS at the emergency spillway crest is 501 ac-ft while the District study estimated the capacity to be 676 ac-ft or an increase of 35 percent.

Section 4.0 of the Part IV provides recommendations for further investigations and analyses for Apache Junction FRS. A discussion is presented recommending a new 100-year HEC-1 hydrologic model for Apache Junction be prepared based on the revised rating curves developed by the District as a result of the aerial mapping provided under Contract FCD 93-51. A re-evaluation of the 100-year storage volume should be conducted with this revised information.

Geotechnical/Geological - Regional Geology

The Apache Junction FRS is located within the Sonoran Desert section of the Basin & Range Physiographic Province near the boundary with the Mexican Highlands Section. The latitude and longitude of the center part of the structure is approximately 33°26'12"N and 111°32'44"W based on NAD 27 datum. This portion of the Basin and Range Province is characterized by northwest, north, and northeast trending mountains that rise abruptly to form broad, elongated, deep, sediment-filled valleys produced by block faulting and folding (Geological Consultants Inc., 1999) during past episodes of mountain/basin bounding fault movements (Cooley, 1977). The section boundary is defined on the north and northeast by the McDowell, Usery, Goldfield and Superstition Mountains and on the south by the Phoenix Basin.

The McDowell and Usery Mountain are composed of pre-Cambrian granitic and metamorphic rocks including granite and schist that is often overlain by early to middle Tertiary sedimentary and volcanic rocks. The Goldfield and Superstition Mountains are composed primarily of Tertiary volcanic rocks consisting of andesite, rhyolite, latite and dacite flows and tuffs. The bedrock is also locally overlain by Quaternary age (younger than 1.6 million years ago (mya)) alluvium. The Phoenix Basins, formed by the down faulted blocks, have been partially filled with material eroded from the higher surrounding mountain ranges. With incision of the Salt River and tectonic disturbances in Tertiary time, subsequent stream rejuvenation, combined with climatic changes in early Quaternary time, terraces were developed along the Salt River. These terraces are reportedly buried under valley fill deposits downstream in the Phoenix Basin (Pewe, 1978; Ertec-Western, 1981).

Alluvial materials deposited in the basins consist of heterogeneous unconsolidated mixtures of clay, silt, sand, and gravel which locally contain cobbles and boulders (see Figure 2-1). Near the mountain fronts the older alluvial deposits are commonly well cemented with caliche to a rock-like consistency at depths of two to twenty feet (FCDMC, 1963).

This material grades from coarser to finer grained with increasing distances from their sources in the surrounding mountains and are variably cemented by calcium carbonate. Rock hills and knobs protrude through the alluvial materials (USBR, 1982 & 1986) as evidenced by Double Knolls, located about six miles to the southeast and Saddle Rock about 3½ miles northeast of Apache Junction FRS. During the Pleistocene Epoch when climatic conditions were much wetter than current conditions, the alluvial basins south of the study area were charged through the percolation of excess water flows. This initial charging created large groundwater basins with abundant groundwater resources that in turn have influenced greatly recent development in south central Arizona.

According to the SCS (1983), the depth to groundwater near the Apache Junction FRS is unknown but it is at least several hundreds of feet deep. The project site is reportedly outside the limit of the deep basin fill water bearing unit. Groundwater is probably restricted to small volume held in joints and fractures within crystalline granitic bedrock that underlies the thin surface alluvium. As with the Signal Butte FRS, water level changes in the Apache Junction FRS area should have no impacts related to ground subsidence.

Regional Seismicity

An abbreviated discussion of seismicity and faulting was presented in the original Geologic Investigation report prepared by the SCS (1983). The report stated, "There is no record of recent seismic activity within a 100-mile radius of the Apache Junction FRS structures. Within a radius of 100 miles, several earthquake epicenters and Quaternary fault traces are shown on the following map (see Figure 2.2). The nearest large recorded earthquake, which was approximately 150 miles away occurred in 1958. It measured between 5 and 5.9 on the Richter scale. Apache Junction FRS is located in seismic zone 2, which has a minimum seismic coefficient of 0.10."

A comprehensive evaluation of Arizona seismicity for the development of seismic maps for the State of Arizona was conducted for the Arizona Department of Transportation (ADOT, 1992). The ADOT database was used to prepare the following updated description of seismicity and faulting that might potentially impact the Apache Junction FRS.

Historic seismicity within a 100-mile radius of Apache Junction FRS is documented for the period from 1776 through May 2000 (Dubois et al, 1982; U.S.G.S., 2000). Several earthquake epicenter locations are depicted on Figure 2.3 within a 100-mile radius of the FRS. Fault structures identified from recent work by ADOT (1992) are depicted on Figure 2.4 for faults within a 100-mile radius from the FRS and on Figure 2-5 for structures within a 25-mile radius. Tables summarizing the seismic source zones or faults, along with their length, estimated displacement, and associated maximum credible earthquake are provided in Table 2-2 and Table 2-3.

Apache Junction FRS is located in the Basin and Range Province in the southwestern portion of Arizona, including Maricopa County and portions of Pinal County, and is just within the Arizona Mountain seismotectonic zone (ADOT, 1992) (Figure 2-2 and 2-3). This zone represents a distinct, coherent crustal block with distinctive seismic activity and its own characteristic earthquake potential. The following paragraphs, excerpted from ADOT (1992), describe the zones' seismotectonic characteristics:

Arizona Mountain Zone: This zone has an area of about 38,000 square miles and forms an arcuate belt around the southern margin of the Colorado Plateau and the Plateau margins seismotectonic zones. The Arizona Mountain Zone encompasses a variety of mountain ranges, plateaus, and valleys between the relatively flat, high elevation Colorado Plateau to the north and the lower elevation Sonoran Zone to the southwest. Geomorphic features (mountains and valleys) were produced by erosional down cutting related to regional uplift and extensional block faulting (ADOT, 1992).

Rock units exposed within the mountainous areas are composed of nearly every rock type in the state. Predominant rock types are Precambrian igneous and metamorphic rocks and Mesozoic through Tertiary age volcanic and sedimentary rock. The wide variety of rocks is a direct result of uplift, extensional faulting, and erosion of the fault blocks exposing the deeper and older basement crystalline rocks that the overlying stratigraphic sequence.

Major neotectonic (post-Miocene age) faults, typical of the Basin and Range tectonic style, lie near the valley margins and separate down-dropped valley blocks. This zone has abundant hot spring activity and a high heat flow. The rate of faulting is slow. Major down faulted block structures are Aubry Valley, Chino Valley, Verde Valley, Tonto Basin, northern San Pedro Valley, northern San Simon Valley, Lordsburg Basin, and San Augustin Plain. In Arizona, major faults and their corresponding fault block structures generally trend north-northwesterly and northwesterly. Faulting is characterized by several young Quaternary age northwest-southeast trending normal faults such as those found in the Verde Valley and Chino Valley located north of Prescott, Arizona.

Seismicity in this zone includes small and moderate magnitude earthquakes. The largest recorded earthquake (magnitude 5.2) epicenter occurred near Prescott in February 1976, which is within a 100-mile radius of the Apache Junction FRS. The maximum earthquake associated with this zone's characteristic fault, the Big Chino Fault, is expected to be about magnitude 7.25. The maximum random earthquake, not considering discrete fault zone seismic sources, is expected to be about magnitude 6.75. Recurrence intervals determined from field investigations are estimated to be 20,000 to 30,000 years (ADOT, 1992)

Three other seismotectonic zones are within a 100-mile radius of the Apache Junction FRS including:

- Sonoran Seismic Source Zone
- Southwestern Plateau Margin Zone
- Southeastern Plateau Margin Zone

Sonoran Seismic Source Zone: Apache Junction FRS is approximately 3½ miles east of the Sonoran Seism Source Zone. The Sonoran seismic zone encompasses approximately 58,900 square miles in southwestern Arizona, southeastern California, and Mexico. The Sonoran zone is characterized by small, scattered mountain ranges (Harquahala Mountains, Big Horn Mountains, Gila Bend Mountains, Maricopa Mountains, South Mountain, Phoenix Mountains, White Mountains, Sierra Estrella Mountains, Sand Tank Mountains and San Tan Mountains) and large flat plains and valleys (Harquahala Plains, Hassayampa Plain, Rainbow Valley, Salt River Valley, Paradise Valley, and Chandler Basin). Some of these ranges and valleys are locally aligned but overall the province has no preferred directional trends. Mountains constitute approximately 20 percent of the total province area and are generally surrounded by broad pediments indicating relative geomorphic maturity. Elevations range from approximately 500 feet to 1,500 feet in the valleys to about 3,000 to 4,000 feet in the mountainous areas. Generally, local relief rarely exceeds 2,500 feet and is generally about 1,000 to 2,000 feet.

Geodetic data suggests the Sonoran zone is tectonically stable compared to the tectonically active regions in California (Burford and Gilmore, 1982). The geomorphology of river terraces along the Colorado and Gila Rivers provides longer-term verification of this tectonic stability (Schell and Wilson, 1982; Arizona Public Service Company, 1974) indicating no substantial crustal warping during late Quaternary time.

Although the Sonoran zone exhibits basin-and-range-type geologic structure, it has not experienced extensive block-faulting typical of the tectonic regime since Pliocene and possibly late Miocene time (Schell and Wilson, 1982; Menges, 1983). Presently, the zone has very little tectonic activity. Earthquakes are rare and of small magnitude and the faults are very minor. The Sonoran zone is relatively aseismic compared to adjacent zones to the northeast and southwest. The largest historical earthquake within the Sonoran zone was the magnitude 5.0 event that occurred in the southern part of the zone in 1956. The maximum credible earthquake is estimated to be Mw = 6.5 although events this large should be exceedingly rare.

In this vast zone there are only a few young faults and these are very minor features. Except for the Sand Tank fault, most of these faults are in proximity to the Colorado River Trough near Blyth, Needles, and Topock. These faults are short (two to eight miles) and discontinuous with low, subtle scarps indicating low rates of activity and small-magnitude earthquakes. For determining the zone recurrence interval, earthquakes of magnitude 6 were assumed to have been associated with these surface ruptures. The age of these events are poorly constrained but they appear to have occurred over the latter part of the Quaternary. Assuming that they occurred within the past 105 years, the average recurrence for the zone as a whole would be about 25,000 years. In addition to such events associated with surface rupture, similar recurrences should be expected for random earthquake events.

In summary, the Sonoran zone represents a nearly stable block between tectonically active regions to the northeast and southwest. The zone can be distinguished by its paucity of earthquakes, few short Quaternary age faults, mature physiography, and thin crust.

Southwestern Plateau Margin Zone: Apache Junction FRS is approximately 65 miles southwest from the boundary of the Southwestern Plateau Margin Zone. The southern margin of the zone is near the Mogollon Rim, a prominent escarpment marking the edge of the Colorado Plateau physiographic province (ADOT, 1992).

Rocks of the zone primarily comprise upper Paleozoic and lower Mesozoic sedimentary rock and volcanic rocks that are of predominantly Cenozoic age including those of the Pliocene and Pleistocene Epoch.

The Southwestern Plateau Margin Zone has numerous neotectonic faults. These faults comprise numerous minor features of short length to several major lengthy faults with relatively small displacement. The largest of these faults are the Sinyala-West Kaibab system and the Bright Angel system.

Seismicity of the zone is one of the more active in Arizona with about the same number of earthquakes as the Arizona Mountain Zone. The largest recorded event was the 1959 Fredonia earthquake of about magnitude 5.6. Reanalysis of the 1912 Grand Canyon/Marble Canyon earthquake resulted in an estimated magnitude of 6.2. There is no evidence of modern surface faulting in the zone. The maximum credible earthquake is estimated to be about Mw = 6.5.

The Southwestern Plateau Margin seismic source zone is characterized by low-activity Quaternary age faults and moderate seismicity. It is differentiated from the Arizona Mountain Zone by is physiography and lower rate of faulting activity, and from the Southeastern Plateau Margin zone by its higher seismicity and more numerous neotectonic faults.

Southeastern Plateau Margin Zone: At its closest point, the Apache Junction FRS is approximately 64 miles southwest from the boundary of the Southeastern Plateau Margin Zone. The southern margin of this zone extends from the central part of the Mogollon Rim eastward to the Rio Grande Rift zone in New Mexico. (ADOT, 1992).

Rocks of this zone are similar to those found in the Southwestern Plateau Margin zone. Cenozoic age volcanic rocks occur in three major fields: the Springerville, the Zuni-Bandara, and Mount Taylor volcanic fields.

Similar to the Southwestern Plateau Margin Zone, the Southeastern zone has several neotectonic faults that are expressed in the same northeast and northwesterly intersecting pattern. Very few Quaternary faults are known to exist in this zone. This may be partly due to some faults being covered by extensive late Quaternary age volcanic flow (ADOT, 1992). This seismic source zone is characterized by low to moderate historical seismicity. There has been no earthquake with a magnitude in excess of five. The maximum credible earthquake is estimated to be about Mw = 6.5.

In summary, the zone is characterized by young volcanic activity, a low to moderate level of seismicity, and few Quaternary faults (ADOT, 1992).

Table 2-2. Summary of Faults & Fault Zones Within 25 Miles of Apache Junction FRS.

Seismic Source Zone Or Fault		Length (Miles)		Displacement		Earthquake
Number	Name/Location	Zone	Longest Segment	Latest Age	Slip Rate	Maximum Credible
141	Sugarloaf Peak Fault: 20 miles West of Roosevelt Dam, AZ	6	3	H	-	6.75
142	Rolls Fault: 20 miles Southwest of Roosevelt Dam, AZ	6	3	L/M & E/P	-	6.5
144	Picketpost Mountain Fault: 7 miles West of Superior, AZ	3	-	?	-	6.5

- See Figures 2-3 and 2-4 for a listing of abbreviations and meanings.

Table 2-3. Summary of Faults & Fault Zones within 100 Miles of Apache Junction FRS.

Seismic Source Zone Or Fault		Length (Miles)		Displacement		Earthquake
Number	Name/Location	Zone	Longest Segment	Latest Age	Slip Rate	Maximum Credible
21	Railroad/Verde River: 9 miles North-northwest of Cottonwood, AZ	12	-	?	-	6.75
22	Verde Fault: Southwest side of Verde Valley, Yavapai County, AZ	38	17	H/L	0.01 to 0.05 mm/year	7.25
36	Sand Tank Fault: 7 miles East-Southeast of Gila Bend, AZ	2	-	H	0.01 to 0.04 mm/year	6.5
91	Date Fault: Northwest of Wickenburg near town of Date, AZ	2	-	?	-	6.5

Seismic Source Zone Or Fault		Length (Miles)		Displacement		Earthquake
Number	**Name/Location**	**Zone**	**Longest Segment**	**Latest Age**	**Slip Rate**	**Maximum Credible**
92	Wagoner Fault: 20 miles northeast of Wickenburg, AZ	4	-	?	-	6.5
93	Lake Pleasant Fault: North of Lake Pleasant, 36 miles North-Northwest of Phoenix, AZ	3	-	?	-	6.5
123	Munds Park Fault Zone-North Segment: 5 miles West of Flagstaff, AZ	15	7.5	M/E	-	7.0
129	Chavez Mountain Faults: 40 miles SE of Flagstaff, AZ; SE side of Chavez Mountains	25	10	?	-	6.75
130	Turret Peak Fault: 22 miles South of Camp Verde, AZ	7	-	Qy	-	6.75
131	East Verde River Fault: 14 miles West of Payson, AZ	4	-	?	-	6.75
132	Deadman Creek Fault Zone: 30 miles Northeast of Carefree, AZ	11	-	?	-	6.75
133	Horseshoe Dam Fault Zone (Tangle Peak Fault): 18 miles Northeast of Carefree, AZ	13	7-8	L/M	0.007 mm/year	6.75
134	Seven Springs Fault: 13 miles North of Carefree, AZ	3	-	?	-	6.5
135	Carefree Fault: 5 miles East of Carefree, AZ	8	4	?	-	6.5
136	Alder Creek Fault Zone: 26 miles Northwest of Roosevelt Dam, AZ	7	4	Qy	-	6.5
137	Tonto Basin-Northwest Fault: Southwest side of Roosevelt Lake, AZ	9	3	?	-	6.5
138	Tonto Basin-Central Fault (Punkin Center Fault): 10 miles Northwest of Roosevelt Dam, AZ	3	2	?	-	6.5
139	Two Bar Mountain (North & South): 2 miles Southeast of Roosevelt Dam, AZ	2	-	?	-	6.5
140	Gold Gulch Fault-West Branch; Southwest side of Roosevelt Lake; 11 to 24 miles NW of Globe, AZ	6	-	?	-	6.5
141	Sugarloaf Peak Fault: 20 miles West of Roosevelt Dam, AZ	6	3	H	-	6.75
142	Rolls Fault: 20 miles Southwest of Roosevelt Dam, AZ	6	3	L/M & E/P	-	6.5
143	Miami Fault: West Side of Miami, AZ	12	-	?	-	6.75
144	Picketpost Mountain Fault:	3	-	?	-	6.5

Seismic Source Zone Or Fault		Length (Miles)		Displacement		Earthquake
Number	Name/Location	Zone	Longest Segment	Latest Age	Slip Rate	Maximum Credible
	7 miles West of Superior, AZ					
145	China Wash Scarp: 6 miles Northeast of Florence, AZ	3	-	?	-	6.5
146	Muscal Creek Fault: Muscal Mountains, 16 miles Southeast of Globe, AZ	3	-	?	-	6.5
147	Antelope Flat Scarps: 28 miles East of Globe, AZ	3	-	?	-	6.5
148	Mammoth Fault: 22 miles Southeast of Hayden, AZ0	9	-	?	-	6.5
149	San Manuel Fault: 8 miles East of San Manuel, AZ	4	2	?	-	6.5

* See Figures 2-3 and 2-4 for a listing of abbreviations and meanings.

Site Geology and Soils

The Apache Junction FRS is located in Apache Junction approximately two and one-half miles south of the Goldfield Mountains and about two miles southwest of Saddle Rock. Alluvial fans extending from the mountain front off the Goldfield Mountains coalesce to form the broad, gently sloping surface of the alluvial basin. The topography of the area consists of sparsely vegetated, flat desert interrupted by narrow, shallow washes where vegetation is concentrated. The ground surface slopes downward to the west-southwest. Depth to granite bedrock is estimated to range from about 50 feet to 200 feet below ground surface in the FRS area.

The Apache Junction FRS is founded on the lower end of a pediment of primarily unconsolidated and semi-consolidated alluvial fan deposits of Quaternary-Tertiary age. Ephemeral stream channels cut across the dam centerline. Surface drainage is toward the south and southwest from the Goldfield Mountains. Caliche-cemented alluvial fan deposits are exposed in many of the washes. The exposed caliche is hard, dense, well-cemented, and usually contains gravel. Overlying, younger alluvial fan soils are composed unconsolidated to semi-consolidated sand with varying amounts of silt, clay, and gravel.

The geotechnical investigation along the dam centerline included 16 drill holes and 38 test pits. Standard Penetration Tests (SPT's) were made in all drill holes. Test holes were drilled to depths ranging from 15 to 30 feet. Most test pits were excavated to the caliche layer. Field permeability tests were conducted at three locations using the permeameter method. The test were mainly in the caliche (SCS, 1983). Results of the field permeability test are summarized in Table 2-4 on the following page.

Table 2-4. Field Permeability Test Results Apache Junction FRS.

Station	Test Interval	Permeability (ft/day)	Material
91+00	2.5 to 10 feet	1.8	Caliche
91+00	2.5 to 20 feet	0.43	Caliche
97+00	30 feet	0.37	Caliche

According to the SCS (1983), surface soils along the dam centerline consist of silty sand (SM) with some gravel. Other soils present include fine to coarse-grained silty, clayey sand (SM-SC) with some gravel. Slightly silty, fine to coarse-grained sand (SM-SP) is found in the recent stream channels. Layers of non-plastic silt (ML) were found at Station 52+50 at depths ranging from 3½ feet to 20 feet and at Station 44+25 from 13 to 20 feet below ground surface.

Caliche cemented soils underlie the entire site at depths ranging from less than one foot to more than 20 feet. The greater depths to caliche are found at the east end of the dam (Station 29+50) to about Station 67+50. The surface of the caliche is irregular where the caliche is deeper but toward the west the caliche becomes more shallow with a more uniform surface relief. The caliche varies from fairly soft to hard and from poorly to moderately cemented. The caliche breaks down to silty gravelly sand with some large cobble-size fragments.

Four dispersion tests were conducted on soil samples obtained in the dam foundation. The test results are summarized in the following table:

Table 2-5. Dispersion Test Results Apache Junction FRS.

Location	Classification	% Passing #200 Sieve	Dispersion* (%)
58+90	SC	25	20
53+90	CL	64	20
53+90	CL	60	13
53+90	ML	53	6

* most likely a double hydrometer test

According to EBASCO (1986), dispersion values greater than 20 to 25 percent are usually indicative that dispersion may be a problem whereas values greater than 50 percent strongly indicate the soil is susceptible to erosion. Based on the tabulated results, dispersion is not a concern at the Apache Junction FRS. However, EBASCO recommended additional tests because the limited number of soil tests may not be representative of the overall dispersive characteristics of the soils present at Apache Junction FRS.

Ground-water in the immediate site area is poorly defined because the shallow alluvial sediments are barren and the underlying granitic basement that contains water in joints and fractures, does not effectively transmit water. According to the SCS (1983), regional water levels in the dam site area is about 150 to 200 feet below ground surface (elevation 1690 MSL). Because of the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment, subsidence due to groundwater withdrawal should not be a problem at the Apache Junction FRS.

Stability analysis of the FRS embankment with a homogeneous section and a filter zone supports the selection of 2½:1 and 2:1 slopes on the upstream and downstream sides of the embankment (EBASCO, 1986). A slope stability analysis using Bishop's Simplified Method was conducted for a critical cross section of the Apache Junction FRS using the SLOPE II computer program. EBASCO also used their own in-house Slip Circle computer program to determine the stability of a few selected cases. In addition, an infinite slope stability analysis was performed (EBASCO, 1986).

Slope stability analyses using both the slip circle and the infinite slope methods were performed to meet the requirement of SCS Technical Release No. 60 and the project Phase I design criteria that are summarized as follows:

1) End of construction without seismic forces.
2) Reservoir at freeboard storm elevation (+1809.4 feet) without seismic forces.
3) (a) Reservoir at crest of emergency spillway (elevation 1799.7 feet) and steady state seepage without seismic forces.
   (b) Reservoir at crest of emergency spillway (elevation 1799.7 feet) and steady state seepage with a horizontal ground acceleration of 0.10g (pseudostatic condition).
4) Complete sudden drawdown condition with reservoir initially at crest of emergency spillway (elevation 1799.7 feet).

It was Ebasco's opinion that the steady state seepage and rapid drawdown conditions (loading conditions 1 and 2) would not be applicable in the analysis of the stability of the Apache Junction FRS under the current (1986) operating criteria which stated that the "FRS will mitigate the flood peak by storing water behind the embankment over a period of 10 days or less" (EBASCO, 1986).

Based on the results of the Ebasco embankment stability analysis, the Apache Junction FRS does not completely satisfy current ADWR embankment stability criteria nor did it completely satisfy the SCS criteria at the time of the original investigation. Ebasco argued (October 1986) that steady state seepage and rapid drawdown loading conditions would not be applicable for the Apache Junction FRS because of the current (1986) operating criteria that states in part that impounded water would only be stored behind the embankment for 10 days or less. This argument was apparently acceptable to the SCS even though they suggested in their design review comments (08/12/85 and (08/15/85) that steady state and rapid drawdown conditions should be analyzed and considered.

Considering the high hazard classification for the Apache Junction FRS and because the original design analysis does not apparently meet current ADWR embankment stability criteria (nor did it meet SCS criteria at the time of the design investigation), it is recommended the embankment stability be re-evaluated based on the current conditions and design criteria.

Results of the slope stability analysis are summarized in Table 2-6.

Table 2-6. Slope Stability Analysis Results.

Loading Condition	Slip Circle Analysis		Infinite Slope Analysis	
	W/O Seismic	**W/ Seismic**	**W/O Seismic**	**W/ Seismic**
(1) End of Construction (downstream slope)	1.65 (1.4)	Not Applicable	1.51 (1.1)	Not Applicable
(2) Reservoir @ freeboard storm elevation (downstream slope)	1.65 Not required	1.32 Not req'd	Not req'd	Not req'd
(3) Reservoir @ crest of emergency spillway & steady state seepage (downstream slope)	1.24 (1.5)	0.97 (1.1)	0.78 (1.1)	0.62 (1.1)
(4) Sudden Drawdown (Upstream slope)	0.87 (1.3)	Not Applicable	0.83 (1.1)	Not Applicable

Note: Failure modes for loading condition 1 and 2 are shallow circles. Factors of safety values in parentheses are required safety factors as per SCS Technical Release No. 60.

The limited amount of soil testing could not characterize the collapse potential for the soils underlying the embankment or structures. An SCS estimate states that the embankment transition zone can accommodate about two feet of settlement in the 20-foot high embankment. This estimate combined with the interpretation of "thin" unconsolidated soil between the caliche and the embankment resulted in a decision to do nothing special to deal with potential settlement other than applying additional compaction effort during embankment construction. Also, no provision of embankment camber was made "to allow for settlement" (EBASCO, 1986). The presence of a thick layer of silt (ML) beneath the east portion of the embankment was apparently not factored into the design regarding potential embankment/foundation settlement or collapse. No design settlement analysis was apparently conducted by either the SCS or EBASCO.

Reportedly, foundation soils of the principal spillway have similar properties and description to that encountered along the dam centerline (SCS, 1984). Two drill holes in the principal spillway revealed that the depth to the caliche-cemented soil zone ranged from 1½ feet to 3½ feet below native grade. The overlying unconsolidated soils are described as fine to coarse silty, slightly gravelly to gravelly sand (SM, SM-SC). The principal spillway outlets into a unlined floodway cut into caliche thereby minimizing channel stability/erosion problems.

A concrete baffle-block emergency spillway structure is constructed through the dam at Station 97+50. Caliche underlies the structure and the outlet channel and is described as being resistant to erosion; however, test pits revealed the presence of some uncemented zones. To mitigate erosion potential, an energy dissipater is provided by a loose riprap channel ending at a control section of grouted riprap founded in the caliche hardpan. Downstream from the grouted riprap, a control section about 25 feet wide of coarse riprap stone is provided to limit degradation that might occur during flood discharges (EBASCO, 1986). The surface soils in the emergency spillway area are fine to coarse-grained silty gravelly sands (SM) with minor amounts of silty, clayey gravelly sand (SM-SC). Caliche cemented soils underlie the unconsolidated sediments at depths ranging from 3 to 9½ feet. The average depth to caliche is about 4½ feet. The caliche is moderately hard and moderately cemented (SCS, 1983).

The borrow site for soil material needed to construct the Apache Junction FRS was obtained from an area between Stations 46+00 and 104+00 extending about 1,200 feet upstream from the dam centerline. Test pits excavated on centers using a 200-foot by 200-foot grid. Test pits were excavated to caliche to depths ranging between 4 and 6 feet. Drill holes were used at selected locations to obtain samples of caliche. Materials in the borrow area consisted primarily of silty sand (SM) that is brown and for the most part fine- to coarse-grained. The soils are reportedly loose, usually dry, and contain gravel in varying amounts as well as some non-plastic silty fines. About 30 percent of the other soils present in the borrow area include silty, clayey, gravelly sand (SM-SC) and 5 percent to 10 percent clean sand (SP) and slightly silty sand (SM-SP). Caliche-cemented soils underlie the unconsolidated surface soil at depths ranging from the surface to about 15½ feet averaging about 4 feet. The caliche in the borrow area is dry, moderately hard to soft, and moderately cemented to weakly cemented. The caliche is a cemented, silty, gravelly, sand with some cobble-size fragments.

Ground Subsidence

Due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment, subsidence due to ground-water withdrawal is not expected to be a problem at the Apache Junction FRS. It appears that, like the Spook Hill FRS and Signal Butte FRS, the Apache Junction FRS is located on the Usery/Goldfield Mountain granitic pediment with bedrock at a relatively shallow depth (probably less than 200 feet) beneath the FRS structure.

Earth Fissures

Due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment on which the Apache Junction FRS is founded, earth fissuring should not be a issue. The nearest ground subsidence-related earth fissure is about five miles southwest of the Apache Junction FRS of the east site of Double Knoll Hill near the intersection of the Apache Trail at 85th Street.

Subsidence and Earth Fissure Monitoring Program

The Apache Junction FRS is located near an area of active ground subsidence and earth fissures. However, due to the presence of shallow granite pediment in the FRS area and the FRS's proximity to the pediment edge, earth fissuring should have minimal impacts on the Apache Junction FRS. Ground subsidence at the FRS is expected to be negligible. However, the Apache Junction FRS should be included in an area-wide monitoring program because of its proximity to the ground subsidence area and known earth fissures. This recommendation is repeated in Section 4.0.

Construction Plans/Specifications/Construction Methodology - Construction of the Apache Junction FRS was accomplished under contract to the Ashton Construction Company. The completion date for the construction of the dam was December 1988. Construction observation reports are available for this dam and include observation reports by ADWR. A review of the project as-built plans indicated no significant changes were made to the dam design during construction with the exception of deepening of the cut off trench between Stations 32+00 to 67+20, Stations 70+00 to 75+90 and intermittently between Stations 75+90 to 116+85. (see Sheets AJ 1 through 9). Typical dam cross sections show the embankment was constructed symmetrically with respect to the dam centerline and cut-off trench (see Sheet AJ 7). The foundation for the dam was prepared by excavating approximately 3 to 6 feet into existing ground to remove unsuitable materials and to expose the firmer siltstone and caliche layers.

The embankment was constructed in compacted lifts appropriate moisture contents. The primary earthfill embankment material placed in the embankment according to the as-built plans is termed "Earthfill" materials. The source of the "earthfill" materials was borrow material from the reservoir pool area. A materials investigation program was conducted by the NRCS to test the suitability of the native earthen materials found within the reservoir pool for embankment construction. The geotechnical investigations are summarized in the NRCS's July 1983 "Apache Junction FRS-Apache Junction Floodway-Bulldog Floodway, Geological Investigation Report, Buckhorn-Mesa Watershed".

The structure was constructed with a central transition filter as depicted on the typical cross section. A review of the project specifications did not reveal the gradation requirements for the transition fill material for the central filter. A "transition material" gradation is provided, however, this material is for material backfill around the reinforced concrete principal spillway outlet pipe.

Settlement Monitoring – A summary of the District settlement monitoring program is provided in the District paper titled " Settlement Monitoring of Earthen Dams Operated by the Flood Control District of Maricopa County". The paper was prepared by Jan Staedicke in June 1995. The purpose of the report was to:

- Compile settlement monitoring data that has been acquired to date,
- Recommend refinements to the monitoring procedure,
- Recommend a schedule of continued monitoring,
- Recommend that the settlement monitoring procedure be supplemented with a) an earth fissure monitoring procedure, and b) periodic inspection using a team of specialists.

Appendix A of the District report contains a summary that lists each structure and shows the maximum settlement between the years surveyed, and the difference between the design crest and the minimum crest elevation. Appendix B of the District report contains detailed comments regarding each structure, while the last appendix of the District report, Appendix C, contains detailed information for each structure. This detailed information includes a data table showing survey elevations, incremental and total settlement, a plot of the crest settlement monuments, and a plot of the change in crest over the years surveyed.

The contents of the three District report appendices are included with this report (Part IV) as Appendix B. However, only those portions of the District appendices specific to Apache Junction FRS are included in Appendix B. Recommendations for continued settlement monitoring for Apache Junction FRS are provided in Section 4.0 of this Part IV.

Two post-construction level surveys were conducted at the Apache Junction FRS: one in 1989 by the SCS and the other in 1998 by Gilbertson & Associates. According to these records, when compared to the design crest elevation (1,810 feet), apparent embankment settlement ranges from 0.25 feet at the west end of the structure to 0.55 feet at the east end. The settlement reported during the period from 1989 to 1998 was negligible at the Apache Junction FRS. The B-series monument measured at the downstream embankment toe of the structure for the same period 1989 to 1998 showed no settlement had occurred.

KHA has plotted the existing settlement surveys and are provided in Appendix B. It should be noted that the maximum water surface elevation for the PMF was determined by EBASCO Services to be 1809.4-ft. The minimum top of dam settlement monument was surveyed in 1998 at Station 44+77 to be 1809.447-ft. The PMF water surface elevation is essentially at the top of the dam at this location. A PMF flood could potentially overtop the dam.

2.7 Structures Inspection Checklist

A customized inspection checklist for Apache Junction FRS was prepared and is based upon the inspection checklist developed by the Dam Safety Section at ADWR. The inspection checklist for Apache Junction FRS is provided in Section 3.0 of Part IV.

2.8 Maintenance Activities

The Operation and Maintenance Division has an established animal and vegetation control program for District structures, including dams and appurtenant features. The District animal and vegetation control program is documented in a recent District paper (November, 1999) that was presented at the workshop on "Plant and Animal Penetration Earthen Dams" held in Knoxville, Tennessee. A copy of the District's paper is included the Policy & Program Report. The following discussion summarizes these control programs. Further details are referenced in the District paper.

The purpose of the District's vegetation management program for District dams is twofold: (1) to minimize erosion of embankment slopes, and (2) eliminate undesired plant species from the dam crest and embankment slopes. The first purpose is actually part of the District's erosion control efforts to prevent or minimize loss of embankment material due to erosion. The District has a history of application of erosion control measures on their structures. These measures include hydroseeding slopes in attempt to establish a vegetation cover, placement of gravel or rock mulch on the embankment slopes to reduce rainfall impacts and flow velocities, and/or a combination of these two measures.

The District's methodology for establishment of vegetation covers on the embankment slopes presently consists of hydroseeding methods. The procedure is discussed in the District's paper. The paper presents the type of seed mix included in the hydroseeding program.

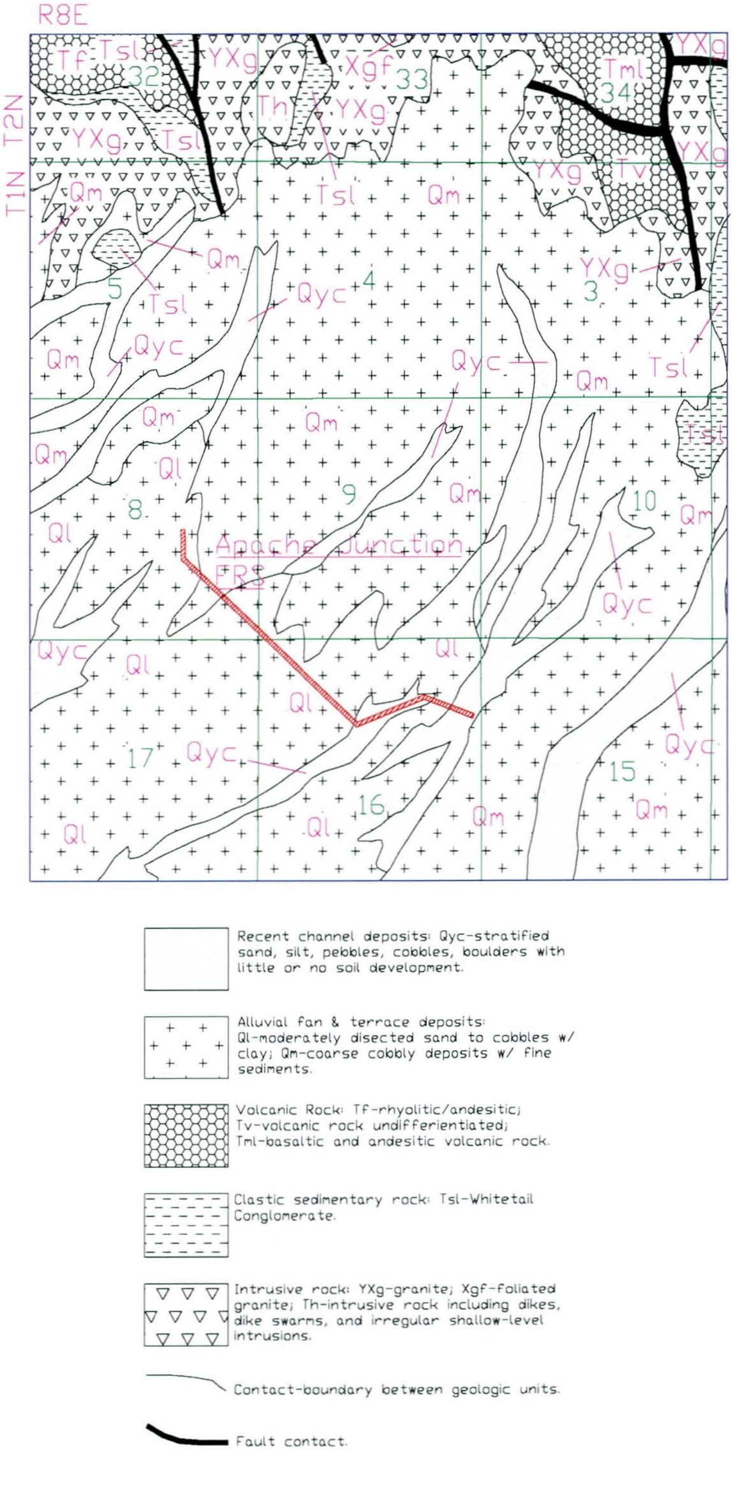
The second purpose of the vegetation management program is to control unwanted plant species, particularly on the embankment slopes. These undesired plant species include all deep-rooted plants typically found in Maricopa County such as desert broom, salt cedar, mesquites, and palo verdes. The method of vegetation control is explained in detail in the District's paper, but includes eradication by herbicides or manual pruning, and trimming by a boom-mower.

District O&M crews maintain low flow channels to principal spillway inlets. The maintenance conducted for the low flow channels consists of eradication of unwanted vegetation within the channel limits and removal of accumulated sediment in the channel bottom. Sediment removal is conducted with the use of a loader and dump truck and conducted on an as-needed basis.

A review of design and as-built plans for Apache Junction FRS indicates that no sediment monuments or markers were installed to monitor sediment accumulation in the reservoir area. Discussions with District staff indicate that very minor activity regarding the monitoring of sediment accumulation has ever been conducted for District impoundment areas. Hardly any sediment removal activities are conducted in the impoundment area. The design reports for the structures, however, do indicate that sediment pools were designed as part of the reservoir. The reports provide the volume of sediment storage available and the elevation of the top of the sediment pool.

District O&M crews conduct maintenance activities at Apache Junction FRS on a regularly scheduled basis. The District has conducted vegetation eradication within the low-flow channel located at the heel of the dam. The low-flow channel takes flows entering the FRS impoundment area and directs the flow towards the principal spillway. The eradication methods include physical removal of unwanted vegetation by clearing and grubbing methods using bulldozers, front-end loaders, and dump trucks. Very little vegetation eradication is conducted within the reservoir pool area outside the low-flow channel. Discussions with District O&M staff indicate that their crews may pick up dead and fallen trees and woody debris within the reservoir pool area, but the extent of the effort and frequency of removal is very limited.

The District performs very minor sediment removal from the inlet and outlet structures of the principal spillway and in the area just upstream of the inlet structure where sediment typically accumulates. Sediment removal from the inlet and outlets structures is typically conducted by hand-labor with shovels and buckets. The buckets are filled and then loaded into an awaiting dump truck. The sediment accumulated upstream of the inlet structure is removed by front-end loader and placed into the dump truck.



Modified from Spencer, J.E., Richard, s.M., & Pearthree, P.A.; 1996; Geologic Map of the Mesa 30' x 60' Quadrangle, East-Central Arizona; Arizona Geological Survey Open-File Report 96-23.

Figure 2-1. Regional Geology Map for Apache Junction

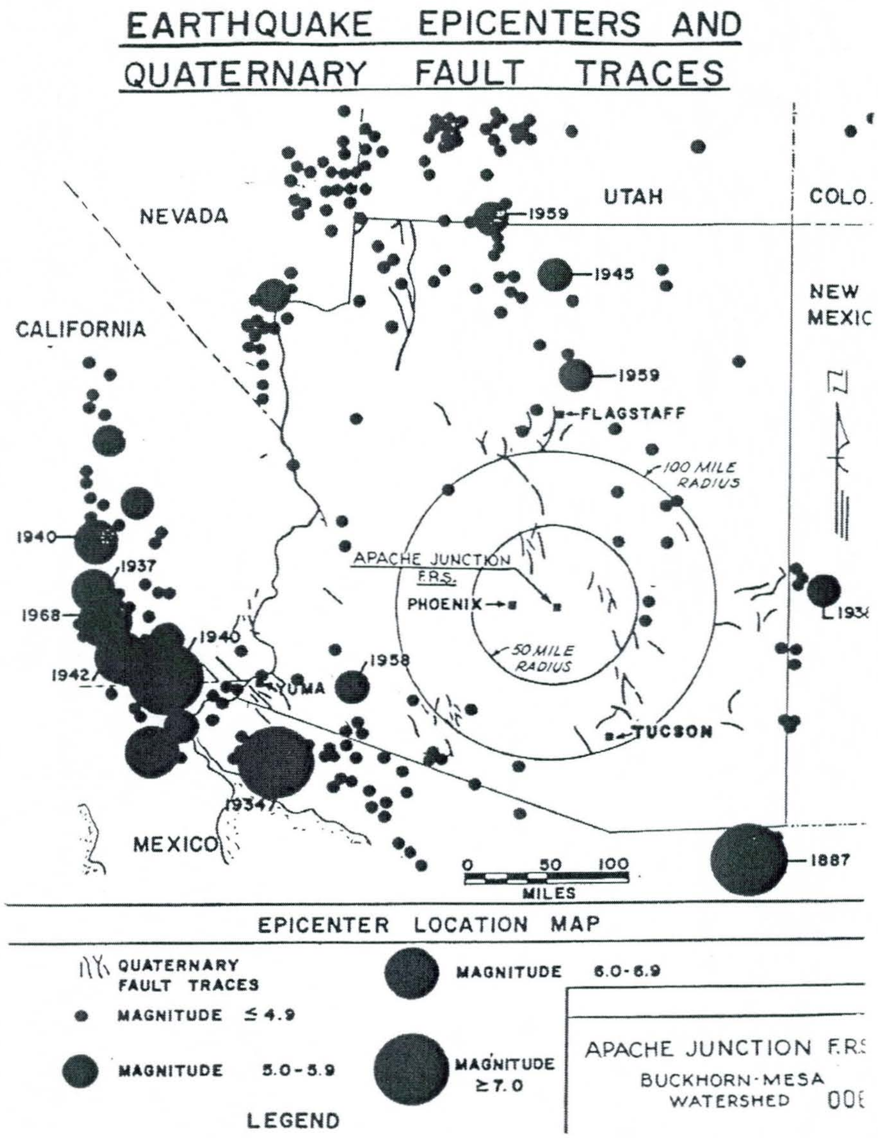


Figure 2-2. Earthquake Epicenters and Quaternary Fault Map (NRCS, 1983).

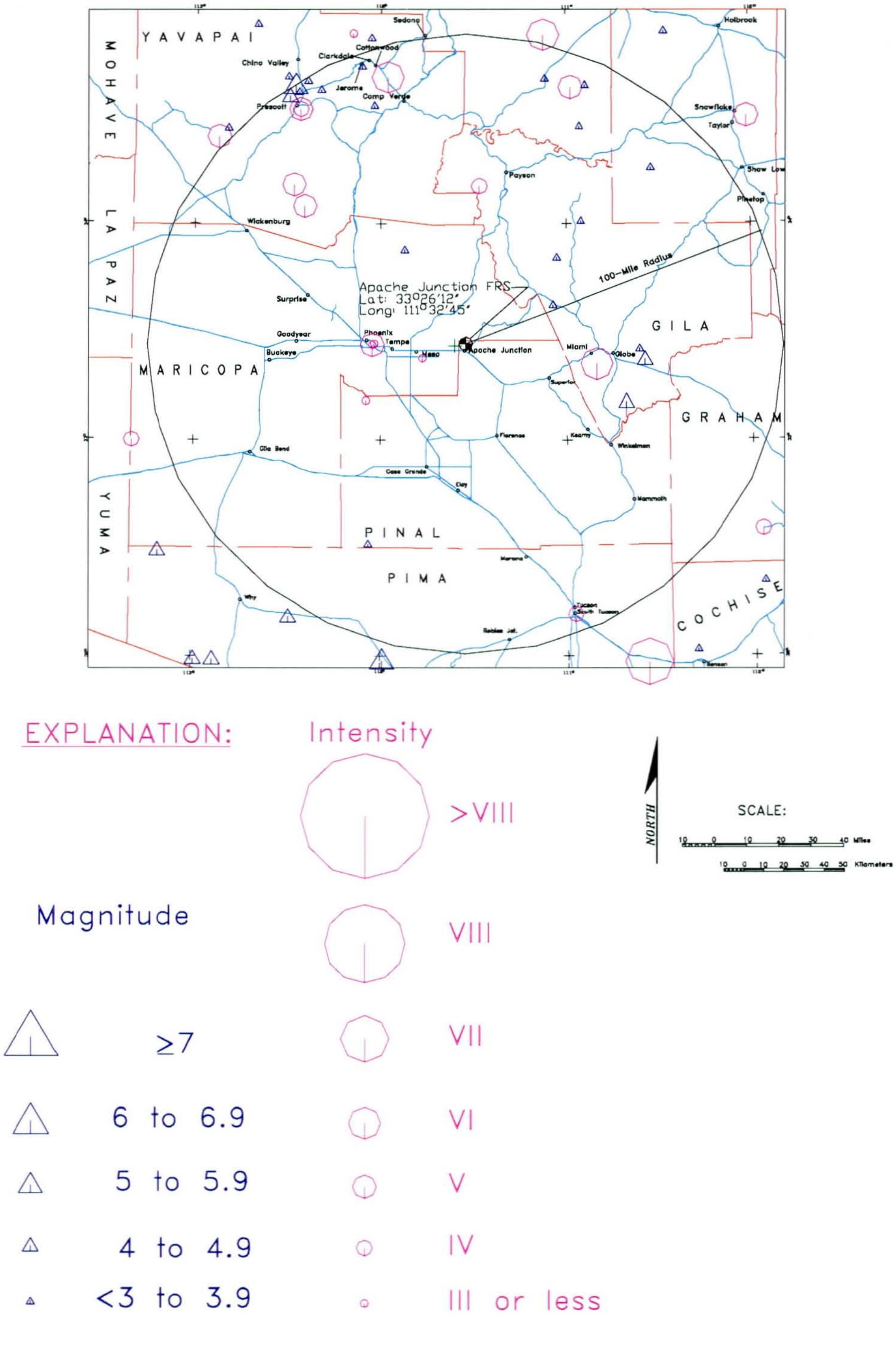


Figure 2-3. Earthquake Epicenter Map: Apache Junction FRS and vicinity.

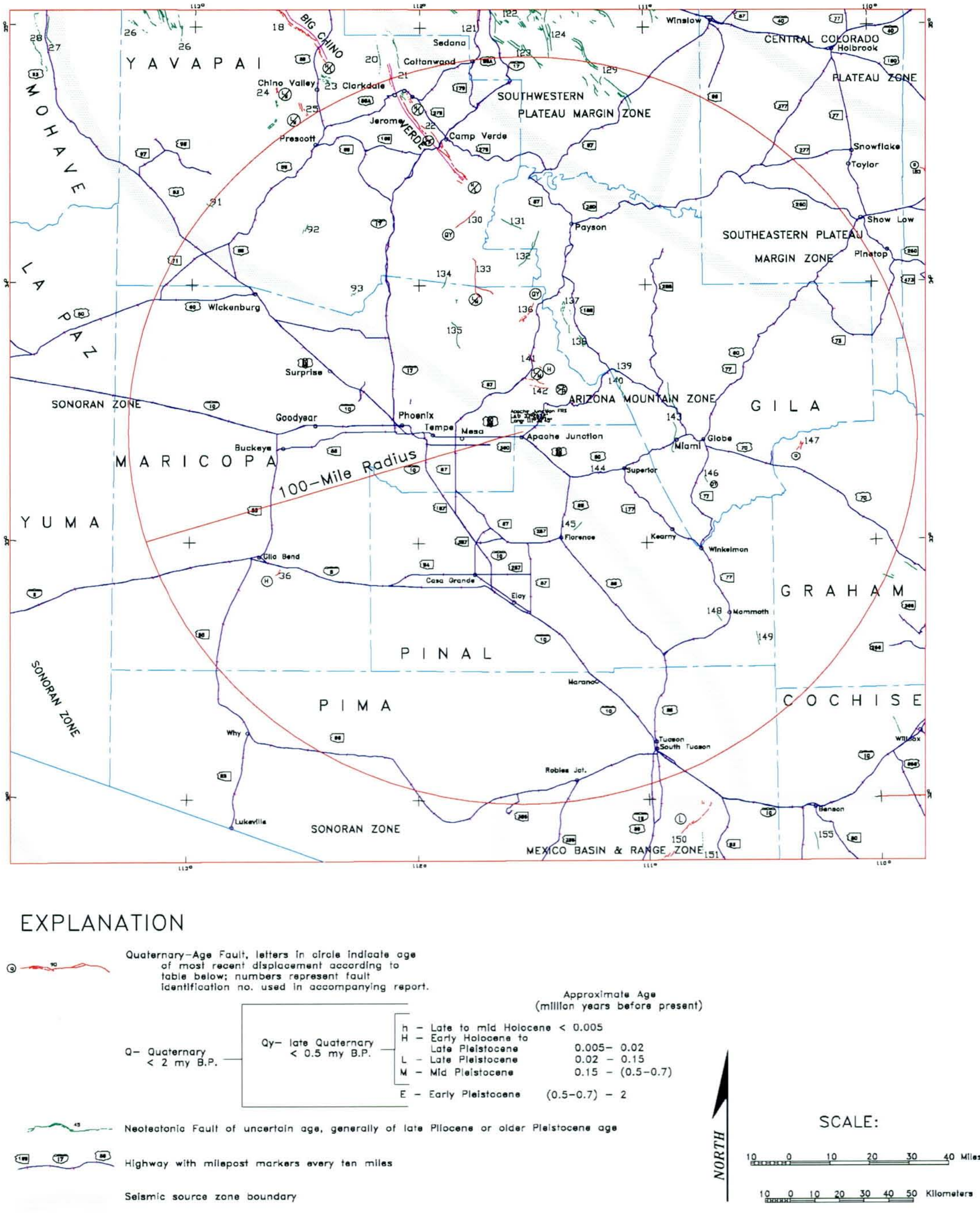
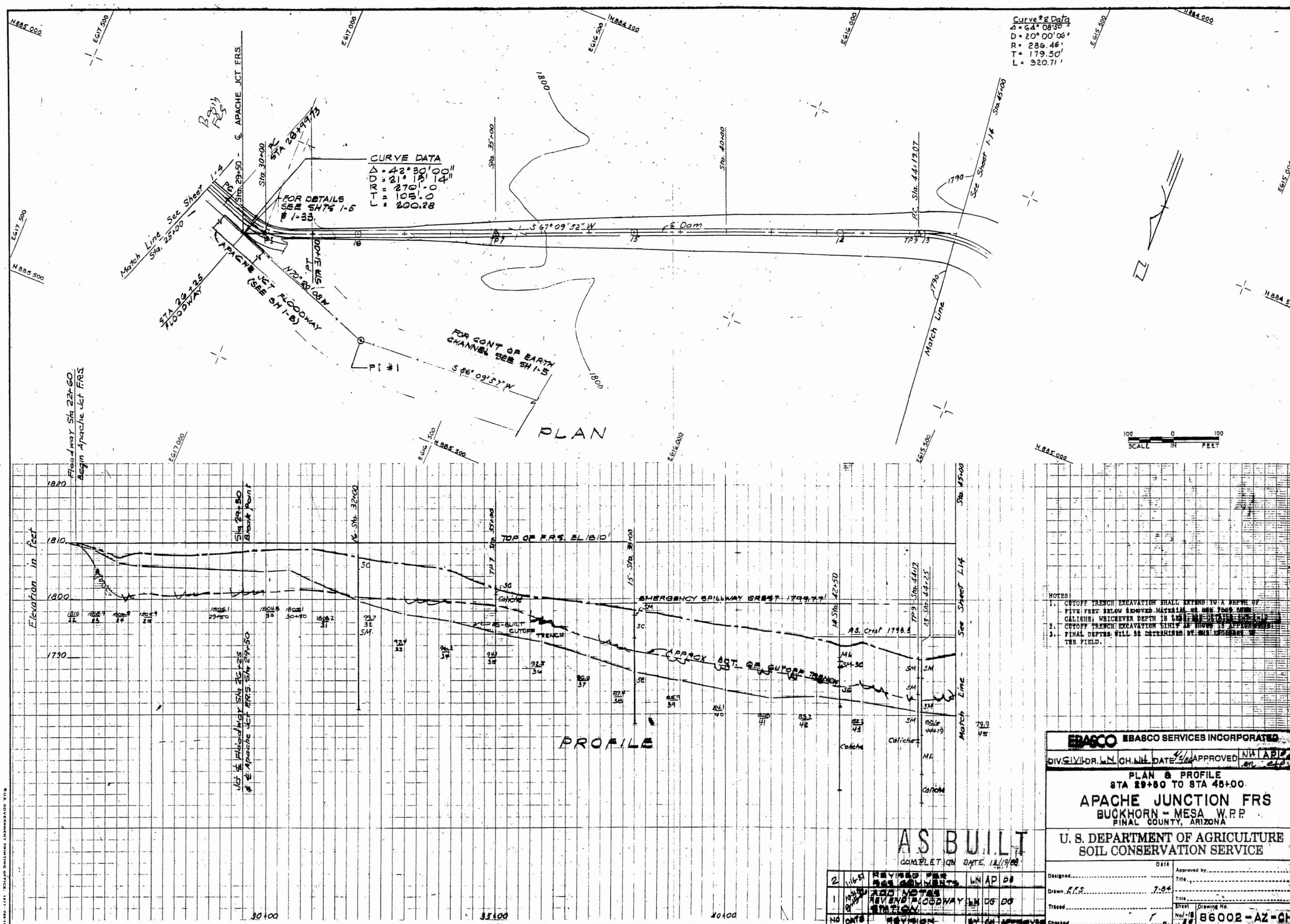
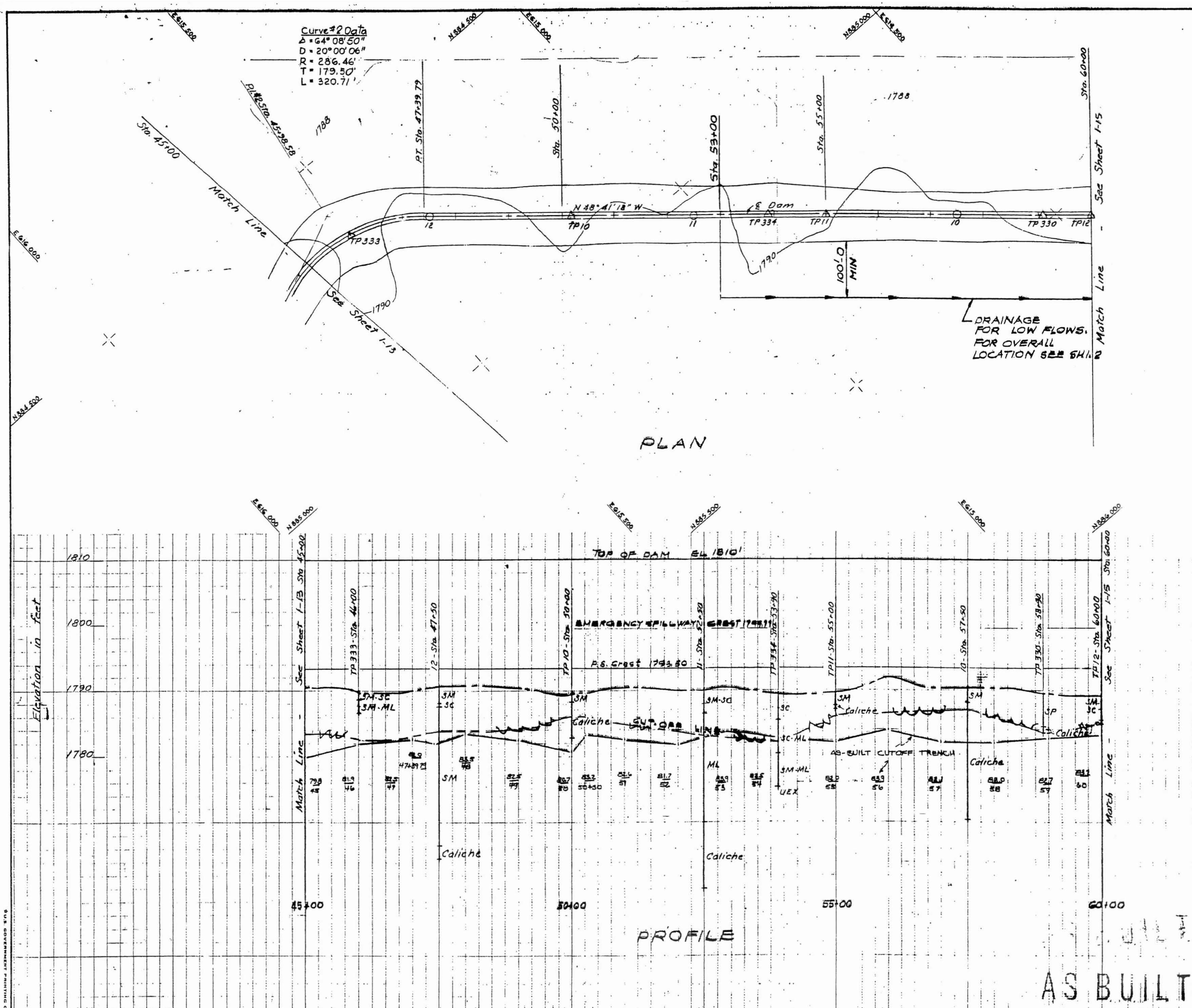


Figure 2-4. Regional Fault Map 100-Mile Radius.


AJ Sheet 1
PLAN
PROFILE
CURVE DATA
Δ = 42°30'00"
D = 21° 13' 14"
R = 270'-0
T = 105'.0
L = 200.28
Curve #2 Data
Δ = 64° 08'50"
D = 20° 00' 06"
R = 286.46'
T = 179.50'
L = 320.71'
℄ APACHE JCT FRS
Match Line See Sheet 1-4 Sta. 25+00
FOR DETAILS SEE SHTS 1-5 & 1-33
APACHE JCT FLOODWAY (SEE SH 1-8)
STA 26+25 FLOODWAY
N70°20'08"W
S 67°09'52"W
℄ Dam
S 86°09'57"W
PI #1
FOR CONT OF EARTH CHANNEL SEE SH 1-5
See Sheet 1-14 Sta 45+00
Match Line
PC Sta 44+17.07
Sta 35+00
Sta 40+00
SCALE IN FEET
Elevation in feet
Floodway Sta 22+60 Begin Apache Jct FRS
Sta 29+50 Break Point
Jct ℄ Floodway Sta 26+25 & ℄ Apache Jct FRS Sta 29+50
TOP OF F.R.S. EL.1810'
EMERGENCY SPILLWAY CREST 1799.77'
AS BUILT CUTOFF TRENCH
APPROX BOT. OF CUTOFF TRENCH
P.S. Crest 1798.5
See Sheet 1-14
Match Line
Caliche
1820
1810
1800
1790
30+00
35+00
40+00
NOTES:
1. CUTOFF TRENCH EXCAVATION SHALL EXTEND TO A DEPTH OF FIVE FEET BELOW REMOVED MATERIAL OR ONE FOOT INTO CALICHE, WHICHEVER DEPTH IS LESS.
2. CUTOFF TRENCH EXCAVATION LIMIT AS SHOWN IS APPROXIMATE.
3. FINAL DEPTHS WILL BE DETERMINED BY THE ENGINEER IN THE FIELD.
AS BUILT
COMPLETION DATE 12/19/88
2 | 1-16-81 | REVISED PER ... COMMENTS | LN | AP | DB
1 | | ADD NOTES REVISED FLOODWAY STATION | LN | DG | DG
NO | DATE | REVISION | BY | CH | APPROVED
EBASCO SERVICES INCORPORATED
DIV. CIVIL DR. LN CH. NH DATE APPROVED
PLAN & PROFILE
STA 29+50 TO STA 45+00
APACHE JUNCTION FRS
BUCKHORN - MESA W.P.P.
PINAL COUNTY, ARIZONA
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Drawn E.F.S. 7-84
Drawing No. 86002-AZ-CH



NOTES:
1. CUTOFF TRENCH EXCAVATION SHALL EXTEND TO A DEPTH OF FIVE FEET BELOW REMOVED MATERIAL OR ONE FOOT INTO CALICHE, WHICHEVER DEPTH IS LESS, SEE DETAILS SHT 1-19
2. CUTOFF TRENCH EXCAVATION LIMIT AS SHOWN IS APPROXIMATE.
3. FINAL DEPTHS WILL BE DETERMINED BY THE ENGINEER IN THE FIELD.

AS BUILT
COMPLETION DATE 12/19/88

NO	DATE	REVISION	BY	CH	APPROVED
2	1-16-87	REVISED PER SCS COMMENTS	LN	AP	DG
1	8.15.86	ADD DRAINAGE DITCH PLAN	LN	DG	DG

EBASCO EBASCO SERVICES INCORPORATED

DIV. CIVIL DR. LN CH. WH DATE APPROVED AP

PLAN & PROFILE
STA 45+00 TO STA 60+00

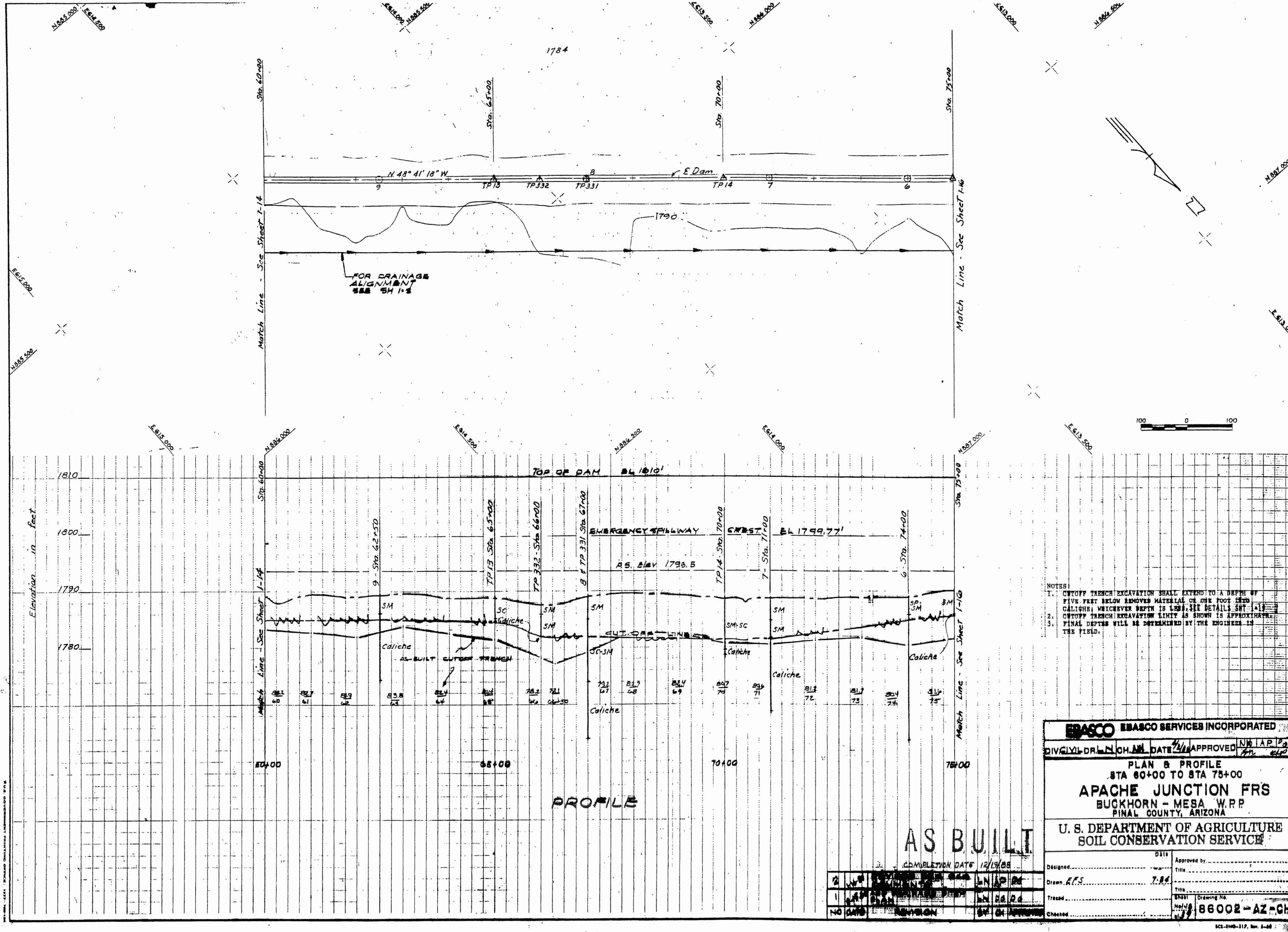
APACHE JUNCTION FRS
BUCKHORN - MESA W.P.P.
PINAL COUNTY, ARIZONA

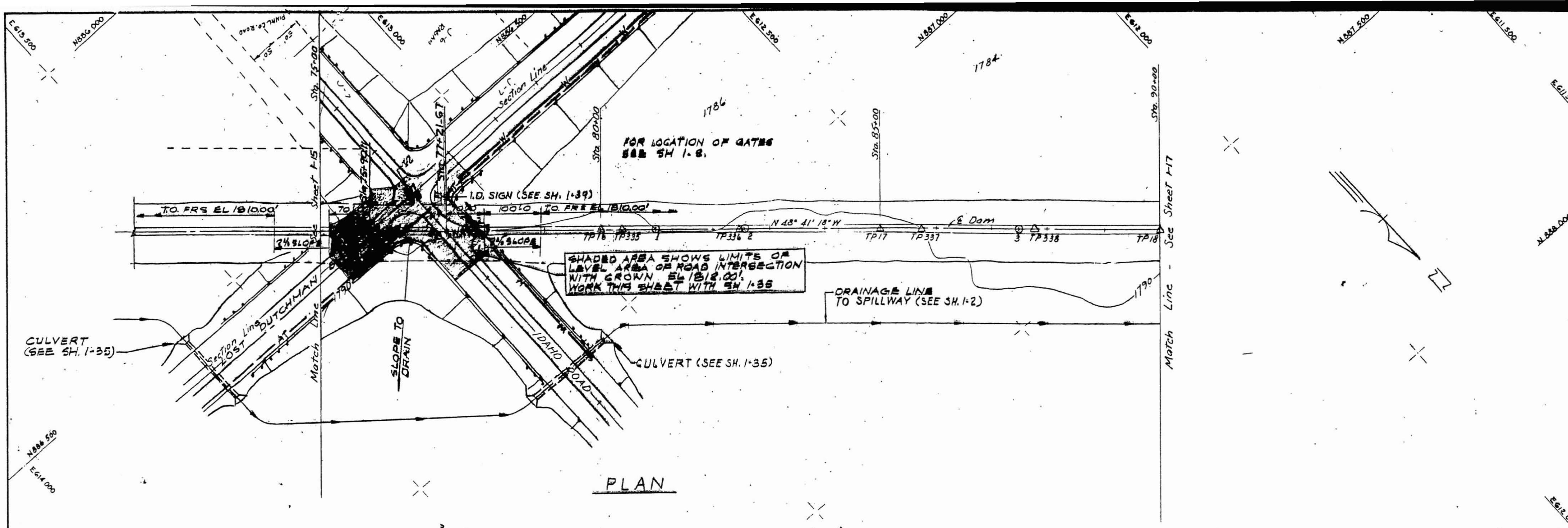
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

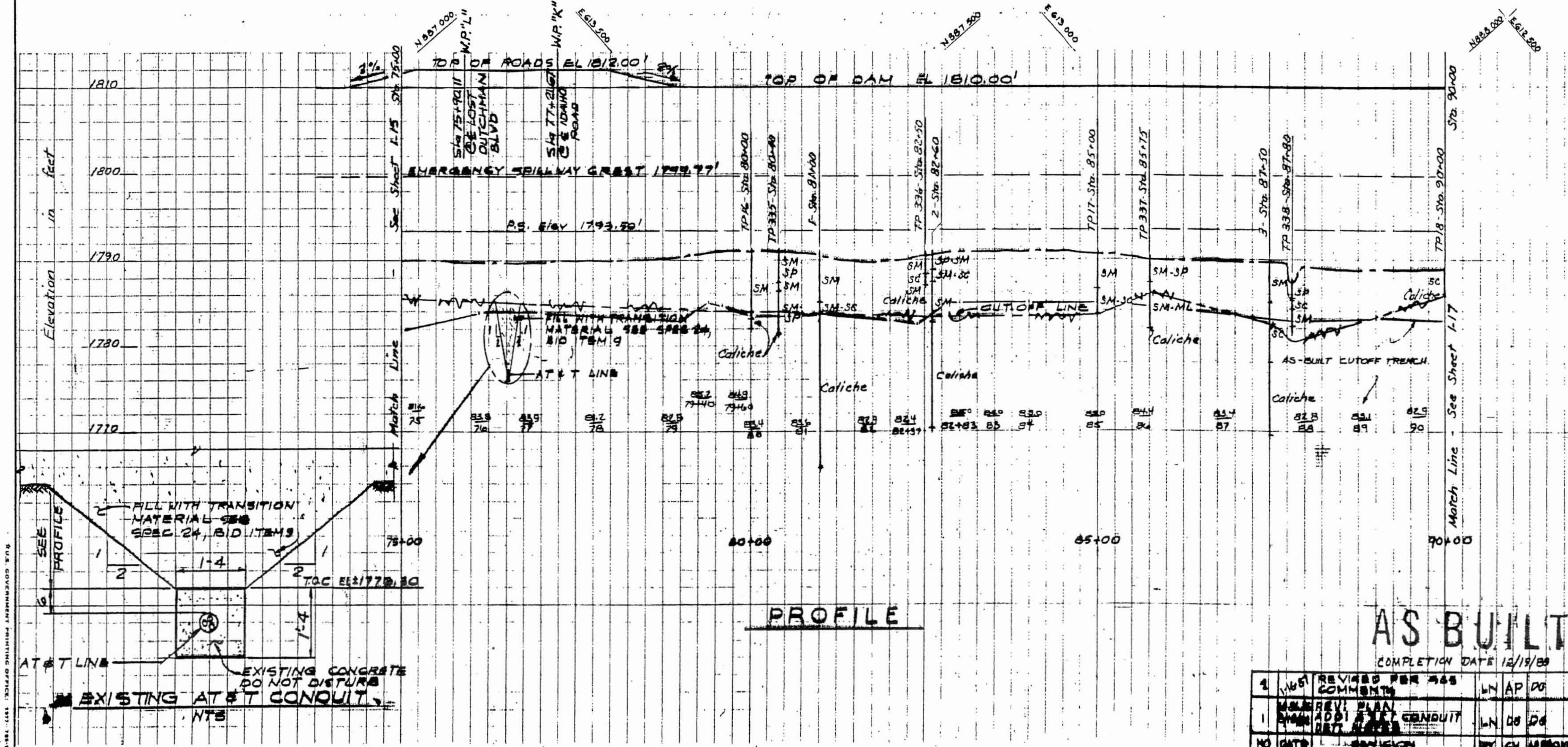
Designed .... Date
Drawn EFS 7-84
Traced
Checked
Approved by
Title
Title

Sheet No. 1-14 of 39 Drawing No 86002-AZ-CH

SCS-ENG-317, Rev. 3-69


N 48° 41' 18" W
℄ Dam
TP 13
TP 332
TP 331
TP 14
1790
1784
FOR DRAINAGE ALIGNMENT SEE SH 1-8
Match Line - See Sheet 1-14
Match Line - See Sheet 1-16
Sta. 60+00
Sta. 65+00
Sta. 70+00
Sta. 75+00
TOP OF DAM EL 1810'
EMERGENCY SPILLWAY CREST EL 1799.77'
P.S. Elev 1793.5
CUT-OFF LINE
AS-BUILT CUTOFF TRENCH
Caliche
SM
SC
SC-SM
SM-SC
Elevation in feet
1810
1800
1790
1780
60+00
65+00
70+00
75+00
PROFILE
NOTES:
1. CUTOFF TRENCH EXCAVATION SHALL EXTEND TO A DEPTH OF FIVE FEET BELOW REMOVED MATERIAL OR ONE FOOT INTO CALICHE, WHICHEVER DEPTH IS LESS. SEE DETAILS SHT 1-19
2. CUTOFF TRENCH EXCAVATION LIMIT AS SHOWN IS APPROXIMATE.
3. FINAL DEPTHS WILL BE DETERMINED BY THE ENGINEER IN THE FIELD.
AS BUILT
COMPLETION DATE 12/19/88
NO DATE REVISION
EBASCO SERVICES INCORPORATED
DIV CIVIL DR. LN CH. NH DATE APPROVED
PLAN & PROFILE
STA 60+00 TO STA 75+00
APACHE JUNCTION FRS
BUCKHORN - MESA W.P.P.
PINAL COUNTY, ARIZONA
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed
Drawn EFS 7-84
Traced
Checked
Approved by
Title
Drawing No. 86002-AZ-CH





NOTES:
1. CUTOFF TRENCH EXCAVATION SHALL EXTEND TO A DEPTH OF FIVE FEET BELOW REMOVED MATERIAL OR ONE FOOT INTO CALICHE, WHICHEVER DEPTH IS LESS. SEE DETAILS SHT 1-19.
2. CUTOFF TRENCH EXCAVATION LIMIT AS SHOWN IS APPROXIMATE.
3. FINAL DEPTHS WILL BE DETERMINED BY THE ENGINEER IN THE FIELD.
4. FOR DETAILS OF ROAD RAMPS, SEE SHTS 1-35, 1-36.
5. AT&T CABLE LOCATION FROM AT&T DRAWINGS WR 52608 AND WR 52932.
6. FOR TYP. CROSS-SECTIONS OF FRS SEE SH 1-19.
7. FOR UTILITY LOCATIONS SEE SHEET 1-8

AS BUILT
COMPLETION DATE 12/19/88

NO	DATE	REVISION	BY	CH	APPROVED
2	1-16-87	REVISED FOR M&S COMMENTS	LN	AP	DG
1		REV. PLAN, ADD'L AT&T CONDUIT	LN	DG	DG

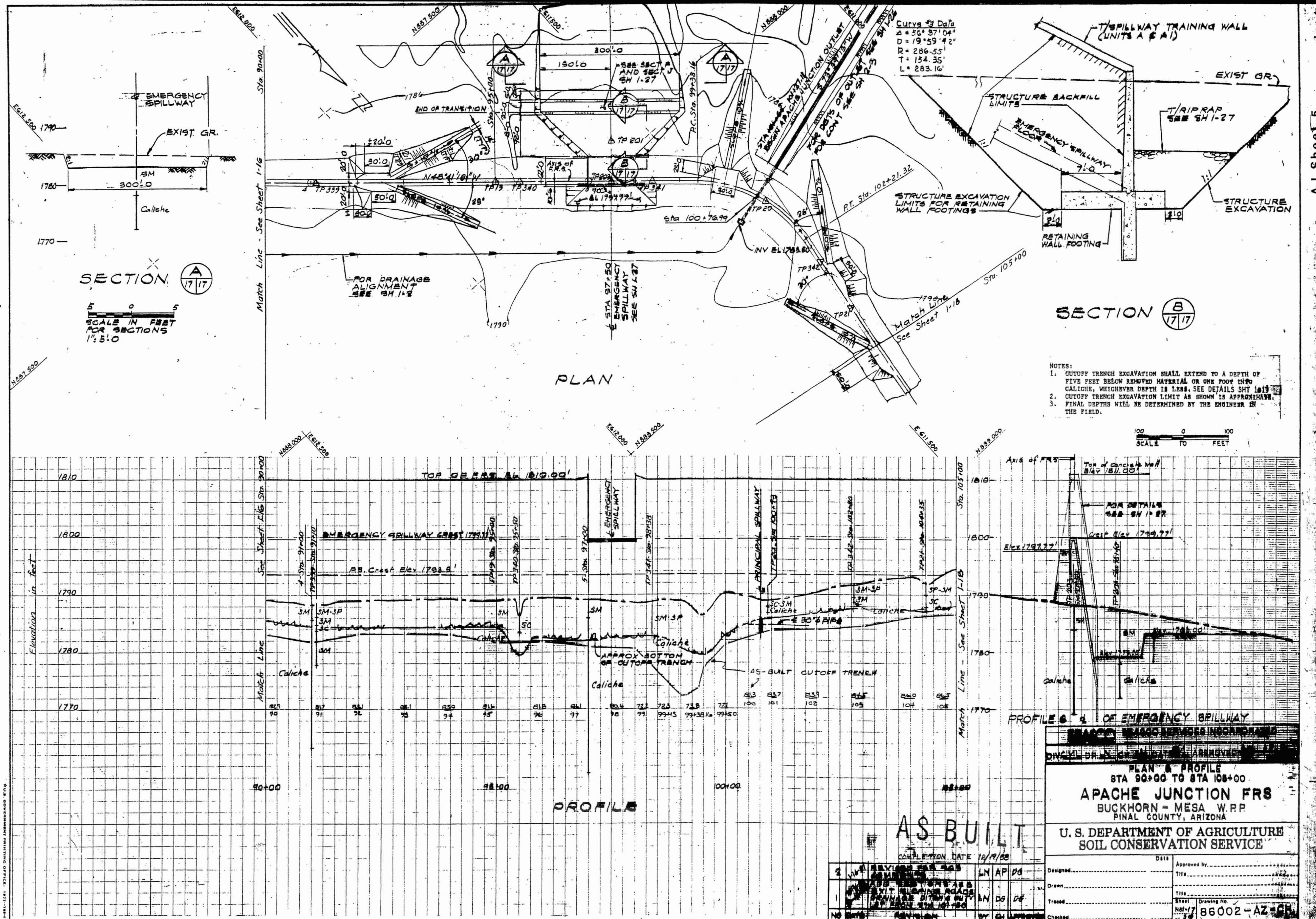
EBASCO SERVICES INCORPORATED

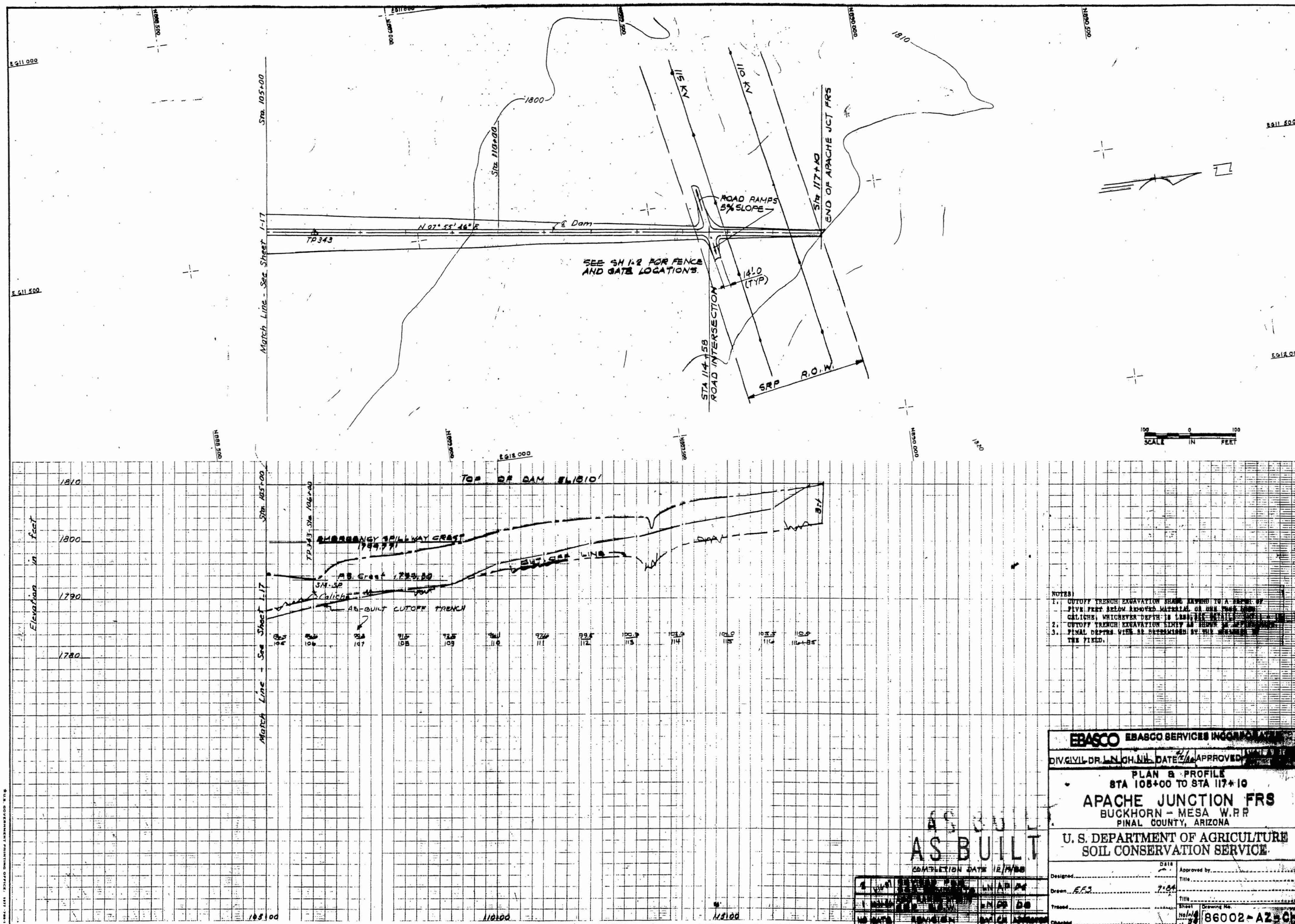
PLAN & PROFILE
STA 75+00 TO STA 90+00
APACHE JUNCTION FRS
BUCKHORN - MESA W.P.P.
PINAL COUNTY, ARIZONA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed ..... Drawn E.F.S. 7-84 ..... Traced ..... Checked .....

Drawing No 86002-AZ-OH


AJ Sheet 5
Curve #3 Data
Δ = 56° 37' 04"
D = 19° 59' 42"
R = 286.55'
T = 154.35'
L = 283.16'
T/SPILLWAY TRAINING WALL (UNITS A & A1)
EXIST GR.
STRUCTURE BACKFILL LIMITS
T/RIP RAP SEE SH 1-27
EMERGENCY SPILLWAY FLOOR
STRUCTURE EXCAVATION LIMITS FOR RETAINING WALL FOOTINGS
RETAINING WALL FOOTING
STRUCTURE EXCAVATION
SECTION B 17/17
EMERGENCY SPILLWAY
EXIST. GR.
SM
300.0
Caliche
SECTION A 17/17
SCALE IN FEET FOR SECTIONS 1" = 5.0
END OF TRANSITION
SEE SECT F AND SECT J SH 1-27
TP 201
N 48° 41' 18" W
Sta 100+76.99
P.T. Sta. 102+21.32
INV EL 1783.50
FOR DRAINAGE ALIGNMENT SEE SH 1-2
STA 97+50 EMERGENCY SPILLWAY SEE SH 1-27
Match Line - See Sheet 1-16
Match Line See Sheet 1-18
PLAN
NOTES:
1. CUTOFF TRENCH EXCAVATION SHALL EXTEND TO A DEPTH OF FIVE FEET BELOW REMOVED MATERIAL OR ONE FOOT INTO CALICHE, WHICHEVER DEPTH IS LESS. SEE DETAILS SHT 1-19
2. CUTOFF TRENCH EXCAVATION LIMIT AS SHOWN IS APPROXIMATE.
3. FINAL DEPTHS WILL BE DETERMINED BY THE ENGINEER IN THE FIELD.
SCALE 100 TO 100 FEET
TOP OF FRS EL 1810.00'
EMERGENCY SPILLWAY CREST 1799.77'
P.S. Crest Elev 1793.6'
EMERGENCY SPILLWAY
PRINCIPAL SPILLWAY
30" C PIPE
APPROX BOTTOM OF CUTOFF TRENCH
AS-BUILT CUTOFF TRENCH
Elevation in feet
Axis of FRS
Top of Concrete Wall Elev 1811.00'
FOR DETAILS SEE SH 1-27
Crest Elev 1799.77'
PROFILE ℄ OF EMERGENCY SPILLWAY
PROFILE
AS BUILT
COMPLETION DATE 12/19/88
PLAN & PROFILE
STA 90+00 TO STA 105+00
APACHE JUNCTION FRS
BUCKHORN - MESA W.P.P.
PINAL COUNTY, ARIZONA
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed
Drawn
Traced
Checked
Approved by
Title
Sheet
Drawing No.
86002-AZ-CH
NO DATE REVISION BY CH APPROVED



NOTES:
1. CUTOFF TRENCH EXCAVATION SHALL EXTEND TO A DEPTH OF FIVE FEET BELOW REMOVED MATERIAL OR ONE FOOT INTO CALICHE, WHICHEVER DEPTH IS LESS.
2. CUTOFF TRENCH EXCAVATION LIMIT AS SHOWN
3. FINAL DEPTHS WILL BE DETERMINED BY THE ENGINEER IN THE FIELD.

AS BUILT
COMPLETION DATE 12/19/86

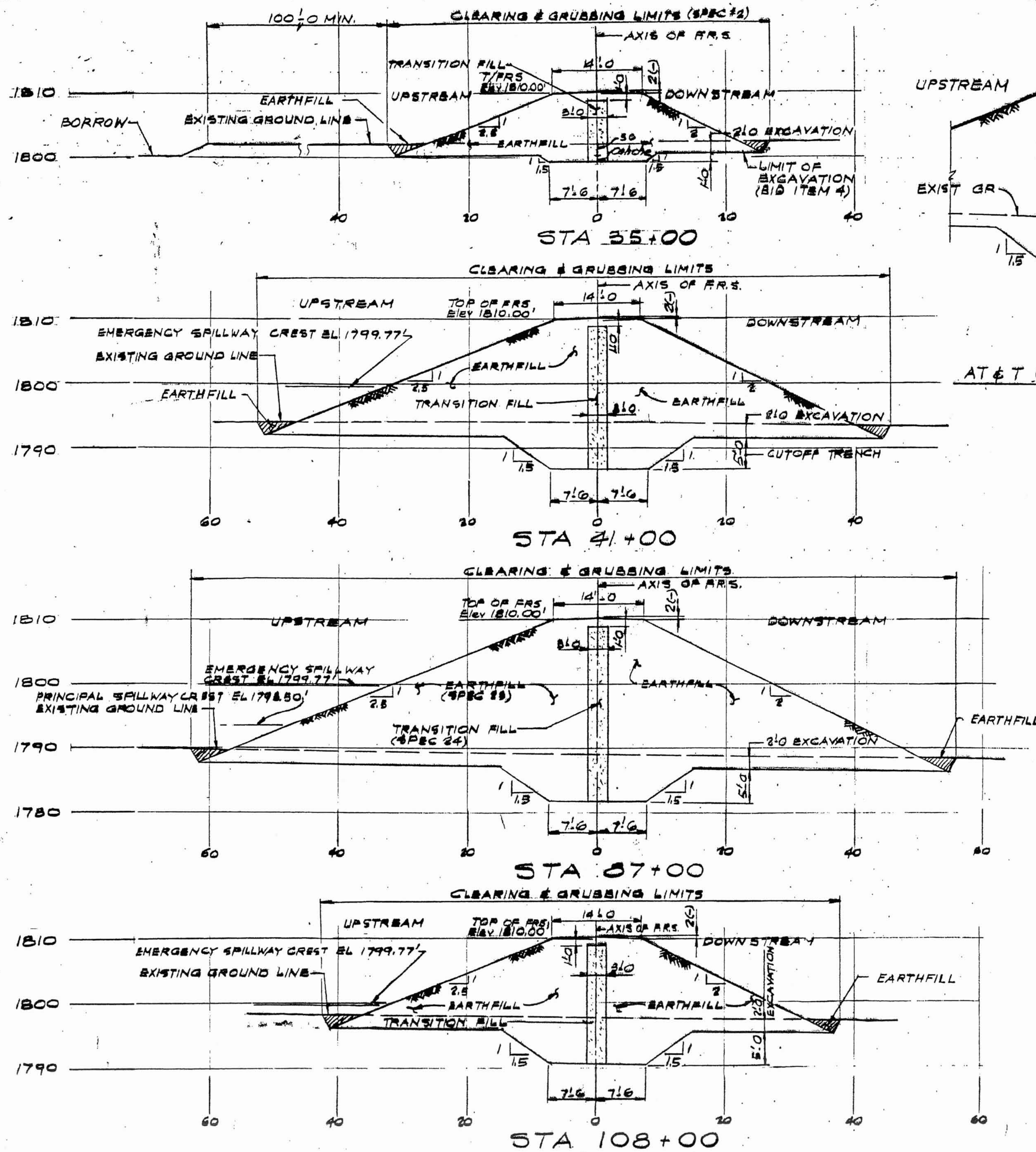
EBASCO SERVICES INCORPORATED
DIV. CIVIL DR. L.N. CH. N.H. DATE APPROVED

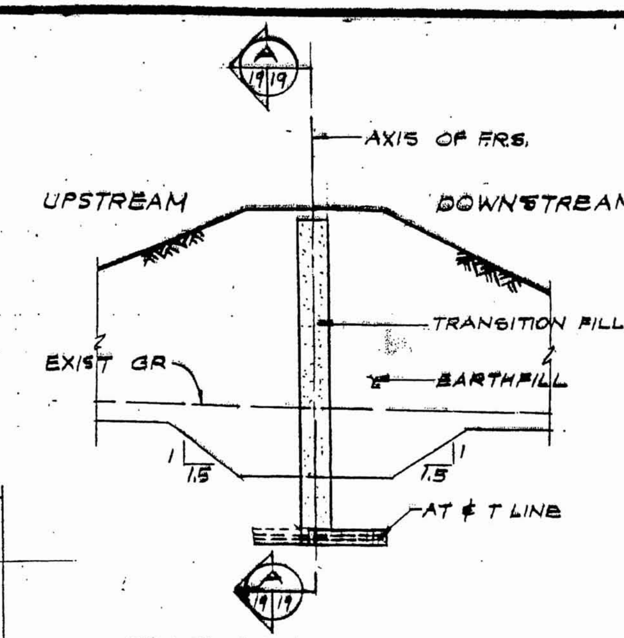
PLAN & PROFILE
STA 105+00 TO STA 117+10

APACHE JUNCTION FRS
BUCKHORN - MESA W.P.P.
PINAL COUNTY, ARIZONA

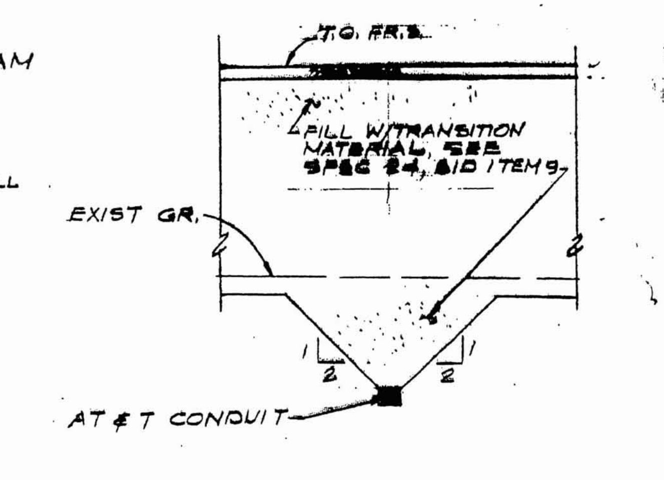
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed .... Date
Drawn EFS 7-84
Traced ....
Checked ....
Approved by ....
Title ....
Sheet No. of 37
Drawing No. 86002-AZ-CH





AT & T CONDUIT CROSSING



SECTION A (1/19)
NTS

NOTES:
1. CUTOFF TRENCH EXCAVATION SHALL EXTEND TO A DEPTH OF FIVE FEET BELOW REMOVED MATERIAL OR ONE FOOT INTO CALICHE, WHICHEVER DEPTH IS LESS. SEE DETAILS SHT 1 & 10
2. CUTOFF TRENCH EXCAVATION LIMIT AS SHOWN IS APPROXIMATE.
3. FINAL DEPTHS WILL BE DETERMINED BY THE ENGINEER IN THE FIELD.
4. WORK THIS SHEET WITH SHEETS 1-13 thru 1-18.

10 5 0 5 10
SCALE IN FT.

COMPLETION DATE 12/19/88

NO	DATE	REVISION	BY	CH	APPROVED
3	4-15-87	Change Back Fill (TYP) to Earth Fill	SCS	DEP	D.O.L
2	1-16-87	REVISED PER SCS COMMENTS	LN	AP	DG
1	10-31-86	ADD AT&T @ AXIS/F.R.S. DET & SECT A	LN	DG	DG

EBASCO SERVICES INCORPORATED
DIV CIVIL DR. LN CH. RO DATE 4/15/86 APPROVED

CROSS-SECTIONS
APACHE JUNCTION FRS
BUCKHORN - MESA W.P.P.
PINAL COUNTY, ARIZONA

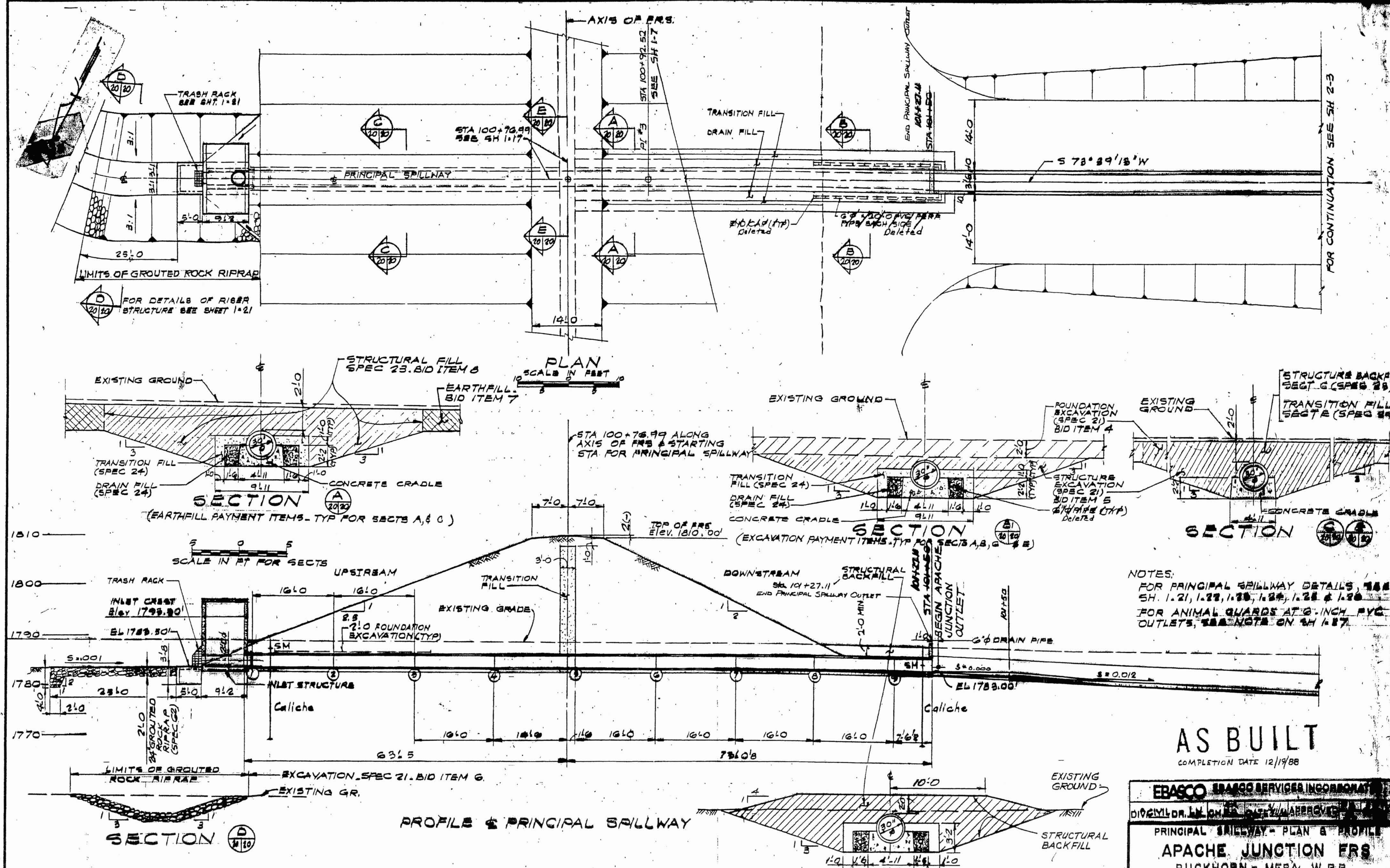
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed / Drawn / Traced / Checked / Date / Approved by / Title

Sheet No. 1-19 of 39
Drawing No. 86002-AZ-CH

SCS-ENG-313C (REV. 8-73)

AJ Sheet 7



PIPE JOINT INVERT ELEVATIONS	
① 1785.40	⑥ 1785.18
② 1785.41	⑦ 1785.13
③ 1785.35	⑧ 1785.07
④ 1785.30	⑨ 1785.02
⑤ 1785.24	

AS BUILT
COMPLETION DATE 12/19/88

NO	DATE	REVISION	BY	CH	APPROVED
2	1-16-87	REVISED PER SCS COMMENTS	LN	AP	DG
1	10-31-86 9/15/86	ADD: RIPRAP THICKNESS; BEARING 6" DRAIN IN WALL REV: PIPE TRENCH SIDE-SLOPES	LN	DG	DG

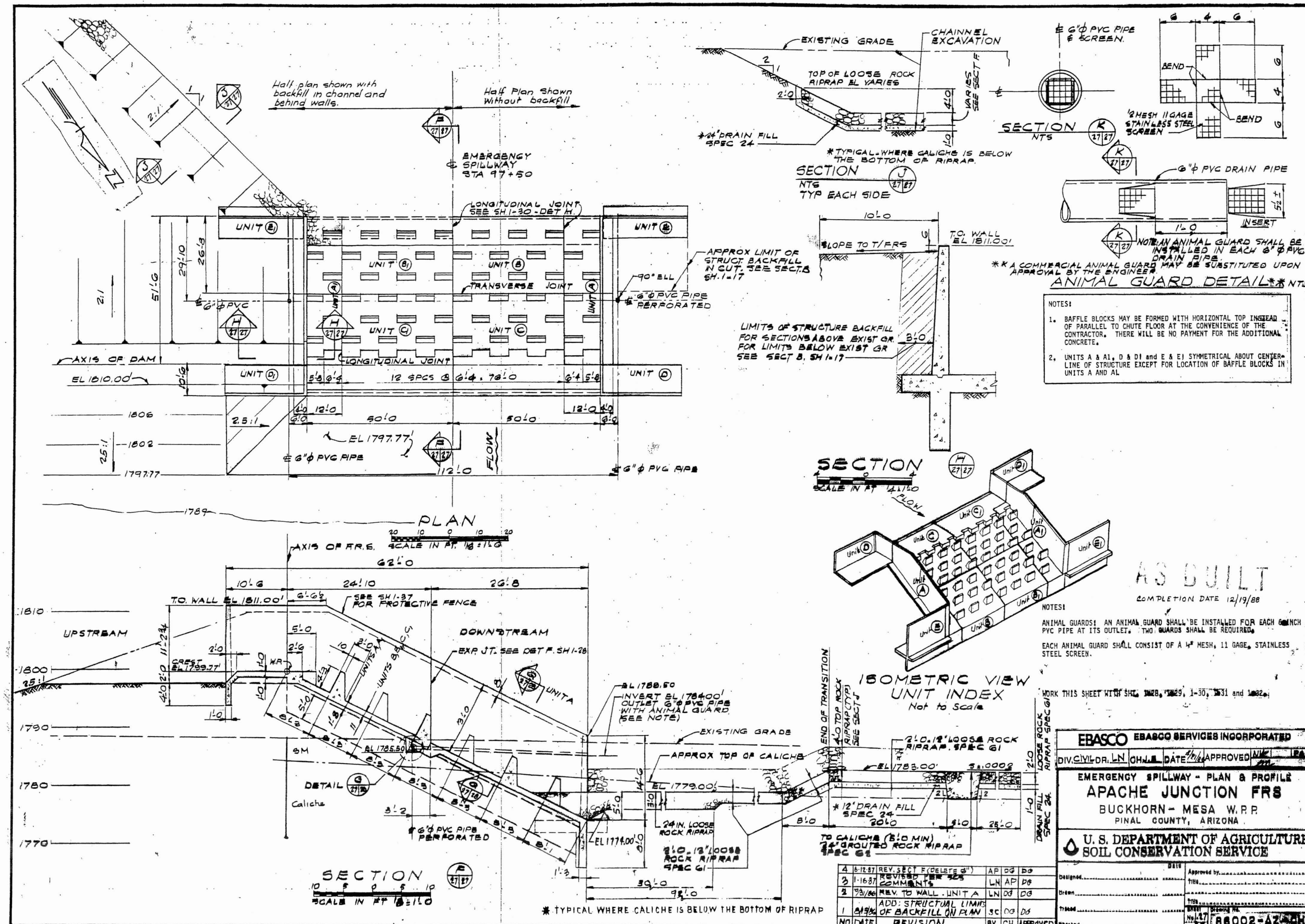
EBASCO EBASCO SERVICES INCORPORATED
DIV CIVIL DR. LN CH. DATE APPROVED

PRINCIPAL SPILLWAY - PLAN & PROFILE
APACHE JUNCTION FRS
BUCKHORN - MESA W.P.P.
PINAL COUNTY, ARIZONA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed / Drawn / Traced / Checked / Approved by / Title

Drawing No. 86002-AZ



NO	DATE	REVISION	BY	CH	APPROVED
4	6-12-87	REV. SECT F (DELETE 6")	AP	DG	DG
3	1-16-87	REVISED PER SCS COMMENTS	LN	AP	DG
2	9/3/86	REV. TO WALL - UNIT A	LN	DG	DG
1	8/19/86	ADD: STRUCTURAL LIMITS OF BACKFILL ON PLAN	JC	DG	DG

EBASCO — EBASCO SERVICES INCORPORATED

DIV. CIVIL DR. LN CH. DATE APPROVED

EMERGENCY SPILLWAY - PLAN & PROFILE

APACHE JUNCTION FRS

BUCKHORN - MESA W.P.P.

PINAL COUNTY, ARIZONA

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

Designed / Drawn / Traced / Checked / Approved by / Title

Sheet No. 1-27 Drawing No. 86002-AZ

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART IV APACHE JUNCTION FRS

Section 3.0 Field Examination

Section 3.0 Field Examination

3.1 Purpose

The purpose of the field examination is to provide a systematic visual field technical investigation in which the structural stability and operational adequacy of the FRS project features are analyzed and evaluated to determine if deficiencies exist at the FRS and associated project features. The examination was conducted by walking the length of the structure and visually examining the crest, upstream and downstream slopes, upstream and downstream toes, and appurtenant structures. Comments are recorded on an inspection log and photographs taken of pertinent observations. Cracks, holes, and burrows were probed with a hand-held 3-foot stainless steel metal rod to examine depth, extent, and resistance to probing. No other intrusive/internal examination method was used during this examination.

The field examination of the structure is accomplished to provide a basis for timely initiation of corrective measures to be taken where necessary. This examination was conducted on July 10 and 11, 2000 by the following technical examination team:

3.2 Technical Examination Team

Robert Eichinger, P.E.	Project Manager, Kimley-Horn and Associates
John Sikora, P.E.	Dam Safety Engineer, URS Corp.
Ken Euge, P.G.	Principal Geologist, Geological Consultants
Diana Davisson, EIT	Civil Analyst, Kimley-Horn and Associates

Other Participants:

Tom Renckly, P.E.	Project Manager, Civil Engineer, Flood Control District of Maricopa County

3.3 Project Summary

Inspection Frequency

Apache Junction FRS is inspected on an annual basis jointly by the Flood Control District and the Arizona Department of Water Resources. The next joint District/ADWR inspection is scheduled for December 2001.

Maximum Water Surface Elevations
The District maintains a historic log of maximum water surface elevations for Apache Junction FRS. The maximum recorded impoundment for Apache Junction reservoir is 15 acre-feet with a stage of 4.76 feet at the FRS (July 23, 1999).

Spillway Erodibility
Based on District records, there has been no recorded emergency spillway flows at Apache Junction FRS. The spillway is a reinforced concrete baffle block chute spillway.

Distress Observations Corrected or Operation and Maintenance Conducted Since Last Inspection
Slope erosion repair is an on-going O&M item.

Past Distress Observations Not Yet Corrected
Noted past erosion on the upstream and downstream slope. This is an on-going maintenance issue.

Flood Control District Operation and Maintenance Responsibilities
The District is responsible for total operation and maintenance of Apache Junction FRS and associated appurtenances.

3.4 Field Examination Results Summary

Embankment
The crest of the FRS is gravel plated. Most crest settlement monuments were found. Station markers were located. The crest is clear of vegetation. The access gates and fences located off and adjacent to Apache Trail and McKellips Road are operational. Centerline longitudinal cracks were observed Sta. 81+00 to 82+50, 86+00, 95+50, and 98+68.

Abutments
The north and south abutment terminus contacts appear in satisfactory operational condition. No slides, sign of instability or erosion of the abutment surfaces were observed.

Upstream Slope
The upstream slope shows minor erosion rills and gullies. There are very few animal burrows on the slope face. The upstream toe shows very minor signs of erosion. There was no evidence of seepage, undermining, settlement or sloughing. There is rock mulch protection on the slope.

Downstream Slope
Animal burrows are evident on this slope face. These burrows range from small reptile burrows (lizards) to ground squirrel activity. The slope has a medium density of small shrubs and grasses. There are minor erosion rills and gullies on the face of the

downstream slope. There was no evidence of seepage, undermining, settlement or sloughing.

Principal Spillway
The approach channel was clear of debris and obstructions. The reservoir pool has a medium density stand of mesquite, acacias, and palo verdes.

The exterior of the inlet was clean. The inlet is a "T" shaped riser typical of NRCS designs. The concrete for the inlet structure showed no signs of structural distress. The trash rack was clear of debris and obstructions. The interior of the 30-inch RCP conduit was inspected visually by shining sunlight reflected with a hand mirror from outlet structure. The walls of the conduit appeared clean and there were no apparent signs of seepage or misalignment.

The discharge outlet of the principal spillway was clear of debris. The joints of the outlet structure were straight and tight. The outlet channel was clear of debris. The outlet structure is a standard impact basin typical of Bureau of Reclamation designs for energy dissipators used on the outlets of culverts.

Emergency Spillway
The emergency spillway located at Station 97+50 and upstation from the principal spillway and the right abutment. The FRS emergency spillway is a reinforced concrete baffle block chute structure. The approach channel to the spillway was clear of debris and obstructions. The walls of the spillway showed signs of spalling and minor vertical cracks (probably due to curing of the concrete during construction). The downstream riprap stilling pool was clear of debris and vegetation.

Instrumentation
Apache Junction FRS has a series of settlement monuments. The "A"-series are located every 500-feet along the downstream crest of the structure. The "B"-series are located approximately every 500-feet along the downstream toe of the dam in combination with the corresponding "A"-series monuments. The "B"-series monuments are offset from the downstream toe. Not all monuments from the "A" or "B" series were located during the inspection. Monuments not readily located are most likely buried in shallow embankment fill.

A staff gauge located on the upstream slope at the principal spillway is used to indicate the level of water impounded in the reservoir. A pressure transducer is located at the inlet structure of the principal spillway. The transducer works in combination with a flood warning telemetry system, which allows signals to be sent to a centralized receiver at the District indicating water levels at the reservoir.

3.5 Conclusions

The overall conclusion of the field examination is that the FRS and appurtenant structures are in satisfactory operational condition.

3.6 Recommendations

The following is a list of recommended corrective actions resulting from this field examination:

a. Continuing observation should be made of the above mentioned items (erosion of slopes).
b. Station posts need to have signs on both sides of post facing both directions of travel.
c. Monitor and repair when necessary erosion gullies on slope faces.
d. Video and photograph log the interior of the principal spillway conduit.
e. Develop a plan for the repair of transverse and longitudinal cracks.
f. Locate, uncover and expose all settlement monuments prior to settlement surveys.

3.7 Future Inspections

The next annual inspection by FCD is scheduled for December 2001.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
EMBANKMENT DAM INSPECTION REPORT

Each item of the checklist should be completed. Repair is required when obvious problems are observed. Monitoring is recommended if there is a potential for a problem to occur in the future. Investigation is necessary if the reason for the observed problem is not obvious.

A [illegible] description should be made of any noted irregularities, needed maintenance, or problems. Abbreviations and short descriptions are recommended. Additional sheet(s) may be used for any items not listed and additional comments.

DAM NO.: **11.15**	DAM NAME: **APACHE JUNCTION FRS**	TYPE: EARTH EMBANK
CONTACTS: Tom Renckly-FCD	REPORT DATE: August 15, 2000	
INSPECTED BY: Bob Eichinger-KHA, Ken Euge-Geological Consultants, John Sikora-URS Corp	INSPECTION DATE: July 10, 2000	
REVIEWED BY: Doug Plasencia, KHA	DATE: August 16, 2000	PAGE 1 of _6_
STORAGE LEVEL: Empty	TOTAL FREEBOARD: 10.23 ft	PHOTOS? YES

Item	Comments	NOT APPLIC.	NO	YES	MONITOR	REPAIR	INVESTIGATE
1. CREST Length = 8,764 ft.; Top of Dam = 1,810 ft.; Top Width = 14 ft.; Height = 22 ft.							
a. Settlements, slides, depressions?			X				
b. Misalignment?			X				
c. Longitudinal/Transverse cracking?	**Centerline longitudinal cracks were observed Sta. 81+00 to 82+50, 86+00, 95+50, 98+68**			X	X		X
d. Animal burrows?	**Minor animal burrows.**		X				
e. Adverse Vegetation?			X				
f. Erosion?				X			
2. UPSTREAM SLOPE (2.5:1) (H:V)							
a. Erosion?	**Minor rolls throughout.**			X	X		
b. Inadequate ground cover?			X				
c. Adverse vegetation?			X				
d. Longitudinal/Transverse cracking?			X				
e. Inadequate riprap?	**Rock mulch crest to midway slope.**						
f. Stone deterioration?		X					
g. Settlements, slides, depressions, bulges?			X				
h. Animal burrows?				X			
3. DOWNSTREAM SLOPE							
a. Erosion?	**Minor soil erosion.**			X	X		
b. Inadequate ground cover?							
c. Adverse vegetation?			X				
d. Longitudinal/Transverse cracking?	**Sta. 36+00 – possible old traverse crack**			X	X		
e. Inadequate riprap?			X				
f. Settlements, slides, depressions, bulges?	**Sta. 46+00, 46+15.**			X	X		
g. Soft spots or boggy areas?			X				
h. Movement at or beyond toe?			X				
i. Animal burrows?	**Minor burrows scattered throughout – monitor and repair if necessary.**			X	X		
4. DRAINAGE-SEEPAGE CONTROL (Longitudinal central filter 3' wide, extends to foundation).							
a. Internal drains flowing?	**Reservoir empty.**	X					
b. Boils at or beyond toe?			X				

EMB. DAM INSP. REPORT	PAGE 2 of 6	DAM NO.: **11.15**						
INSPECTED BY: Bob Eichinger, Ken Euge, John Sikora		DATE: July 10, 2000						
Item	Comments		N/A	NO	YES	MON	REP	INV
c. Seepage at or beyond toe?				X				
d. Does seepage contain fines?			X					
5. ABUTMENT CONTACTS								
a. Erosion?				X				
b. Differential movement?				X				
c. Cracks?				X				
d. Settlements, slides, depressions, bulges?				X				
e. Seepage?	**Reservoir empty.**			X				
f. Animal burrows?	**Minor burrows.**				X	X		
6. OUTLET WORKS-APPROACH CHANNEL Unlined, Concrete, Riprap, or Other?								
a. Eroding or backcutting?				X				
b. Sloughing?				X				
c. Restricted by vegetation?				X				
d. Obstructed with debris?				X				
e. Silted in?				X				
7. OUTLET WORKS-INLET STRUCTURE								
a. Seepage into structure?	**Reservoir empty.**			X				
b. Debris or obstructions?				X				
c. If concrete, do surfaces show:								
1. Spalling or Scaling?				X				
2. Cracking?				X				
3. Erosion?				X				
4. Exposed reinforcement?				X				
d. If metal, do surfaces show:								
1. Corrosion?			X					
2. Protective coating deficient?			X					
3. Misalignment or spilt seams?			X					
e. Do the joints show:								
1. Displacement or offset?				X				
2. Loss of joint material?				X				
3. Leakage?	**Reservoir empty.**			X				
f. Are the trash racks:								
1. Broken or bent?				X				
2. Corroded or rusted?				X				
3. Obstructed?				X				
g. Sluice/Drain gates:	**Principal Spillway is ungated.**							

Item	Comments	N/A	NO	YES	MON	REP	INV
1. Broken or bent?		X					
2. Corroded or rusted?		X					
3. Leaking?		X					
4. Not seated properly?		X					
5. Not operational?		X					
6. Not periodically maintained?		X					
7. Date last operated?							
8. OUTLET WORKS-CONDUIT	**Concrete**						
a. Seepage into conduit?	**Reservoir empty.**		X				
b. Debris present?			X				
c. If concrete, do surfaces show:	**Did not inspect interior of pipe – recommend video survey.**						
1. Spalling or scaling?							X
2. Cracking?							X
3. Erosion?							X
4. Exposed reinforcement?							X
5. Other?							X
d. If Metal, do surfaces show:							
1. Corrosion?		X					
2. Protective coating deficient?		X					
3. Misalignment or spilt seams?		X					
e. Do the joints show:							
1. Displacement or offset?			X				
2. Loss of joint material?			X				
3. Leakage?	**Reservoir empty.**		X				
9. OUTLET WORKS-STILLING BASIN/POOL - None							
a. If concrete, do surfaces show:							
1. Spalling or Scaling?		X					
2. Cracking?		X					
3. Erosion?		X					
4. Exposed reinforcement?		X					
b. If concrete, do joints show:							
1. Displacement?		X					
2. Loss of joint material?		X					
3. Leakage?		X					
c. Do the energy dissipators show:							
1. Signs of deterioration?		X					

EMB. DAM INSP. REPORT	PAGE 4 of 6	DAM NO.: **11.15**	N/A	NO	YES	MON	REP	INV
INSPECTED BY: Bob Eichinger, Ken Euge, John Sikora		DATE: July 10, 2000						
Item	Comments							
2. Covered with debris?			X					
3. Signs of inadequacy?			X					
10. OUTLET WORKS-OUTLET CHANNEL	**Concrete, Apache Junction Outlet channel**							
a. Eroding or backcutting?				X				
b. Sloughing?				X				
c. Obstructed?				X				
d. Poorly riprapped?				X				
e. Tailwater elevation and flow condition: **None.**								
11. EMERGENCY SPILLWAY-APPROACH CHANNEL	**Unlined.**							
a. Eroding or backcutting?				X				
b. Sloughing?				X				
c. Restricted by vegetation?				X				
d. Obstructed with debris?				X				
e. Silted in?				X				
12. EMERGENCY SPILLWAY-CONTROL STRUCTURE								
a. If concrete, do surfaces show:								
1. Spalling or scaling?	**Minor spalling.**				X	X		
2. Cracking?	**Minor vertical cracks.**				X	X		
3. Erosion?				X				
4. Exposed reinforcement?				X				
b. If concrete, do joints show:								
1. Displacement or offset?				X				
2. Loss of joint material?				X				
3. Leakage?	**Reservoir empty.**			X				
c. If spillway is unlined:								
1. Are slopes eroding?			X					
2. Are slopes sloughing?			X					
3. Is crest eroding?			X					
d. Is weir in poor condition?				X				
e. Where is control structure? **Sta. 97+50**								
13. EMERGENCY SPILLWAY - CHANNEL	**Reinforced concrete baffle block spillway**							
a. Obstructions or restrictions?				X				
b. If concrete, do surfaces show:								
1. Spalling or scaling?	**Minor spalling on surfaces.**				X	X		
2. Cracking?					X	X		
3. Erosion?	**Minor vertical cracked surface faces.**			X				

EMB. DAM INSP. REPORT	PAGE 5 of 6	DAM NO.: **11.15**						
INSPECTED BY: Bob Eichinger, Ken Euge, John Sikora		DATE: July 10, 2000	N/A	NO	YES	MON	REP	INV
Item	Comments							
4. Exposed reinforcement?				X				
c. If concrete, do joints show:								
1. Displacement or offset?				X				
2. Loss of joint material?				X				
3. Leakage? **Reservoir empty.**								
d. If an unlined channel, does it show:								
1. Erosion?			X					
2. Slopes sloughing?			X					
3. Poorly protected w/ vegetation/riprap?			X					
14. EMERGENCY SPILLWAY-TERMINAL STRUCTURE	**Stilling basin 92 ft. long – riprap.**							
a. If concrete, do surfaces show:								
1. Spalling or scaling?			X					
2. Cracking?			X					
3. Erosion?			X					
4. Exposed reinforcement?			X					
b. If concrete, do joints show:								
1. Displacement or offset?			X					
2. Loss of joint material?			X					
3. Leakage?			X					
c. Do the energy dissipators show:								
1. Signs of deterioration?				X				
2. Covered with debris?				X				
3. Signs of inadequacy?				X				
15. EMERGENCY SPILLWAY - OUTLET CHANNEL	**Riprap lining on bottom soft – unlined beyond.**							
a. Eroding or backcutting?				X				
b. Sloughing?				X				
c. Obstructed or restricted?				X				
16. RESERVOIR Empty								
a. High water marks?				X				
b. Erosion/Slides into pool area?	**Did not observe.**		X					
c. Sediment accumulation/Vegetation growth?				X				
d. Floating debris present?				X				
e. Depressions, sinkholes or vortices?				X				
f. Low ridges/saddles allowing overflow?				X				
g. Structures below dam crest elevation?				X				
17. INSTRUMENTATION								

Item	Comments	N/A	NO	YES	MON	REP	INV
a. List type(s) of instrumentation: Staff gages, ALERT gage-water pressure transducer, settlement monuments, station markers at downstream edge of crest of dam							
b. In poor condition?			X				
c. Not read or analyzed regularly?	**Last Survey 1998. Need to provide results to ADWR. Include in Structures Assessment Report.**			X			
d. Is data available?				X			
18. CONDITION SUMMARY / LICENSE / EAP / NEXT INSPECTION							
a. Dam condition:	No Safety Deficiencies						
b. Safe storage Level:	**Principal spillway invert bar permanent storage and temporary storage above this level; elevation 1793.5 ft.**						
c. List date of current License: January 22, 1992							
d. Should new License be issued?		X					
e. In compliance with License?				X			
f. In compliance with Statute and Rules?				X			
g. In compliance with ADWR/District Actions?				X			
i. List current size; accurate?	**Small**			X			
j. List current downstream hazard; accurate?	**High**			X			
k. Is there a current EAP? If so, list latest revision date:	**EAP needs to be prepared according to FEMA 64 guidelines.**		X				
l. List normal inspection frequency:	**Annual**						
m. Recommend date for next inspection:	**November 2000**						

Notes/Sketches

Apache Junction FRS

Station	U/S	D/S	Crest	Observation	Detailed Description	Photo	Stake	nspecto
Start Left Abutment 7/10/00 6:30AM Temperature 78F								
				Sign	Apache Junction Floodway/Watershed sign	R1-0		KE
29+50			X	Embankment	View to northeast along structure crest	R1-1		KE
30+00			X	Station Marker				RAE
30+00			X	Photo-Vegetation	Photo looking down center line of FRS - note vegetation on centerline of crest follows transition fill	R1P1		RAE
30+00	X			Photo	Photo looking right at left abutment	1269		JHS
30+00				Photo	Photo of floodway outlet into flood pool	1270		JHS
30+00				Photo	Photo of floodway outlet into flood pool	1271		JHS
31+00	X			Photo	Upstream face	1272		JHS
31+00	X			Rodent Hole	Rodent Hole			JHS
35+00		X	X	Station Marker & Settlement Monuments	Crest: A-1 Toe: B-1, & stake 50 ftoffset from downstream toe, 1 angle iron on upstream & 1 angle iron on downstream crest			RAE
35+00		X		Survey Monument	Survey monument B1 @ DS embankment toe	R1-2		KE
35+00		X		Survey Monument	Survey monument offset from DS embankment toe	R1-3		KE
35+30		X		Erosion/Borrows	Minor rill erosion on DS slope face w/ minor rodent borrows	R1-4		KE
35+30		X		Rill Erosion	Minor rill erosion on DS slope face	R1-5		KE
30+00 --- 35+00	X	X		Vegetation	Recent maintenance on vegetation			RAE
36+00	X			Rill Erosion	Rill Erosion minor			JHS
36+00		X		Rill Erosion	Minor rill erosion on DS slope face			KE
36+00	X	X		Old Transverse Crack	From crest to toe, Probed-no depth			JS
39+00		X		Animal Burrow	4ft down from crest, 12 ft long, Probes easily down to 15 inches			RAE
40+00			X	Station Marker	No settlement monuments			RAE
42+50		X		Rill Erosion	Rill erosion on DS slope face	R1-6		KE
44+50		X	X	Station Marker & Settlement Monuments	Crest: A-2 Settlement marker, Toe: B-2 Settlement marker, & offset Point of Curvature monument			RAE
45+00			X	Station Marker				RAE
46+00		X		Bulge	100 ft, Possible overbuilt since on curve			RAE
46+15		X		Slope face bulge	Over-steepened slope section in lower half of slope; 34 degrees slope angle; upper half of slope about 20 degrees; rill erosion @ toe may produce oversteepening or slope may have been overbuilt.	R1-8		KE
47+00	X			Pot Hole	Pot hole 20-feet upstream from embankment toe			JHS
47+00	X			Photo	Picture of pot hole	1273		JHS
47+50		X		PT Monument				RAE
47+50		X		Survey Monument	PT monument about 50 feet offset from embankment toe			KE
49+00			X	Ant Colony	Ant holes in linear alignment along centerline of FRS, follows transition fill, probed 2 inches			RAE
50+00		X	X	Station Marker	Found Pin (no monument) found pin at 50 ft offset from toe			RAE
50+00		X		Erosion	Occasional rill erosion and rodent activity between 45+00 to 50+00			KE
51+50		X		Erosion	Erosional cut bank at slope toe about one-foot deep with heavy rodent activity	R1-7		KE
52+00	X			Removal of vegetation	Woody vegetation has been removed			JHS
52+50	X			Grade Break	Midway between toe and crest			RAE
52+50		X		Erosion	Erosional oversteepening of lower slope w/ rill erosion	R1-9		KE

Apache Junction FRS

Station	U/S	D/S	Crest	Observation	Detailed Description	Photo	Stake	nspecto
55+00		X	X	Station Marker & Settlement Monuments	Crest: A-3 Settlement monument, Toe: B-3 Settlement monument, & Offset post			RAE
55+00	X			Photo Point	did not get number			RAE
55+00		X		Slope	View of DS slope near Ironwood Road	R1-10		KE
55+00		X		Survey Mon./Erosion	Survey monument @ DS embankment toe w/ rill erosion & rodend activity			KE
57+00		X		Rill Erosion	Rill erosion transitioning to gulleys			KE
57+50	X			Rill Erosion	Rill Erosion minor			JHS
59+00		X		Erosion Rill	Incised, 4-6 inches deep			RAE
59+00		X		Erosion Gulley	4 to 6-inch deep rill gulley on DS slope face; may need repair	R1-11		KE
60+00			X	Station Marker				RAE
60+00		X		Survey Monument	No survey monument @ this station			KE
60+20		X		Ridge	Previous reports note bulge, found same, recommend monitor for future inspections	R1P2 or P3		RAE
60+20		X		Slope face bulge	See above	R1-12		KE
60+50	X			Rodent Hole				JHS
62+00	X			Rill Erosion				JHS
65+00		X	X	Station Marker & Settlement Monuments	Crest: A-4 Settlement marker, Toe: B-4 Settlement marker, & Offset post			RAE
70+00			X	Station Marker				RAE
70+00	X			Slough	Small slough on upstream slope			JHS
70+00		S		Survey Mon./Plating	No survey monument @ this station; rock mulch plating covers DS slope face	R1-13		KE
70+00---75+00		X		Gravel Mulch	From crest to toe, 3 inch			RAE
74+50			X	Station Marker	Access Gate top of FRS			RAE
77+00	X	X	X	Road Crossing	Ironwood Road Crossing			KE
80+00			X	Station Marker				RAE
80+00		X		Survey Monument	No survey monument on DS slope			KE
80+00	X	X		Gravel Mulch	Crest to midway down slope (this point to end of FRS)			RAE
81+00--- 82+50			X	Longitudinal Crack	Linear array of small holes and vegetation, probe to 2 ft	R1P4		RAE
81+00			X	Longitudinal Crack	See above	R1-14		KE
81+00			X	Longitudinal Crack	See above	R1-15		KE
84+80---85+00			X	Longitudinal Crack	Longintudinal crack approximately 20-feet long			JHS
84+00		X		Slope face	Over-steepened slope section; rock mulch cannot hold to slope face; gulleys	R1-16		KE
85+00		X	X	Station Marker & Settlement Monuments	Crest: A-6 Settlement marker, Toe: B-6 Settlement marker, & Offset post			RAE
85+00		X		Rock mulch	Rock mulch plating on upper half of DS slope face	R1-17		KE
85+20	X			Footers	Could be from towers			RAE
85+50	X			Shallow Depression	30 ft offset from toe, easily probe to 3 ft,			RAE
86+00			X	Longitudinal Crack	Centerline of FRS, Probe to 3ft	TR		TR
90+00			X	Station Marker				DD
90+00		X		Survey Mon./Erosion	No survey monument @ this station; gulley & rill erosion below rock mulch plating from station 85+00 to 90+00; minor rodent activity @ toe of slope			KE
92+50		X		Rill Erosion	Erosion gulleys in lower portion of slope beloe rock mulch plating	R1-18		KE
93+00		X		Emergency Spillway	View to northwest toward emergency spillway	R1-19		KE

Apache Junction FRS

Station	U/S	D/S	Crest	Observation	Detailed Description	Photo	Stake	nspecto
95+00				Station Marker & Settlement Monuments	Crest: A-7 Settlement marker, Toe: B-7 Settlement marker, & Offset post			DD
95+00		X		Rock mulch	Rock mulch plating from top to toe of DS slope face	R1-20		KE
95+50			X	Longitudinal Crack	Centerline of FRS, Probe to 8 inches, 48 ft long, deeper at end (to transition fill)	R1P5		RAE
??+??				Emergency Spillway	Repair noted between embankment and spillway wall, spillway clean and clear	D1		RAE
97+00		X		Emergency Spillway	View of emergency spillway w/ boulder riprap outlet	R1-21		KE
97+00		X		Emergency Spillway	View to northwest of slush grouted riprap sill DS from emergency spillway structure	R1-22		KE
97+00		X		Emergency Spillway	Elastomeric joint compound has dried out in joints in east wall of ES			KE
97+50			X	Photo	Baffle block spillway	1275		JHS
97+50			X	Photo	Left spillway chute walls seperation of embankment from chute	1276		JHS
97+50			X	Photo	Energy dissipation basin for emergency spillway	1277		JHS
97+50			X	Photo	Downstream of baffle block spillway	1278		JHS
97+50			X	Photo	Downstream of baffle block spillway	1279		JHS
97+50			X	Photo	Grout repair of right side of spillway chute	1280		JHS
97+50			X	Observation	Emergency spillway in good shape no deformation in spillway chute walls. Concrete in good condition, no spalling. Energy dissipation basin does not show any signs of use.			JHS
98+68				Longitudinal Crack	Just after spillway, Centerline of FRS, Probe to 18 inches	TR		TR
98+69		X		Photo	Longintudinal crack	1282		JHS
100+77	X			Principle Spillway Inlet Structure	Grouted rip-rap inlet structure, trash rack, minor debris in conduit	R1P7 D2		RAE
100+77	X			Photo	Principle Inlet structure	1281		JHS
100+77	X			Photo	Principle Inlet structure	1283		JHS
100+77	X			Photo	Principle Inlet structure	1284		JHS
100+77			X	Observation	Inlet structure in good shape no deformation of the concrete walls and no spalling of concrete.			JHS
101+25		X		Principal Spillway	View looking downstream at principal spillway outlet channel	R1-23		KE
101+25	X			Principal Spillway	View looking upstream @ principal spillway inlet structure	R1-24		KE
101+25		X		Principal Spillway	View looking upstream @ 30-inch diameter PS outlet; few small cobbles in pipe; no other obstructions; pipe open.	R2-1		KE
		X		Principle Spillway Outlet Structure		D3		DD
105+00		X	X	Station Marker & Settlement Monuments	Crest: A-9 Settlement marker, Toe: B-9 Settlement marker, & Offset post			DD
105+00		X		Rock mulch	Rock mulch plating upper half of slope face	R2-2		KE
107+00		X		Rodent holes	Large rodent borrows about 100 feet downstream from DS embankment toe	R2-3		KE
110+00			X	Station Marker	& offset stake & concrete marker			DD
110+00				Survey Monument	No survey monuments at this station; rock mulch plated top to toe of DS slope face			KE
115+00		X	X	Station Marker & Settlement Monuments	Crest: A-10 Settlement marker, Toe: B-10 -? Settlement marker, & Offset post			DD
115+00		X		Survey Monument	No survey monument off DS embankment slope			KE

Apache Junction FRS

Station	U/S	D/S	Crest	Observation	Detailed Description	Photo	Stake	nspector
115+00	X			Photo Point	Just below crest , # 27U			RE
END								
	Inspector Initials							
	RAE		Bob Eichinger		Kimley-Horn and Associates			
	DD		Diana Davisson		Kimley-Horn and Associates			
	KE		Ken Euge		Geological Consultants Inc.			
	TR		Tom Renckly		Flood Control District			
	JS		John Sikora		URS-Grenier Woodward-Clyde			

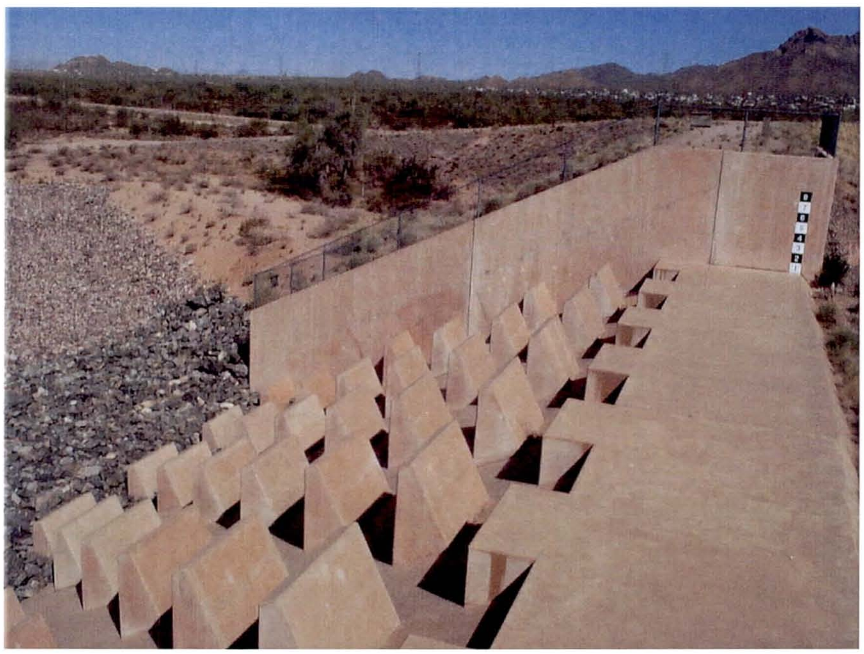
Apache Junction FRS. Crest Station 30+00. Gravel plating surface. Line of small shrubs along longitudinal centerline crack?.

Apache Junction FRS Downstream Slope Station 60+20. Found bulge reported in previous ADWR report. Recommend monitoring during each inspection.

Apache Junction FRS. Crest. Longitudinal Crack Station 82+00.

Apache Junction FRS. Station 95+50. Longitudinal crack on crest.

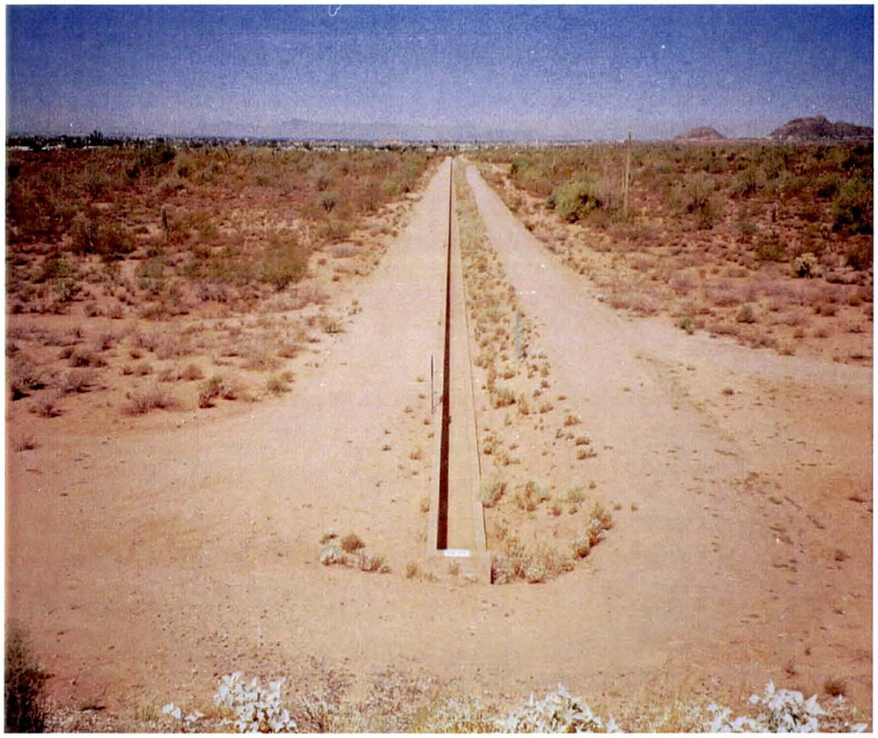
Apache Junction FRS. Left wingwalls of emergency spillway chute slight separation between embankment of concrete walls



Apache Junction FRS. Emergency Spillway. Baffle-block chute with concrete control sill

Apache Junction FRS. Baffle block spillway chute for emergency spillway and downstream riprap basin.

Apache Junction FRS. Principal Spillway inlet structure. Note clear approach channel, staff gages, and alert monitoring tower.



Apache Junction FRS. Outlet into Bulldog Floodway.

Apache Junction FRS. Close up of Principal Spillway outlet.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
EMBANKMENT DAM INSPECTION CHECKLIST

Each item of the checklist should be completed. Repair is required when obvious problems are observed. Monitoring is recommended if there is a potential for a problem to occur in the future. Investigation is necessary if the reason for the observed problem is not obvious.

Brief description should be made of any noted irregularities, needed maintenance, or problems. Abbreviations and short descriptions are recommended. Additional sheet(s) may be used for any items not listed and additional comments.

DAM NO.: **11.15**	DAM NAME: **APACHE JUNCTION FRS**	TYPE: EARTH EMBANK	NOT APPLIC.	NO	YES	MONITOR	REPAIR	INVESTIGATE
CONTACTS:		REPORT DATE:						
INSPECTED BY:		INSPECTION DATE:						
REVIEWED BY:	DATE:	PAGE 1 of __						
STORAGE LEVEL: ft. Above/below Spillway Crest	TOTAL FREEBOARD:	PHOTOS? YES/NO						
Item	Comments							

Item	NOT APPLIC.	NO	YES	MONITOR	REPAIR	INVESTIGATE
1. CREST						
a. Settlements, slides, depressions?						
b. Misalignment?						
c. Longitudinal/Transverse cracking?						
d. Animal burrows?						
e. Adverse Vegetation?						
f. Erosion?						
2. UPSTREAM SLOPE						
a. Erosion?						
b. Inadequate ground cover?						
c. Adverse vegetation?						
d. Longitudinal/Transverse cracking?						
e. Inadequate riprap?						
f. Stone deterioration?						
g. Settlements, slides, depressions, bulges?						
h. Animal burrows?						
3. DOWNSTREAM SLOPE						
a. Erosion?						
b. Inadequate ground cover?						
c. Adverse vegetation?						
d. Longitudinal/Transverse cracking?						
e. Inadequate riprap?						
f. Settlements, slides, depressions, bulges?						
g. Soft spots or boggy areas?						
h. Movement at or beyond toe?						
j. Animal burrows?						
4. DRAINAGE-SEEPAGE CONTROL						
a. Internal drains flowing? Est. Left ___ gpm; Est. Right ___ gpm						
b. Boils at or beyond toe?						
c. Seepage at or beyond toe? Estimated ___ gpm						

EMB. DAM INSP. CHECKLIST	PAGE 2 of	DAM NO.: **11.15**
INSPECTED BY:		DATE:

em	Comments	N/A	NO	YES	MON	REP	INV
d. Does seepage contain fines?							
5. ABUTMENT CONTACTS							
a. Erosion?							
b. Differential movement?							
c. Cracks?							
d. Settlements, slides, depressions, bulges?							
e. Seepage? Est. Left ___gpm; Est. Right ___gpm							
f. Animal burrows?							
6. OUTLET WORKS-APPROACH CHANNEL Unlined, Concrete, Riprap, or Other?							
a. Eroding or backcutting?							
b. Sloughing?							
c. Restricted by vegetation?							
d. Obstructed with debris?							
e. Silted in?							
7. OUTLET WORKS-INLET STRUCTURE							
Seepage into structure?							
b. Debris or obstructions?							
c. If concrete, do surfaces show:							
1. Spalling or Scaling?							
2. Cracking?							
3. Erosion?							
4. Exposed reinforcement?							
d. If metal, do surfaces show:							
1. Corrosion?							
2. Protective coating deficient?							
3. Misalignment or spilt seams?							
e. Do the joints show:							
1. Displacement or offset?							
2. Loss of joint material?							
3. Leakage?							
f. Are the trash racks:							
1. Broken or bent?							
2. Corroded or rusted?							
3. Obstructed?							
g. Sluice/Drain gates:							
1. Broken or bent?							

EMB. DAM INSP. CHECKLIST	PAGE 3 of	DAM NO.: **11.15**						
INSPECTED BY:		DATE:						
Item	Comments		N / A	N O	Y E S	M O N	R E P	I N V

2. Corroded or rusted?						
3. Leaking?						
4. Not seated properly?						
5. Not operational?						
6. Not periodically maintained?						
7. Date last operated?						
8. OUTLET WORKS-CONDUIT Concrete, Metal, or Plastic						
a. Seepage into conduit?						
b. Debris present?						
c. If concrete, do surfaces show:						
1. Spalling or scaling?						
2. Cracking?						
3. Erosion?						
4. Exposed reinforcement?						
5. Other?						
d. If Metal, do surfaces show:						
1. Corrosion?						
2. Protective coating deficient?						
3. Misalignment or spilt seams?						
e. Do the joints show:						
1. Displacement or offset?						
2. Loss of joint material?						
3. Leakage?						
9. OUTLET WORKS-STILLING BASIN/POOL						
a. If concrete, do surfaces show:						
1. Spalling or Scaling?						
2. Cracking?						
3. Erosion?						
4. Exposed reinforcement?						
b. If concrete, do joints show:						
1. Displacement?						
2. Loss of joint material?						
3. Leakage?						
c. Do the energy dissipators show:						
1. Signs of deterioration?						
2. Covered with debris?						

EMB. DAM INSP. CHECKLIST	PAGE 4 of	DAM NO.: **11.15**						
INSPECTED BY:		DATE:						
Item	Comments		N/A	NO	YES	MON	REP	INV

Item	N/A	NO	YES	MON	REP	INV
3. Signs of inadequacy?						
10. OUTLET WORKS-OUTLET CHANNEL Unlined, Concrete, Riprap or Other						
a. Eroding or backcutting?						
b. Sloughing?						
c. Obstructed?						
d. Poorly riprapped?						
e. Tailwater elevation and flow condition:						
11. EMERGENCY SPILLWAY-APPROACH CHANNEL Unlined, Concrete, Riprap or Other						
a. Eroding or backcutting?						
b. Sloughing?						
c. Restricted by vegetation?						
d. Obstructed with debris?						
e. Silted in?						
12. EMERGENCY SPILLWAY-CONTROL STRUCTURE						
a. If concrete, do surfaces show:						
1. Spalling or scaling?						
2. Cracking?						
3. Erosion?						
4. Exposed reinforcement?						
b. If concrete, do joints show:						
1. Displacement or offset?						
2. Loss of joint material?						
3. Leakage?						
c. If spillway is unlined:						
1. Are slopes eroding?						
2. Are slopes sloughing?						
3. Is crest eroding?						
d. Is weir in poor condition?						
e. Where is control structure?						
13. EMERGENCY SPILLWAY - CHANNEL Unlined, Concrete, Riprap or Other						
a. Obstructions or restrictions?						
b. If concrete, do surfaces show:						
1. Spalling or scaling?						
2. Cracking?						
3. Erosion?						
4. Exposed reinforcement?						

c. If concrete, do joints show:						
1. Displacement or offset?						
2. Loss of joint material?						
3. Leakage?						
d. If an unlined channel, does it show:						
1. Erosion?						
2. Slopes sloughing?						
3. Poorly protected w/ vegetation/riprap?						
14. EMERGENCY SPILLWAY-TERMINAL STRUCTURE						
a. If concrete, do surfaces show:						
1. Spalling or scaling?						
2. Cracking?						
3. Erosion?						
4. Exposed reinforcement?						
b. If concrete, do joints show:						
1. Displacement or offset?						
2. Loss of joint material?						
3. Leakage?						
c. Do the energy dissipators show:						
1. Signs of deteriation?						
2. Covered with debris?						
3. Signs of inadequacy?						
15. EMERGENCY SPILLWAY - OUTLET CHANNEL Unlined, Concrete, Riprap or Other?						
a. Eroding or backcutting?						
b. Sloughing?						
c. Obstructed or restricted?						
16. RESERVOIR						
a. High water marks?						
b. Erosion/Slides into pool area?						
c. Sediment accumulation/Vegetation growth?						
d. Floating debris present?						
e. Depressions, sinkholes or vortices?						
f. Low ridges/saddles allowing overflow?						
g. Structures below dam crest elevation?						
17. INSTRUMENTATION						
a. List type(s) of instrumentation: Staff gages, ALERT gage-water pressure transducer, settlement monuments, station markers at downstream edge of crest of						

EMB. DAM INSP. CHECKLIST	PAGE 6 of	DAM NO.: **11.15**	N/A	NO	YES	MON	REP	INV
INSPECTED BY:		DATE:						
Item	Comments							

dam						
b. In poor condition?						
c. Not read or analyzed regularly?						
d. Is data available?						
18. CONDITION SUMMARY / LICENSE / EAP / NEXT INSPECTION						
a. Dam condition: Unsafe Nonemergency / Safety Deficiencies / No Safety Deficiencies						
b. Safe storage Level:						
c. List date of current License: June 22, 1993						
d. Should new License be issued?						
e. In compliance with License?						
f. In compliance with Statute and Rules?						
g. In compliance with ADWR/District Actions?						
i. List current size; accurate? Medium						
j. List current ds hazard; accurate? Significant						
k. Is there a current EAP? If so, list latest revision date:						
l. List normal inspection frequency: Triennial						
m. Recommend date for next inspection:						

Notes/Sketchs

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART IV APACHE JUNCTION FRS

Section 4.0 Recommendations for Further Actions/Investigations

Section 4.0 Recommendations for Further Actions/Investigations

This Section of Part IV provides recommendations for further actions, work plans, and recommended investigations to be accomplished to remediate, repair, or modify, if necessary and required, the dam embankment, reservoir, and/or appurtenant structures. These recommendations are based on the technical review of historic documents (designs, reports, construction plans, as-builts, specifications, etc), review and evaluation of District procedures regarding operation and maintenance and inspection of dams, and from the field examinations of the structures. Structure specific recommendations and work plans are developed for each of the Work Assignment No. 3 dams as well as general operation and maintenance recommendations. The recommendations are in response to District and ADWR concerns and questions on methods and procedures to monitor, investigate, evaluate, repair, or modify a structure showing signs of distress or evaluate previous dam repairs or modifications.

4.1 Detailed Dam Safety Inspections – A procedure for detailed dam safety inspections was provided in the companion report "Policy & Program Report". The report provided in Appendix H detailed inspection guidelines, inspection checklists, and an inspection equipment checklist.

4.2 Phase II Engineering and Geotechnical Investigations – Phase II engineering and geotechnical investigations for the Apache Junction FRS should include the following:

Risk Assessment - A risk assessment of Apache Junction FRS should be conducted. It is recommended that the initial level for the risk assessment be conducted to evaluate the failure modes and effects analysis. Failure modes will need to be identified for Apache Junction FRS and may consist of failures due to transverse cracks, piping, or changes in upstream hydrology. Failure modes and effects analysis should be conducted through the use of an outside facilitator.

Geotechnical - A slope stability analyses of the exiting dam embankment under various loading conditions should be conducted. The stability analyses can be conducted using a model such as UTEXAS3. The results of the study will provide factors of safety for the embankment given the loading conditions anticipated and can be compared against ADWR rules and required factors of safety for embankment dams.

Concerns regarding soil dispersion in the Apache Junction FRS embankment and cut-off were raised by EBASCO (1986). EBASCO recommended additional dispersion tests to fully assess soil dispersion potential. No records in the NRCS or FCDMC files indicated this concern was resolved. KHA concurs with the EBASCO's recommendation and KHA recommends a soil dispersion evaluation of the embankment soils. The types of test to include at the crumb test, pinhole test, dispersion test (double hydrometer), and ESP. This will require a geotechnical field investigation to obtain soil samples for dispersion testing. The types of tests should be determined after consultation with the NRCS (typical tests include: dispersion, pinhole, and crumb tests).

Hydrology/Hydraulics – KHA recommends that the District develop an updated hydrologic model of the Apache Junction FRS watershed to include recent watershed improvements. The updated model should be based on District methodology and the HEC-1 computer program. The rating curve developed by the District in 1997 and the 1993 mapping should be used to develop new outflow discharges from the principal spillway and emergency spillways. The full PMF should be routed through the dam, reservoir, and emergency spillway and examine the impacts of the PMF on freeboard for the dam and spillway. The results should be compared with ADWR dam safety requirements.

A future watershed conditions land use hydrologic model should also be prepared and evaluated. This model should incorporate the impacts of the Pinal County drainage criteria on the upstream system elements (Apache Junction FRS). It is recommended that the District review any requests for drainage clearances submitted to Pinal County or the City of Apache Junction that are within the contributing watersheds.

An evaluation of upstream and downstream watershed conditions should be conducted during every other inspection of this structure. The purpose for conducting an examination of the upstream and downstream watershed conditions is to evaluate changes within the watershed such as urbanization which may affect the inflow design flood (IDF).

Current techniques for calculating the IDF involve using HMR-49 to estimate the Probable Maximum Precipitation (PMP). HMR-49 is generally considered to be conservative, especially for large watersheds over 50 square miles. A recommendation is to conduct a site specific PMP for this watershed prior to reevaluating the hydrology and hydraulics of the dam. A site specific PMP will evaluate storm centering on the watershed and storm distribution. A typical PMF evaluation will assume uniform rainfall and a storm distribution such as the SCS. This design storm approach while it may be valid for small watershed and lower frequency events it may be unrealistic for major storm events on large watersheds.

An Incremental Damage Analysis (IDA) could also be performed on this structure. The purpose of an IDA analysis is to estimate if there would be additional damage to downstream structures if the dam were to fail during a large storm event over no structure in place and a large flood event occurring within the watershed. If the analysis demonstrates that for a smaller flood event than the full PMF there would be an insignificant difference in damage with or without the dam in place, the dam would only have to be graded to that ratio of the IDF.

Sediment Yield – An updated sediment yield study should be undertaken to determine the sediment yield from the upstream watershed. The original methods undertaken by the NCRS for the design of the sediment reservoir were based on USGS topographic mapping with 4-foot contours. With new aerial mapping and updated sediment yield methodologies the results may indicate that there is less sediment contribution to the reservoir that originally designed.

Capacity Analysis - Recent aerial topographic mapping was prepared for the District in 1993. The District conducted a capacity analysis of the Apache Junction FRS in 1997. The results of this study indicate that the dam may have more than 100-year capacity and provides a higher level of flood protection. The dam may have a greater capacity than the design capacity, especially if the 100-year sediment volume is reduced depending upon the above suggested reanalysis. The District should re-survey the elevation of the emergency spillway crest elevation. The benchmark and the results of the survey should be compared against the District study conducted previously in 1997.

The 1993 mapping and the new mapping prepared as part of the Apache Junction ADMS can subsequently be used for future settlement/subsidence surveys, used as base mapping for crack location and monitoring, and used as base sheets for future alterations or modifications of the dam.

Utility Database - A utility database should be prepared. The database would consist of utility records that cross over, under, or through the dam embankment and/or ancillary features (such as the emergency spillway or outlet channels), or within the FCD right-of-way or easements. The database would track at a minimum: the type of utility crossing, location of crossing, skew to centerline of dam, depth of burial, type of encasement, provisions for piping and seepage control, utility owner (name, address, phone, contact person), location of as-built drawings, utility monumentation on dam, and method of construction (trenching, bore and jack).

Operation and Maintenance Plan - An operation and maintenance plan was located for Apache Junction FRS. The plan is very minimal at best and includes discussions regarding inspections and emergency actions. It is recommended that an extensive O&M plan be prepared according to the minimum guidelines provided in the "Policy and Program" report (KHA, April 2000).

Emergency Action Plan - It is recommended that an emergency action plan be prepared according to the minimum guidelines as published by FEMA in their report titled "Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners" (FEMA 64, October 1998). A peacetime disaster plan was prepared for Apache Junction FRS by the Maricopa County Department of Emergency Affairs. However, this plan is short of the requirements stated by FEMA 64 and the ADWR rules for dam safety.

4.3 Crack Monitoring Program

It is recommended that the District monitor the location and size of surface expressed transverse and longitudinal cracks. This effort goes beyond just documenting the observations of cracks in inspection reports. A crack location plan needs to be prepared using the dam construction plans or the previously discussed topographic mapping as a base. It is recommended that the plan be developed in AutoCad or some other electronic plan retrieval system (HIS for example). Observed crack locations can be plotted on the crack plan and coded by type. A database of transverse and longitudinal cracks needs to be prepared. The input to the database includes location of crack (station: location on upstream slope, downstream slope, or crest), width of crack, depth of crack, and any other distinguishing characteristics. A photograph should be taken and labeled for each crack. Follow-up observations and notations can then be compared to previous observations and conclusions drawn regarding crack propagation. The long-term benefit of the crack monitoring plan is to determine if particular segments of the embankment are more predominant in showing signs of cracking than other segments. In this fashion the District may in the future consider complete rebuilding of a particular segment of the dam embankment.

4.4 Operations and Maintenance

Landscaping: Where the safety of the structure is not compromised and effective flood-fighting and maintenance of the structure is not seriously affected, appropriate landscape plantings can be incorporated into the design of dam embankments (Corps of Engineers, "Guideline for Landscape Plant and Vegetation Management at Floodwalls, Levees, and Embankment Dams", January, 2000).

The primary objectives of plantings at dam embankments are to harmonize the development with the surrounding natural and human environment, enhance structures, control dust and slope erosion, provide privacy or screen out undesirable features, provide incidental habitat for wildlife, and create a pleasant environment for recreation. Plantings should be naturalistic and should avoid "arboretum-type" plantings.

Landscape plantings (aside from slope protection for erosion control) for flood control embankment dams should be confined to areas adjacent to the dam embankment. Because of the need for access at the upstream and downstream toe area by maintenance and construction equipment during periods of flooding, a minimum 50-foot vegetation-free zone should be maintained immediately downstream and upstream of the toes of the dam in the floodplain and on the abutments.

One method of establishing landscape plantings on embankment slopes is to provide for overbuilt areas on the dam faces. After establishing the minimum embankment section required to satisfy stability requirements, additional material could be added to the basic section to provide an area to support plantings. Overbuilt areas must include adequate consideration of the internal drainage system for the main structure. In no case should trees be directly planted on embankment slopes or crest.

Overbuilt areas require a root-free zone, which provides a margin of safety between the greatest extent of plant roots and the beginning of the basic structure. The basic structure is the engineered feature required for human safety. The bottom of the root-free zone will be the external limits of the cross section of the embankment established by the engineer for stability and/or seepage control.

Vegetation Management: Vegetation management at an earthen dam takes the form trimming of overgrown vegetation and the clearing of unwanted growth (large shrubs and trees). Trimming is conducted so that inspection of the slopes can be conducted without hindrance from vegetation. Locally, grasses and small shrubs are ideal for embankment dams along with rock mulch for slope protection against erosion. Vegetation should be trimmed on an ongoing basis and not be allowed to grow any higher than two to three feet. Trimming methods are labor intensive, usually involving gas powered weed trimmers or boom mowers.

Removal of dead trees and debris is recommended within the approach channels to principal spillways. This will reduce the chance that the inlet to the principal spillway would become clogged with debris. Typically, District dams have trash racks and/or a multiple-staged or tiered inlet for the principal spillways. In the event debris accumulates at a lower level on the inlet/trash rack, floodwater can still overtop the debris and flow into the principal spillway conduit. This type of inlet structure is recommended for all District dams where debris might be a concern.

Debris blockage of the principal spillway can cause operational constraints on the performance of the spillway to evacuate floodwaters. Depending on the volume of inflow, a blocked principal spillway can become non-functional and cause flow to occur in the emergency spillway for storm events less that the inflow design flood. Several of the District dams have a pedestrian/maintenance bridge that connects to the crest of the dam and the inlet tower of the principal spillway. In the event that the principal spillway become clogged during an event, District forces have the capability to remove the debris by standing on the bridge and using rakes or other means to remove debris.

Sediment Management: Sediment markers should be installed within the reservoir impoundment area. The sediment markers will provide the District with an indication of the rate of sediment build-up as well as when sediment removal activities are required.

Generally, District forces remove sediment when sediment build-up becomes apparent at the inlet and outlet structures of the principal spillway. No sediment maintenance has been conducted for the sediment pool. This may be due to the fact that: 1) there is no method to determine the level of sediment buildup in the pool, and 2) sediment build-up has not been a problem.

The District should develop a sediment management plan for District dams. The plan elements would require identification of the equipment, manpower, and for the disposal of removed sediment.

Clean Water Act (CWA)– Section 404: Certain activities relating to excavation-only activities are exempt from Corps jurisdiction under Section 404 of the CWA. However, the Corps' definition of exempt excavation activity is based on 'incidental fallback" and is very restrictive. The generally accepted definition of "incidental fallback" allows only for the spillage of material from the actual excavation device. This prohibits the pushing, windrowing or stockpiling (even temporarily) of material during the excavation activity.

Sediment must be lifted (as opposed to pushed) from the site and deposited outside of the jurisdictional boundary to be exempt from Section 404. Sediment cleaning operations conducted with a backhoe or front-end loader (bucket equipment) would likely be exempt, while sediment clearing conducted with a grader or other blade equipment would not be exempt.

Sediment removal activities may also be subject to Section 401 and Section 402 regulations regardless of their Section 404 status. Ground disturbance of greater than 5 acres is subject to authorization under Section 402 of the CWA and Section 401 authorization may be required if the site will have a surface water discharge to jurisdictional areas. The ESA and Migratory Bird Treaty Act regulations may apply to areas of potential inhabitation or suitable habitat particularly if the area is vegetated. .

Flood control structures may result in increased vegetation growth. Structures in ephemeral channels can impound water for short periods after flow events, therefore increasing the hydroperiod of the site. An increase in available moisture can result in increased vegetation density or enhanced vegetation species composition.

In general, the type of vegetation communities created or enhanced by flood control structures will benefit wildlife species associated with riparian habitat or those species requiring a more dense growth of vegetation. Such habitat is rare in most areas of Arizona. Therefore, the vegetation communities have a higher probability for providing habitat for several Endangered Species Act (ESA) listed species. Depending on the type of structure other habitat may be created or enhanced.

The ESA and the Migratory Bird Treaty Act provide protection to listed species and to the species habitat. Removal of this vegetation may be considered a violation of the ESA and/or the Migratory Bird Treaty Act. Restrictions on activity timing and the extent of the activity may be imposed under these regulations.

Further, the removal of the vegetation may require permit authorization under Section 404 of the CWA. The removal of vegetation by mechanized land clearing (grubbing) is not considered an exempt activity under the Clean Water Act. The Corps' believes that the soil clinging to the roots will be dislodged in the process and will fall into other areas thus creating a discharge or fill situation. Removal of vegetation by cutting is not considered a jurisdictional activity. If stump or whole vegetation is removed in such a manner that the stump/stem is lifted from the site (as opposed to pushed across the site) the activity is considered to be exempt from Section 404 jurisdiction.

Vegetation clearing activities may be subject to regulation under Section 402 of the CWA if more than five acres of ground is disturbed and may also be restricted under the ESA adherence clause of the NPDES permit. Vegetation clearing may be subject to Section 401 if the area may discharge to a jurisdictional area or require a Section 404 authorization.

Riprap Placement/Repair: The placement of riprap or other armoring material is a jurisdictional activity under Section 404 and is subject to Corps' approval. In most instances this includes the repair or replacement of previously installed materials (As noted in NWP#3). Riprap activities may be subject to regulation under Section 402 of the CWA if more than five acres of ground or vegetation will be disturbed. Riprap material may also be subject to Section 401 approval.

Recommendations for Section 404 Regulatory Compliance

Clean Water Act.

- Conduct Jurisdictional Determinations on areas subject to periodic maintenance.
- Train Maintenance Workers in the identification of potential CWA Section 404 jurisdictional areas and the restriction of activities within jurisdictional boundaries.
- Conduct an audit of existing facilities to determine which have been previously authorized under Section 404 or other applicable regulation.
- Develop a vegetation management program that monitors and controls growth of vegetation to prevent the establishment of wetlands. (By definition a wetland must be vegetated). Under the proposed regional conditions of the new Nationwide Permit Program impacts to wetlands are not allowed, with certain exemptions for NWP 3 and 31.
- Coordinate with the Corps to develop a standard procedure for sediment removal, which identifies the type of equipment and methodologies that will be exempt from Section 404 jurisdiction based on the incidental fallback rule.
- Develop Best Management Practices (BMPs) and standard procedure for earth disturbance activities associated with maintenance activity to satisfy Section 402.
- Design and permit new facilities to include the appropriate maintenance activity in the original Section 404/401 authorization.
- Establish baseline conditions for existing facilities (Required under Section404 NWP31)
- Coordinate with Corps to determine if a Regional or other General permit for all maintenance activity is appropriate.
- Coordinate with the ADEQ and/or EPA to determine if a Section 401 water quality certification is applicable.

Endangered Species Act/Migratory Bird Treaty Act

- Train Maintenance Workers to identify potential habitat and to be aware of seasonal nesting times.
- Obtain appropriate ESA permit to allow for field survey and possible incidental take of certain listed species.
- Coordinate with USFWS to determine appropriate habitat conditions and survey protocols for areas of potential ESA restrictions.
- Develop a Maintenance Schedule that avoids activity in suitable habitat during the breeding season.

- Coordinate with USFWS regarding the potential development of suitable habitat in or adjacent to flood control structures. This may include the establishment of a pseudo Safe Harbor agreement.
- Design new facilities to provide for enhanced habitat outside of the area of maintenance disturbance. Thus developing long-term enhanced habitat and mitigation areas.

Federally Managed Areas

- Identify responsible Management Agency.
- Determine Management requirements for specific area.
- Conduct necessary NEPA documentation to support a CATEX.
- Include an ongoing Maintenance Plan in required NEPA documentation for new projects.

State and Local Regulations

- Coordinate with SHPO regarding potential historical significance of older facilities and of potential eligibility of areas requiring periodic maintenance.
- Train Maintenance Workers in the identification of vegetation listed in the various Native Plant regulations.
- Develop potential donor sites and acceptable salvage protocol for native vegetation removed from maintenance areas.

4.5 Subsidence and Earth Fissure Monitoring Program

Although the Apache Junction FRS is believed to be outside the limits of active ground subsidence in the east valley area, conducting a horizontal and position survey of established benchmarks in the area of the FRS should be used to verify this belief. The control benchmark for this survey must be a witnessed, established benchmark in bedrock that has been in place for at least 30 years.

Subsidence due to groundwater withdrawal is not expected to be a problem at the Apache Junction FRS due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment. Apache Junction FRS is located on the Usery Mountain granitic pediment with bedrock at a relatively shallow depth (probably less than 50 feet) beneath the FRS structure.

Earth fissuring at the Apache Junction FRS site and local vicinity has a low degree of probability due to the lack of thick sequences of unconsolidated and compressible sediments and the presence of the granitic rock pediment on which the Apache Junction FRS is founded. The nearest ground subsidence-related earth fissure is about two and one-half miles south of the south end of the FRS.

The Apache Junction FRS is located near an area of active ground subsidence and earth fissures. However, due to the presence of shallow granite pediment in the FRS area and the FRS's proximity to the pediment edge, earth fissuring should have minimal impacts on the Apache Junction FRS. Ground subsidence at the FRS is expected to be negligible. However, the Apache Junction FRS should be included in an area-wide monitoring program because of its proximity to the ground subsidence area and known earth fissures.

However, general guidelines have been prepared and should be implemented if the physical regional characteristics change in the vicinity of the dam. The following presents recommended guidelines for subsidence and earth fissure monitoring.

General Guidelines for Recommended Subsidence and Earth Fissure Monitoring

Many embankment flood control dams under the jurisdiction of the District are located in areas of active ground subsidence and earth fissures. The prognosis for continued ground subsidence and earth fissure development is excellent for the foreseeable future. Therefore, the assessment of existing and future potential ground subsidence and earth fissures and their impact on the safety of existing District dams is a critical element of the dam safety evaluation process

KHA recommends the District Subsidence monitoring program outlined by Staedicke (1995) be adopted. It should also be refined and modified or amended where appropriate for application to District dams and to satisfy other regulatory requirements. The following outline incorporates the salient items of the District program and lessons learned by the BuRec, NCRS, and consultants with professional experience dealing with ground subsidence and earth fissures.

Ground subsidence due to groundwater withdrawal from deep aquifers is known to impact alluvium-filled basins in central Arizona including the District. The surface manifestations of ground subsidence include lowering of the ground surface over time and the development of earth fissures (or ground cracks) due to induced tensile stresses within the alluvium-filled basins. The initial activity of the subsidence monitoring program will be an evaluation of known subsidence within the District. This evaluation will be performed to assess current ground subsidence conditions and characterize the earth fissures present. These results will help formulate the general parameters of the monitoring program and the specific details for monitoring at each of the District's embankment dams. Where critical subsidence and each fissure conditions exist that might jeopardize dam safety, the monitoring program results could be used to help develop mitigation measures to reduce potential ground subsidence impacts caused by regional groundwater withdrawal.

The recommended scope of activities to accomplish the subsidence evaluation is separated into three tasks. Task 1 would be directed to an overview assessment of the District using available geological and hydrogeological data and geological interpretation of available aerial photography. Output from Task 1 would be a preliminary map of the District area identifying potential and known subsidence areas and earth fissures. This information would be used to target sites for direct field examination during Task 2. Task would verify the presence of fissures close to District structures. Task 3 includes the preparation of comprehensive settlement/subsidence and earth fissure monitoring program tailored to each embankment dam structure. The monitoring program would be designed to incorporate trigger mechanisms that would be used when excessive subsidence or earth fissure emergency conditions are identified.

Task 1: Compile Preliminary Subsidence/Earth Fissure Map:

- Research and compile existing earth fissure and ground subsidence data pertaining to the District service area.
- Assess future potential ground subsidence induced by groundwater withdrawal at the site and in the site vicinity. Data to complete this assessment will be obtained from the Arizona Department of Water Resources, U.S. Geological Survey-Water Resources Branch and private sector hydrogeological consultants familiar with the area.
- Acquire aerial photographs from available sources, such as Maricopa County, Arizona Department of Transportation, BuRec, NRCS, and private sector companies. Aerial photograph interpretation would be used to identify suspect ground subsidence areas and earth fissures.
- Compile and analyze the data gathered and prepare a preliminary subsidence/earth fissure map of the District area and target areas for the Task 2 field reconnaissance. Use available subsidence monitoring data to determine past subsidence and calculate future potential ground subsidence estimates.
- Prepare summary report documenting the Task I study findings and conclusions.

Task 2: Subsidence/Earth Fissure Field Reconnaissance

- Conduct a ground-truth field reconnaissance within a 5-mile radius of flood control embankment dams, identified in Task 1, that are in a subsidence area to:

  (1) Verify, or refine, and update the earth fissure and ground subsidence data compiled during Task 1.

  (2) Identify and map earth fissures or other related 'suspect' features that may be present and potentially affect District flood control dams.

  (3) Determine the rate of earth fissure growth where feasible using Task 2 information and historical aerial photography or other documentation.

- Stake and survey the location of the earth fissures and identify exploration sites.

- Prepare a Task 2 summary report documenting the results of the field reconnaissance.

Task 3: Prepare Preliminary Subsidence and Earth Fissure Monitoring Program

- Locate, relocate, or reestablish settlement/subsidence monitoring monuments on crest and downstream toe of embankment dams. Establish new monuments where deemed necessary. Relocated, reestablished, or new monuments should be constructed in accordance recognized plans and specifications (NRCS, BuRec, ADOT, District). The number of survey monuments should be determined considering the future potential subsidence in the dam area, the structure hazard classification, and other factors that may be deemed critical based on discussion with District staff.

- Locate, relocate, or reestablish monitoring benchmarks in rock tied to an established survey network such as the National Geodetic Survey. All benchmarks should be thoroughly documented and witnessed.

- Identify and locate wells near each embankment dam that can be used to monitor changes in groundwater levels. This information would be used to refine estimates of future potential ground subsidence.

- Verify benchmark survey control and survey the elevation of all monitoring monuments. Using the new survey data, rectify all previously obtained subsidence monitoring data relative to an established survey datum.

- Based on the results of the new survey and the rectifying of past data, develop a resurvey schedule suited to each dam structure. The surveys should be rerun at yearly intervals for two or three years to see if any trends exist. The monitoring intervals could be changed to range from 1 year to 4 or 5 years depending upon trends established or the calculated estimates of future potential subsidence. A suggested monitoring schedule is provided in the following table.

Table 4-1. Recommended Subsidence & Earth Fissure Monitoring Schedule.

Dam Hazard Classification	Monitoring Schedule			
	Ground Subsidence	Earth Fissures		
		≤ ¼ mile	¼ mile < D < 1 mile	1 mile < D < 5 miles
High	Annual	Annual	Annual	Biennial
Significant	Biennial	Annual	Biennial	Biennial
Low	Triennial	Triennial	Triennial	Pentad
Very Low	Pentad	Pentad	Pentad	Pentad

The monitoring schedule should be reevaluated on a triennial basis and revised if deemed necessary.

- Earth fissure monitoring should be conducted concurrently with the subsidence monitoring program. In areas of known active earth fissures, the monitoring intervals may need to be more closely spaced especially where an earth fissure is located within one mile of an District structure. Earth fissure monitoring could be conducted using (1) direct examination on the ground by geologists or geotechnical engineers or (2) low-sun-angle aerial photography. The earth fissure survey should also include measurement of its surface expression (length, width, depth, orientation, differential displacement, evidence of activity or inactivity).

- Surveying of subsidence benchmark and structure monuments should be conducted using currently accepted surveying methods and standards of practice. Survey accuracy standards should be 0.05 feet (or about 2 centimeters).

- Data collected should be recorded a format such as Microsoft EXCEL. As a minimum, reporting should be done annually. The report should be distributed to other interested parties including BuRec, Corps, USGS, AGS, ADOT, ADWR, County highway departments, and local jurisdictions. Additional report could be necessary where rapidly occurring subsidence is documented or when earth fissure growth or development is observed.

Subsidence Monitoring for Apache Junction FRS

Settlement monuments were established on the embankment crest (A-series) and along the downstream toe (B-series). Some of the monuments have been destroyed or damaged.

The monitoring program should consist of a series of elevation data measurements taken at both the "A"-series and "B"-series monuments located along the Dam. The A-series and B-series monuments are located approximately every 1000 feet along the crest and toe of the embankment, respectively. A recent dam safety field investigation revealed that many of these benchmarks have either been removed or destroyed. Additional survey monuments should be installed on the upstream and downstream toe and the upstream and downstream crest of the dam. The District database needs to be updated to store and plot the new settlement data to detect trends or movements.

Once all survey monuments are in place, a survey of the elevation of each point should be conducted in accordance with the recommended schedule for high hazard potential dams. The survey method used should have a vertical accuracy to at least 0.05 feet (2 centimeters). The results of the surveys, over time, would give:

- Subsidence/settlement measurements
- Subsidence/settlement rates (increase/decrease)
- Data on differential subsidence/settlement.

Although ground subsidence and earth fissures are expected to have a negligible impact on the Apache Junction FRS, subsidence data gathered at the Apache Junction FRS should be obtained, compiled, analyzed, and reported (to ADWR) in accordance the general ground subsidence/earth fissure monitoring program guideline.

A summary of the Phase II recommendations is provided in Table 4-2 on the following page.

Table 4-2. Summary of Recommendations for Apache Junction FRS.

	Recommendation	Remark
Dam Safety Program Elements	Dam Safety Inspections	See "Policy and Program" Report
	Develop Utility Database	See "Policy and Program" Report
	Update Operations and Maintenance Plan	See "Policy and Program" Report
	Prepare Emergency Action Plan to meet Minimum requirements of FEMA 64	See "Policy and Program" Report
	Develop/prepare Crack Monitoring Plan	
	Install Sediment Markers in Reservoir	
	Continue Settlement Surveys	See "Policy and Program" Report
	Prepare Subsidence and Earth Fissure Monitoring Plan	See "Policy and Program" Report
Phase II Analyses	Conduct Risk Assessment	See "Policy and Program" Report
	Conduct Slope Stability Analyses	Design vs Existing vs ADWR requirements
	Conduct Soil Dispersion Tests	Test for dispersive soils in foundation
	Update Hydrologic Models (100-yr, PMF)	New methodology and changes in land use
	Prepare Future Conditions hydrologic model	Evaluate detention/retention
	Evaluate upstream/downstream land use and watershed conditions	Impact on IDF
	Conduct Incremental Damage Analysis	Impact on IDF
	Conduct updated Sediment Yield Analysis	Reservoir capacity and upstream development
	Conduct updated Reservoir Capacity Analysis	

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART IV APACHE JUNCTION FRS

Appendix A – Summary of NRCS Design Criteria

Item	NRCS Criteria	ADWR Criteria	Comment/Remarks
Publications and References for Corps, NRCS, and ADWR Criteria	Technical Release No. 60 TR-60. Earth Dams and Reservoirs. Oct. 1985. Amended Jan 1991	Rules for Dam Safety Procedures	
Size	Maximum ht = 22.0 ft Floodwater storage = 540 AF Sediment storage -- 95 AF	**Small:** 25' <height< 40' and 1000 ac-ft < capacity< 10,000 ac-ft	Presently an small dam.
Structure Classification (Hazard Classification)	**Class C**. Failure may cause loss of life, serious damage to homes, industrial and commercial buildings, important public utilities, major highways, or railroads	**High**: probably loss of life and low to high economic losses	Currently a high hazard dam;
Inflow Design Flood (IDF)	One-percent event (100-year)	**0.5PMF to PMF**: High hazard class with any size class will vary based on downstream population and potential economic losses (pg 26)	May be required to pass 0.5 PMF with change in classification
Total Freeboard	10 ft per design plans (between Emergency Spillway crest and the settled top of the dam crest)	ADWR definition: vertical distance between the emergency spillway crest and the top of the dam Shall be the largest of the following : (note: this is for new dams) a) the sum of the IDF max water depth above the spillway crest plus wave runup b) the sum of the IDF max water depth above the spillway crest plus 3 ft c) The minimum of 5 ft	
Residual Freeboard	between maximum water surface elevation to dam crest		
Principal Spillway Design Flood	100-year	N/A	100-year
Principal Spillway Capacity	(a) Discharge through the emergency spillway will not occur (b) Adequate to empty the retarding pool in 10 days or less. Or adequate to empty 80 percent or more of the maximum volume of retarding storage after 10 days. The 10-day is measured starting from the time the maximum water surface elevation is attained during the passage of the principal spillway flood	N/A	(a) Discharge through the emergency spillway will not occur (b) Adequate to empty the retarding pool in 10 days or less. Or adequate to empty 80 percent or more of the maximum volume of retarding storage after 10 days. The 10-day is measured starting from the time the maximum water surface elevation is attained during the passage of the principal spillway flood (
Initial Reservoir Stage for Principal Spillway Hydrograph Routing	Crest elevation of the lowest ungated principal spillway inlet or the anticipated elevation of the sediment storage, whichever is higher	N/A	Crest elevation of the lowest ungated principal spillway inlet or the anticipated elevation of the sediment storage, whichever is higher
Design Procedures for Principal Spillways	TR 60 Chapt 6 Principal Spillways	for high and significant hazard dams principal spillway shall be 36-inches or greater; all high and significant hazard dams shall have the capacity to evacuate 90% of storage capacity of reservoir within 30 days, excluding reservoir inflows; corrugated metal pipe not acceptable	
PMP Storm Types	General and local. HMR No. 49	N/A	N/A
Minimum Emergency Hydrologic Criteria	For Class C Structure 1: emergency spillway hydrograph P100 + .26(PMP - P100) 2: freeboard hydrograph = PMP	N/A	
Emergency Spillway Capacity	(a) Pass the emergency spillway hydrograph resulting from P100 at the safe velocity (b) Pass the freeboard hydrograph with the water surface elevation at or below the design top of the dam (c) Capacity must not be less than that determined from Figure 7-1 on Page 7-8 in TR-60	Spillways and outlets of flood control dams shall be able to pass all the flood water at a discharge rate as calculated on the basis of the spillway design flood.	

Item	NRCS Criteria	ADWR Criteria	Comment/Remarks
Emergency Spillway Crest Elevation	(a) Satisfy the 2500 ac-ft total capacity limit (PL 83-566, NWM 500.20) (b) The discharge through the emergency spillway will not occur during the routing of the principal spillway hydrograph (c) If the 10-day drawdown requirement is not met for principal spillway capacity design, then the crest elevation of the emergency spillway will be raised as noted on Page 6-1, Capacity of Principal Spillway.	N/A	(a) Satisfy the 2500 ac-ft total capacity limit (PL 83-566, NWM 500.20) (b) The discharge through the emergency spillway will not occur during the routing of the principal spillway hydrograph (c) If the 10-day drawdown requirement is not met for principal spillway capacity design, then the crest elevation of the emergency spillway will be raised as noted on Page 6-1, Capacity of Principal Spillway.
Initial Reservoir Stage for Emergency Spillway Hydrograph Routing	The highest value from the following elevations: (a) Elevation of the lowest ungated principal spillway inlet (b) The anticipated elevation of the sediment storage (c) The elevation of the water surface associated with significant base flow (d) The pool elevation after 10 days of drawdown from the maximum stage attained when routing the principal spillway hydrograph. (Page 7-2 in TR 60)	N/A	
Sedimentation	100-year sediment reservoir	N/A	
Dam Breach		Unless waived by the Director, owners of high and significant hazard potential dams shall prepare, maintain, and exercise Emergency Action Plans for immediate defensive action to prevent failure of the dam and minimize threat to downstrem development.	Develop EAP
Special Requirement for Storage	2500 ac-ft (total reservoir capacity = water volume plus the anticipated sediment volume) according to Table 500-2 in Public Law 83-566, National Watershed Manual-Part 500.20. Based on Table 500-2, any amount for construction costs and >4,000 ac-ft of total capacity require a committee on Environment and Public Works of the Senate and committee on Public Works and Transportation of the House of Representatives.	The temporary storage will be evacuated as soon as possible following such periods of flood.(from License)	
Seismic	See TR-60	There are no seismic design requirements for existing flood control dams.	See Appendix B in Engineering Pamphlet 1110-2-1155 US Army Corps of Engineers
Design for Vegetated and Earth Emergency Spillways	(a) From EM - 27 Pages Appendix F (b) Spillway will not breach during passage of the freeboard storm (f) Maximum permissible velocity in vegetated emergency spillways: Table 7-1 in TR-60 (g) Maximum permissible velocity in earth emergency spillways: Table 7-2 in TR-60(Fortier and Scobey's Study) (h) Manning's n = 0.02 for design velocity in earth spillways; Capacity of earth spillways will be based on a appraisal of the Manning's n at the site. (i) Manning's n = 0.04 for vegetated spillways	Criteria depends on whether earthen spillway is located on soils subject to liquefaction.	

INDIVIDUAL STRUCTURES ASSESSMENT REPORT

PART IV APACHE JUNCTION FRS

Appendix B – Settlement Monitoring Record

SETTLEMENT MONITORING OF EARTHEN DAMS OPERATED BY THE FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

DRAFT

Prepared by

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Civil Engineering Technician III
Flood Control District of Maricopa County

June 1, 1995

Purpose

The purpose of this report is to:

a) Compile settlement monitoring data that has been acquired to date.

b) Recommend refinements to the monitoring procedure.

c) Recommend a schedule of continued monitoring.

d) Recommend that the settlement monitoring procedure be supplemented with:

    a) earth fissure monitoring procedure

    b) Periodic inspection using a team of specialists (geologist, structural engineer, etc.)

Introduction

Beginning in 1977 survey monuments were installed on the crest and downstream toe of the Flood Control District's (FCD's) earthen dams to monitor the settlement of these structures. It is assumed that changing elevations of monuments at the downstream toe of the structures indicate subsidence, and changing elevations of the crest monuments are the sum of subsidence plus expansion/contraction of the embankment fill. The difference between these two is then the apparent expansion/contraction of the fill material.

Subsidence is the downward movement or sinking of the Earth's surface caused by removal of underlying support (typically the withdrawal of groundwater). The estimated groundwater pumpage in the Salt River Valley basin area peaked in the 1950's. Due to an abundance of rainfall and surface water supply between 1976 and 1982, pumpage was greatly reduced and water levels rose over much of the basin during that time.[1] The Phoenix Active Management Area (AMA) was created by the Groundwater Management Act of 1980. Although groundwater levels have stabilized throughout much of the valley, they continue to decline in the area of Luke Air Force Base, so structures in this vicinity warrant greatest concern (White Tanks and McMicken).

The crest monuments are typically placed about 6" below the crest. Since the distance from the crest to the monument isn't constant, variation from the design crest of less than 1 foot is probably not significant. A more telling number is the settlement between years surveyed. Because groundwater pumping peaked in the 1950's, and our earliest survey data is 1977, we lack data for the most critical time period. Structures which should have the highest priority for continued monitoring are those in which the minimum elevation is more than 1 foot below design crest, or those which show the greatest settlement in the years surveyed.

Data Analysis

Appendix A contains a summary table that lists each structure and shows the maximum settlement between years surveyed, and the difference between the design crest and the minimum crest elevation. The table appears twice, sorted first by greatest settlement, and then by greatest change from the design crest.

Appendix B contains detailed comments regarding each structure.

Appendix C contains the following detailed information for each structure:

    1) Data table showing survey elevations, incremental and total settlement

    2) Plot of the crest settlement monuments

    3) Plot of the change in crest over the years surveyed.

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[1]Arizona Department of Water Resources Hydrologic Map Series Report No. 12 Sheet 1 of 3 Depth to Water and Altitude of the Water Level. Dated 1983

In each data table anomalies have been shaded. These have been checked from the plans, but they should also be checked from the survey notes. In cases where the error is obvious, it has been corrected and noted.

In addition to the data gathered in the settlement surveys, the District is in the process of conducting GPS surveys of each dam, to verify their capacities. The first of these surveys (Buckeye Structures 1,2,&3) has been submitted to the District, and the remaining surveys are to be submitted in late June. This data should be analyzed before prioritizing and conducting future subsidence surveys. Although the GPS surveys don't have the same level of accuracy, and don't include elevations of the settlement monuments, they do include spot elevations on the dams, and provide ties to the benchmarks used in the subsidence surveys. This should help us confirm those locations where enough subsidence has occurred to cause concern and/or warrant increased monitoring.

Groundwater Withdrawal Induced Subsidence fissuring

An earth fissure is a crack at or near the Earth's surface that is caused by subsidence.[2] According to SH&B's study of McMicken Dam "This kind of crack would in all probability lead to very rapid failure of the unrepaired dam in the event of major runoff into the reservoir."[3] SH&B's 1983 study of McMicken Dam states "it is considered highly probable that at least several earth fissures will form through the dam in the next few decades. The central vertical drain concept of repair yields...the only positive defence against subsidence induced fissuring through the dam."[4] It is recommended that we supplement our program of settlement monitoring with a program of monitoring fissures near FCD Dams. Fissures are known to exist in the vicinity of McMicken and Powerline Dams, and we would be wise to determine if fissures are present near other dams, and monitor their progression. The SH&B report has numerous references to publications regarding fissures, and this would be a good place to start.

Recommendations:

Recommended refinements to the settlement monitoring procedure:

1) Surveys should be tied into a grid of USC&GS monuments established in rock.
2) Surveys should include elevations of the crest, if monuments are below the surface.
3) Surveys should include the elevation of the emergency spillway.
4) Water levels in the vicinity should be checked at timing close to that of the surveys.
5) Establish monuments at the downstream toe, if they don't exist (McMicken)

Recommended schedule of continued monitoring:

ADWR has stated that after several surveys have been completed, surveys can be delayed indefinitely unless a trend of settlement has been established. The recommended survey interval is approximately 5 years, but this varies depending on the sponsor of the project. Table 1 shows the survey record and proposed schedule (assumes 5 year interval)

Corps Structures

Corps regulation no. 1110-2-100 states that their structures should be monitored at a 5 year interval.

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[2]Steven Slaff, Land Subsidence and Earth Fissures in Arizona, Arizona Geological Survey, 1993, p.11.

[3]SH&B, p. 66.

[4]Sergent, Hauskins & Beckwith, Design Report, McMicken Dam Restoration Study, 1983, Pages 2 and 3.

Recommended Periodic inspection:

Although the dams are regularly inspected by FCD's maintenance division, the Corps has stated that for their own structures they normally conduct a more formal inspection (called Periodic) at five year intervals. The settlement surveys are completed about six months prior to the inspection, so their results can be studied by the inspection team. The inspection team consists of a geologist, a structural engineer, and other specialists. It may be worthwhile for us to use this procedure, especially for dams which are in areas of known subsidence and fissuring.

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Arizona Department of Water Resources, Hydrologic Map Series Report No. 12: Depth to Water and Altitude of the Water Level, Sheet 1 of 3, 1983.

McLain Harbers Co, Inc., Buckeye FRS's Numbers 1,2, & 3: Field Survey Report, for Flood Control District of Maricopa County, 1995.

Sergent, Hauskins & Beckwith, Geotechnical Investigation Report: McMicken Dam Restoration Study, for Flood Control District of Maricopa County, 1982.

Sergent, Hauskins & Beckwith, Design Report: McMicken Dam Restoration Study, for Flood Control District of Maricopa County, 1983

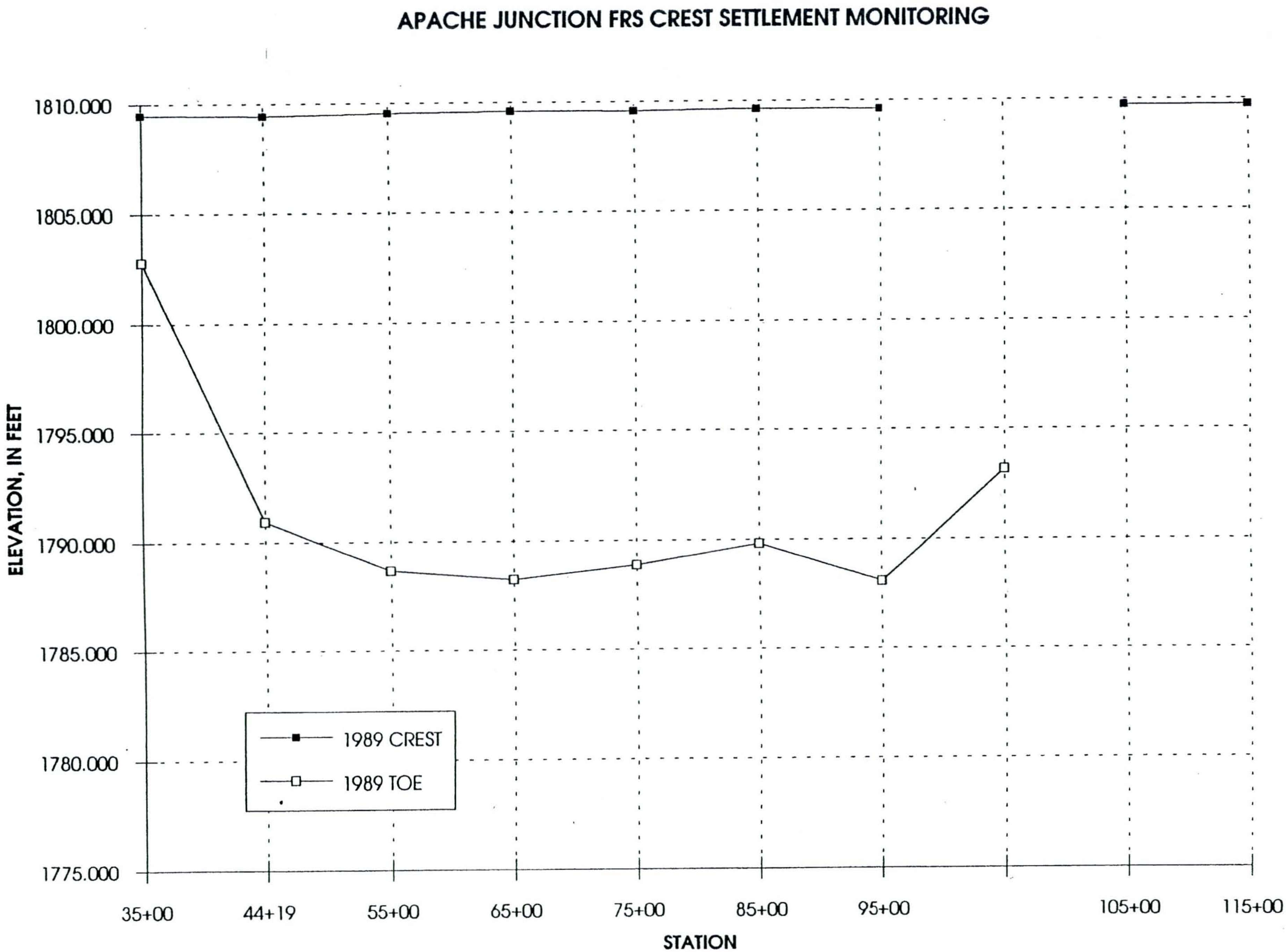
Slaff, Steven, Land Subsidence and Earth Fissures in Arizona, Arizona Geological Survey, Tucson, Arizona, 1993.

United States Department of Agriculture, Soil Conservation Service, Proposal for Rehabilitation: White Tank Mountains Flood Retarding Structures #3 and #4, Pilot Watershed Project, 1991.

U.S. Army Engineer District, Los Angeles Corps of Engineers, Adobe Dam: Dam, Outlet Works and Spillway, Periodic Inspection, Report No. 1, June 1982.

U.S. Army Engineer District, Los Angeles Corps of Engineers, New River Dam: Dam, Outlet Works and Spillway, Periodic Inspection Report No. 1, March 1985.

4/26/95



APACHE JUNCTION FRS CREST SETTLEMENT MONITORING
1810.000
1805.000
1800.000
1795.000
1790.000
1785.000
1780.000
1775.000
ELEVATION, IN FEET
1989 CREST
1989 TOE
35+00
44+19
55+00
65+00
75+00
85+00
95+00
105+00
115+00
STATION

APACHE JUNCTION FRS SUBSIDENCE MONITORING			
MARKER	**STATION**	**1989**	
A-1	35+00	1809.459	
A-2	44+19	1809.435	
A-3	55+00	1809.522	
A-4	65+00	1809.594	
A-5	75+00	1809.576	
A-6	85+00	1809.643	
A-7	95+00	1809.607	
A-8			
A-9	105+00	1809.732	
A-10	115+00	1809.739	
MINIMUM		1809.435	
MAXIMUM		1809.739	
B-1	35+00	1802.794	
B-2	44+19	1790.941	
B-3	55+00	1788.669	
B-4	65+00	1788.238	
B-5	75+00	1788.874	
B-6	85+00	1789.811	
B-7	95+00	1788.062	
B-8	105+00	1793.136	
	29+86.95	1808.110	
	35+00	1801.190	
	40+00	1795.890	
	44+18.33	1790.580	
	44+19.07		
	47+39.79	1789.870	
	50+00	1788.480	
	55+00	1788.360	
	60+00	1787.050	
	65+00	1787.380	
	70+00	1787.300	
	75+00	1787.700	
	80+00	1789.680	
	85+00	1788.790	
	90+00	1788.460	
	95+00	1788.420	
	99+37.48	1784.940	
	99+38.16		

	102+21.62	1790.580	
	105+00	1791.710	
	110+00	1801.000	
	115+00	1806.260	
	117+00	1808.770	
APACHE JUNCTION FLOODWAY			
	12+00	1812.150	
	15+00	1811.640	
	20+00	1818.480	
	25+00	1807.500	
	25+88.03	1808.110	
	28+70	1805.200	
	30+67.19	1803.490	
	35+00	1800.290	
	40+00	1796.750	
APACHE JUNCTION FRS OUTLET			
	105+00	1781.330	
	110+00	1775.610	
	115+00	1769.210	
	120+00	1763.700	
	125+00	1759.360	
	129+23.99	1752.220	
NOTES:			
1) CONSTRUCTION COMPLETED 1987			
2) DESIGN CREST ELEVATION =			
3) DESIGN SPILLWAY CREST =			

Printed 11/13/2000

SUBSIDENCE SURVEY DATA
APACHE JUNCTION FRS

1989 SURVEY			
"A" SERIES		"B" SERIES	
STATION	ELEVATION (ft)	STATION	ELEVATION (ft)
35+00	1809.459	35+00	1802.794
44+19	1809.435	44+19	1790.941
55+00	1809.522	55+00	1788.669
65+00	1809.594	65+00	1788.238
75+00	1809.576	75+00	1788.874
85+00	1809.643	85+00	1789.811
95+00	1809.607	95+00	1788.062
105+00	1809.732	105+00	1793.136
115+00	1809.739		

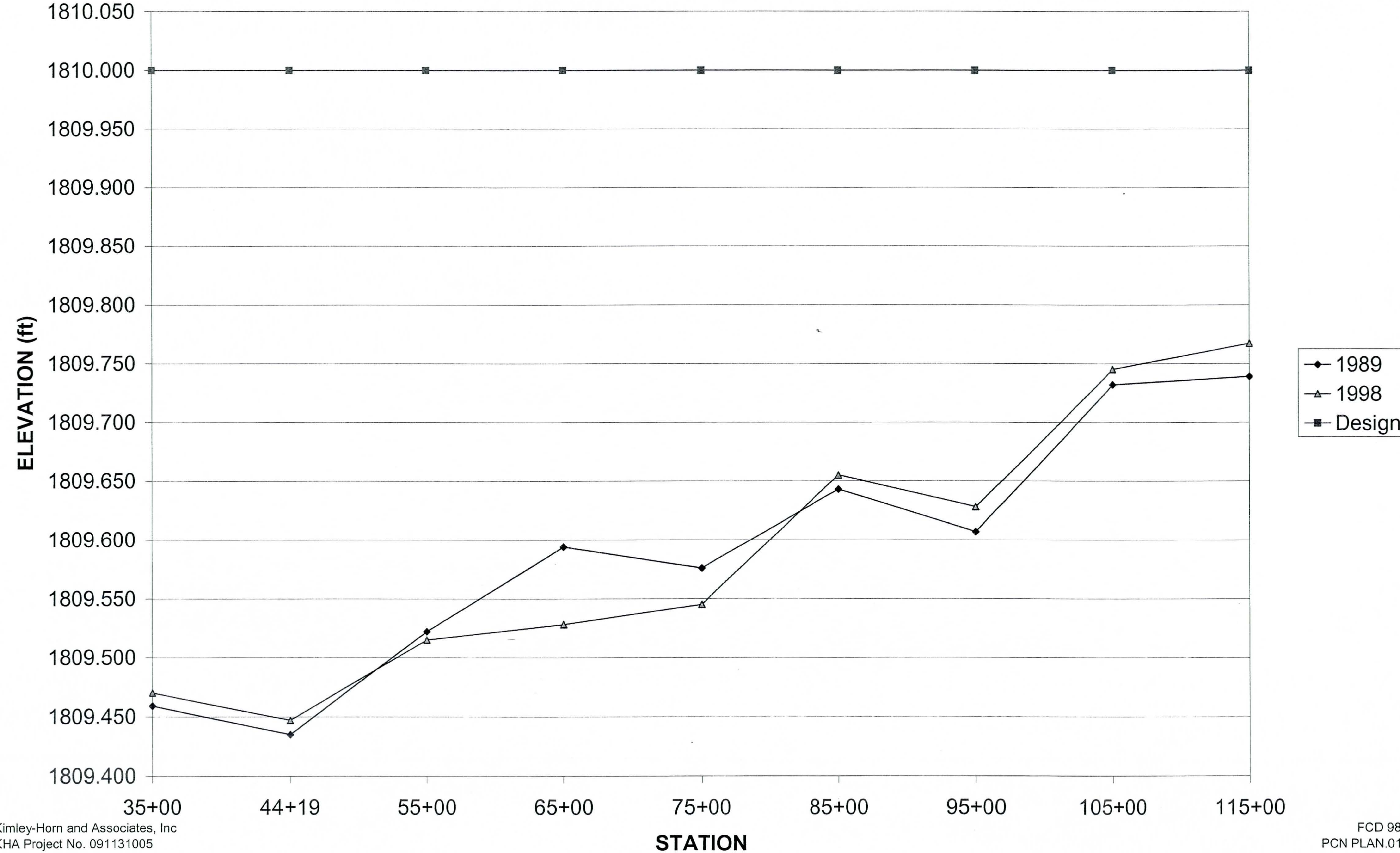
1998 SURVEY			
"A" SERIES		"B" SERIES	
STATION	ELEVATION (ft)	STATION	ELEVATION (ft)
35+00	1809.470	35+00	1802.830
44+70	1809.447	44+70	1790.973
55+00	1809.515	55+00	1788.695
65+00	1809.528	65+00	1788.255
75+00	1809.545	75+00	1788.885
85+00	1809.655	85+00	1789.795
95+00	1809.628	95+00	1788.085
105+00	1809.745	105+00	1793.193
115+00	1809.767		

DESIGN CREST	
STATION	ELEVATION (ft)
35+00	1810.000
44+19	1810.000
55+00	1810.000
65+00	1810.000
75+00	1810.000
85+00	1810.000
95+00	1810.000
105+00	1810.000
115+00	1810.000
EMER. SPWY.	1799.770
PRIN. SPWY.	1793.500

1989 SURVEY DRAWN BY D. CLOUGH OF THE USDA SOIL CONSERVATION SVC., 2/89
1998 SURVEY SEALED BY RICHARD D. TABOR OF GILBERTSON ASSOCIATES, INC., 10/2/98

APACHE JUNCTION FRS CREST ("A" SERIES) ELEVATIONS

Printed 11/13/2000



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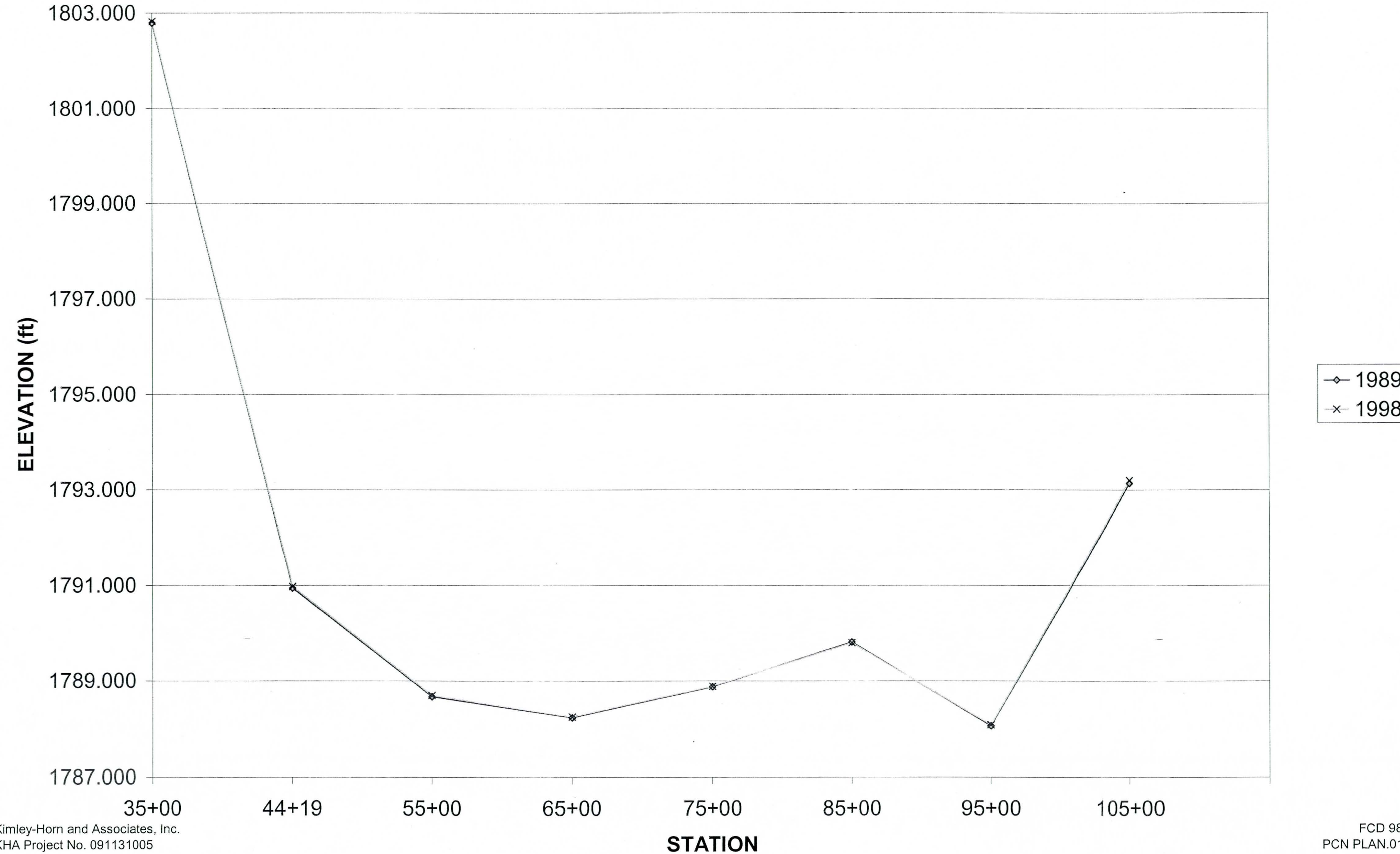
APACHE JUNCTION FRS TOE ("B" SERIES) ELEVATIONS



1.0 Closing

The purpose of the Individual Structures Assessment Report is twofold: (1) to assess the existing condition of Spook Hill, Signal Butte, and Apache Junction Flood Retarding Structures; and (2) to recommend actions for further investigations/monitoring of the structures and develop work plans to repair signs of distress in the structures.

The Individual Structures Assessment Report is a companion report to one other major report under FCD 98-41- Work Assignment No. 3. This other report is the Alternatives Analysis Report for Spook Hill, Signal Butte, and Apache Junction Flood Retarding Structures currently under preparation.

The Individual Structures Assessment Report is the culmination of an investigation, evaluation, and assessment of the present condition of the three District structures – Spook Hill, Signal Butte, and Apache Junction Flood Retarding Structures. The investigation was founded in the scope of work for Work Assignment No. 3, Task 3.0 – Individual Structures Assessment. Under Task 3.0, Kimley-Horn and Associates reviewed current dam safety criteria as related to the existing structure and the original dam safety design criteria. KHA also reviewed the historic dam safety records for each dam to identify and assess any modifications to the dams related to dam safety. The records review also included identification of modifications not related to dam safety. The historic records review included reviewing documents, for example previous inspection reports, to identify documented potential dam safety signs of distress such as transverse and/or longitudinal cracking. KHA recommended methods to reduce, eliminate, or counteract evidence of distress.

Part of Task 3.0 includes a review of the available technical documentation for each structure. The purpose of the technical review is to review the historic records related to the dam and through this review familiarize the project team with the structure, familiarize the team with the history of the structure, and acquaint the team with the original analysis and design criteria, and compare the original to current (year 2000) criteria.

Finally, a field examination was conducted for each structure. The examination was visual in manner and included the dam embankment and associated features. An inspection log was prepared summarizing the results of the field examinations. The purpose of the field examinations was to familiarize the project team with the existing field conditions at each structure, note past signs of distress, and to document any new signs of distress.

The assessment of each structure was based upon the technical review and field examinations. Recommendations were prepared for each structure for further investigations, analyses and work plans prepared to repair and/or reduce distress signs found at each dam.

At the present time, all three structures examined as part of the Individual Structures Assessment Report appear to be in satisfactory operational condition for the original design and field conditions, criteria, and assumptions under which the dams were constructed. The District will be faced with ongoing repair of slope erosion and transverse and longitudinal cracks at the Spook Hill, Signal Butte, and Apache Junction Flood Retarding Structures.

2.0 References

The references listed in this section are mainly complied from data sources from the Flood Control District of Maricopa County, the Arizona Department of Water Resources (ADWR) – Office of Dam Safety, and the Natural Resources Conservation Service (formerly the Soil Conservation Service – SCS). Many of the SCS references are bound notebooks of various project related documents, such as, but not limited to: past project office correspondence, preliminary and design engineering calculations, preliminary and design construction specifications, quantity and costs estimates, preliminary and design structure alignments, right-of-way requirements, materials testing results, geological investigations. KHA expresses gratitude to Mr. Noller Herbert, P.E. of the NRCS and Mr. Michael Greenslade, P.E., of ADWR, for their generous assistance for allowing access to their respective agency dam safety records and library.

The NRCS documents included reports, studies, and correspondence that not only are directly project related to each of the three flood retarding structures (Spook Hill, Signal Butte, and Apache Junction FRS) but also includes documentation to the major Buckhorn-Mesa floodways (Spook Hill, Signal Butte, Bulldog, and Apache Junction). For example, Spook Hill FRS documents collected for review included documents that referred to the Spook Hill Floodway. The following references include both flood retarding structures and floodways.

Spook Hill Flood Retarding Structure

Parsons Brinkerhoff Quade and Douglas, Inc. for FCDMC, City of Mesa, MCDOT	Spook Hill Area Drainage Master Study (Master Drainage Plan for the Spook Hill FRS watershed, Phase 1)	1987
Soil Conservation Service - SCS	Buckhorn-Mesa WPP: Spook Hill FRS Road Ramp Alternatives: McKellips Road/McDowell Road	1976
Maricopa County Flood Control District	Spook Hill FRS Floodway and Landscape Treatment: Buckhorn-Mesa Watershed	1977
Soil Conservation Service - SCS	Spook Hill Floodway Design Calculations	1976
Soil Conservation Service - SCS	Spook Hill FRS and Floodway Design, Vol. 2, Preliminary Design	1976
Soil Conservation Service - SCS	Spook Hill FRS Floodway Landscape Treatment 'As-Builts' Maricopa and Pinal Counties	1986
	Reconstruction of Spook Hill Earth Dam at East McKellips Road and East McDowell Road	Oct-97
	East Brown Road Transmission Water Main CAP Plant to Crimson Reservoir	Jun-86
McLaughlin, Kmetty Engineering, Ltd.	Flood Inundation Analysis of Emergency Spillway Operation of the Spook Hill Flood Retarding structure	Aug-90
Monville, Paul	Overland Flow Calculations w/map	
Soil Conservation Service - SCS	Spook Hill Specifications	
McLaughlin, Kmetty Engineering, Ltd.	Spook Hill Flood Retarding Structure Flood Inundation Analysis	Oct-90
Lowry and Associates	Spook Hill Flood Retarding Structure Spillway Inundation Area Study	1985
McLaughlin, Kmetty	Spook Hill Flood Retarding Structure Dam Break and	May-90

Engineering, Ltd.	Flood Inundation Study - Flood Hydrology Report	
McLaughlin, Kmetty Engineering, Ltd.	Identification of Dam Failure and Flood Inundation Scenarios for the Spook Hill Flood Retarding Structure	Jun-90
McLaughlin, Kmetty Engineering, Ltd.	Dam Breach Analysis and Inundation Flood Hydrographs for the Spook Hill Flood Retarding Structure	Jul-90
Soil Conservation Service - SCS	Buckhorn-Mesa WPP Spook Hill Floodway Design Calculations (Alignment, Hydraulics, Structural Design, Appendix, Cost Estimates	received 2/24/87
Soil Conservation Service - SCS	Buckhorn-Mesa Watershed Spook Hill Flood Retarding Structure (Reports, Construction Correspondence, Moisture and Density Determinations, Design Correspondence)	
Soil Conservation Service - SCS	Geologic Investigation Report Spook Hill Dam Site (Conclusions and Recommendations, Report, Log of Test Holes, Permeability Tests, Materials Testing Results, Drawings)	
Soil Conservation Service - SCS	Spook Hill Flood Retarding Structure Pumping Plant (Correspondence addressing Irrigation issues, Report on Abandonment of Irrigation System, sewer and telephone issues addressed briefly)	
Soil Conservation Service - SCS	Spook Hill FRS and Floodway Landscape Architecture Design Report (Design Review Report, Construction Specs)	
Soil Conservation Service - SCS	Spook Hill Site No. 4 and Outlet (Engineer's Cost Analysis, Structure Quantities, Land Rights, Site Data, Geologic Data, Hydraulic Data, Hydrologic Data, Correspondence)	
Soil Conservation Service - SCS	Spook Hill "Landscaping" (Plants and Seeds Information, Design Ideas, Citizens Information)	
Soil Conservation Service - SCS	Maps Developed for Hydrologic Studies	
Soil Conservation Service - SCS	Spook Hill FRS Floodway Landscape Treatment (Project Agreement, Suspend and Resume Work Orders, Contract Pay Estimate Summaries, Contracts	
Sverdrup Corp	Spook Hill Pump House Data	
Soil Conservation Service - SCS	Spook Hill Watershed Summary Sheets (Clearing and Grubbing, Channel Excavation Unclassified, Structural Excavation Unclassified, Structural Backfill, Embankment Earth Fill, 24" CMP, 30" CMP, Special Fittings, Loose Rock Rip Rap, Fencing, Grouted Rip Rap)	
Soil Conservation Service - SCS	Cracking Studies 1979	
Soil Conservation Service - SCS	Spook Hill FRS and Floodway Design Vol 3 Final Design (Alignment, Hydraulics, Structural Design, Appendix, Cost Estimates)	
Soil Conservation Service - SCS	Spook Hill FRS and Floodway Design Vol 1 Correspondence	
Soil Conservation Service - SCS	Spook Hill FRS Alignment	
Soil Conservation Service - SCS	Spook Hill Misc. Engineering Data	
Soil Conservation Service - SCS	Spook Hill Design Correspondence	
Soil Conservation Service - SCS	Spook Hill FRS and Floodway Design Vol4A Support Data (Alignment, Quantities, Miscellaneous)	
Soil Conservation Service - SCS	Spook Hill Design Vol 4B Support Data (Hydraulics, Flood Hydraulics etc.)	
Soil Conservation Service - SCS	Spook Hill Design (Design Report, Layout, Hydrology, Hydraulics, Embankment and Foundation Design, Structure Design, Cost Estimate)	
Soil Conservation Service - SCS	Spook Hill FRS and Floodway Design Vol 2 Preliminary Design (Design Report, Alignment, Hydraulic Design, Embankment and Foundation Design, Structural Design, Cost Estimate, Plan & Profile, Emergency Spillway, Road Ramps)	

Soil Conservation Service - SCS	Spook Hill Correspondence 1979-1980	
Soil Conservation Service - SCS	Spook Hill Construction Correspondence	

Signal Butte Flood Retarding Structure

Soil Conservation Service - SCS	Hydrologic Investigation Emergency Action Plan Signal Butte FRS Buckhorn-Mesa Watershed	1984
Soil Conservation Service - SCS	Signal Butte Floodway Buckhorn-Mesa Watershed: Engineering Report	1985
Soil Conservation Service - SCS	Signal Butte Flood Retarding Structure Design Report Book II - Hydraulics, Hydrology and Spillway Selection	Aug-84
Soil Conservation Service - SCS	Signal Butte Flood Retarding Structure Design Report Data Book 2 - Geologic Investigation and Slope Stability	
Soil Conservation Service - SCS	Contract for the Construction of the Signal Butte Flood Retarding Structure Pass Mountain Diversion and Outlet	
Soil Conservation Service - SCS	Signal Butte Flood Retarding Structure Design Report (Includes: Design Report, Correspondence and References, O&M Plan, Cost Estimate and Specifications)	
McArthur, RP: Soil Conservation Service - SCS	Hydrology Peak Discharges for Design of Signal Butte Floodway	Feb-78
Soil Conservation Service - SCS	Signal Butte FRS Design Hydrology (Design Parameters and Data)	
Soil Conservation Service - SCS	Signal Butte FRS Original Quantities 1981 (Clearing and Grubbing, Excavation, Earth Fill, Concrete, Steel Reinforcement, Fencing, Pipe, Liner)	
Soil Conservation Service - SCS	Signal Butte Floodway Montana Design File (see hand written data collection sheet)	
Soil Conservation Service - SCS	Preliminary Design Calculations Signal Butte Floodway (Design Report, Alignment, Earth Section, Concrete Section, Quantities and Cost Estimate, Specifications)	
Soil Conservation Service - SCS	Construction Specs for the Landscaping of the Buckhorn-mesa Structures	Nov-89
Soil Conservation Service - SCS	Modification of Side Inlets Signal Butte Floodway	
Soil Conservation Service - SCS	Supplemental Calculations Signal Butte Floodway	
Soil Conservation Service - SCS	Investigation Committee Signal Butte Floodway (Engineering Investigation Report w/pics)	
Soil Conservation Service - SCS	Signal Butte Floodway Side Inlet Study and Repair (Correspondence and Report)	
Soil Conservation Service - SCS	Signal Butte Floodway Miscellaneous Construction Data (Safety Program, Soils Tests/Classifications)	
Soil Conservation Service - SCS	Centerline Survey Signal Butte Floodway	Aug-76
Soil Conservation Service - SCS	Signal Butte Floodway Misc. Data (Vegetative Outlets, Quality Assurance Pay limits and As-builts)	
Soil Conservation Service - SCS	Signal Butte Floodway Design Data (Engineering Report (9/85)-short, primarily correspondence)	
Soil Conservation Service - SCS	Preliminary Design Pipeline Alternate C Signal Butte Floodway (Supplemental C Bid Schedule, Cost Estimate, Specifications)	
Soil Conservation Service - SCS	Signal Butte Floodway Pipeline Alternate A Preliminary Design (Supplement A Quality Comps)	
Soil Conservation Service - SCS	Preliminary Design Pipeline Alternate Signal Butte Floodway Supplement D (Design Report, O&M Guide)	
Soil Conservation Service	Signal Butte Floodway Pipe Outlet Design Comps (no tabs)	

- SCS		
Rogers, Gladwin & Harmony, Inc.	Signal Butte FRS supplement Designs (Landscape Rehabilitation Preliminary Plan Report)	
Soil Conservation Service - SCS	Signal Butte Site No. 2 (Engineers Cost Analysis, Structure Quantities, Land Rights, Site Data Geologic Data, Hydraulic Data, Hydrologic Data, Correspondence)	
Repologle, John A and Clemmens, Albert J.	Model Studies for Signal Butte Floodway - "Side Weir flows into Supercritical Channels" - Draft Copy, but no Final report ever prepared)	
Soil Conservation Service - SCS	Signal Butte Floodway Miscellaneous Engineering data (Plans and Specs)	
Soil Conservation Service - SCS	Geologic Investigation Signal Butte FRS (Logs Centerline, Principal Spillway, Emergency Spillway, Logs Borrow Area)	
Pedone, Paul F. Soil Conservation Service - SCS	Geologic Investigation Report Signal Butte Floodway Buckhorn-Mesa Watershed	Jul-78
Soil Conservation Service - SCS	Modifications for Overchutes Bulldog Floodway and Apache Junction Outlet and Extension Signal Butte FRS	none
Soil Conservation Service - SCS	Signal Butte FRS Emergency Spillway Headwall Extension	Dec-84
Soil Conservation Service - SCS	Signal Butte Floodway Design Data (1973-1981)	
Soil Conservation Service - SCS	Signal Butte Floodway Supplement No. 2 to Final Design Report Dated Dec '80	Jun-83
Soil Conservation Service - SCS	Signal Butte Floodway Planning and Design	
Soil Conservation Service - SCS	Signal Butte Flood Retarding Structure Design Report II	
Soil Conservation Service - SCS	Signal Butte Floodway Design Calculations Supplement No. 1 to Final Design Report Dated Dec '80 (Supplement to Design Report, Hydraulics Structural Design, Cost Estimate, Specifications, O&M Plan)	
Soil Conservation Service - SCS	Signal Butte Floodway Side Inlet Repair	
Soil Conservation Service - SCS	Signal Butte Floodway Side Inlet Design Final	
Soil Conservation Service - SCS	Signal Butte Floodway Correspondence	
Soil Conservation Service - SCS	Signal Butte Floodway Quantities	Mar-83
Soil Conservation Service - SCS	Signal Butte Floodway Preliminary Design Report (Design Report, Alignment, General, Earth Section, Concrete Section, Outlet Channel, Quantities and Cost Estimate)	
Soil Conservation Service - SCS	Plans and Specifications for the Construction of Buckhorn-Mesa Watershed Project Signal Butte Floodway	
Soil Conservation Service - SCS	Supplemental Watershed Work Plan Agreement No. 1 and Supplemental Watershed Work Plan No. 1	Jun-76
Soil Conservation Service - SCS	Signal Butte Floodway Correspondence	Jul-82
Soil Conservation Service - SCS	Signal Butte Floodway Preliminary Design Pipeline Alternate	Aug-82
Soil Conservation Service - SCS	Signal Butte Floodway Correspondence	1982-1986
Soil Conservation Service - SCS	Signal Butte Floodway Correspondence	1975-1981
Soil Conservation Service - SCS	Two Grey Boxes of Claims Items and Documents related to them	

Apache Junction Flood Retarding Structure

EBASCO Services Inc. for SCS	Apache Junction FRS and Floodway: Phase IV.2, Final Design Report, Vol. 1, 10-86	1986
EBASCO Services Inc. for SCS	Apache Junction FRS and Floodway: Phase IV.2, Final Design Report, Vol. 2, 10-86	1986
EBASCO Services Inc. for SCS	Apache Junction Flood Retarding Structure Downstream Inundation Study	1986
EBASCO Services Inc. for SCS	Apache Junction Flood Retarding Structure - Inundation Study and Hydrology	Feb-86
Soil Conservation Service - SCS	Correspondence and Notes Book 1	
Flood Control District	1971 Flood Photographs	
Flood Control District	Apache Junction-Gilbert Magma, Williams-Chandler Watersheds Flood Photos	Oct 1972
Thomas Hartig & Associates	Contractors Gradation Analysis	1988
Soil Conservation Service - SCS	Density Summaries	1988
Soil Conservation Service - SCS	Apache Junction FRS Signal Butte FRS Extension (Plan and Profile, vegetative Pipe Overchutes, Cross Sections)	
	Modifications for Overchutes Bulldog Floodway and Apache Junction Outlet and Extension Signal Butte FRS	
Western Engineers Arizona Inc.	Quality Control Program for Bulldog Floodway and Apache Junction FRS	1987
Flood Control District	Meridian & Ironwood Bridges	1983-1987
Ebasco Services Inc.	Bulldog Floodway Steel Placement	1987
Ebasco Services Inc.	Lost Dutchman Blvd./ Idaho Rd. Intersection @ Apache Junction Flood Retarding Structure	1987
Ebasco Services Inc.	Apache/Bulldog Supplement Designs and Modifications	1987-1988
AT&T	Bulldog/Apache Junction Flood Control Project AT&T Cable Crossing	1985
Ebasco Services Inc.	Phase I Feasibility Study Report Revised 1985 "Bulldog Floodway and Apache Junction"	
Ebasco Services Inc.	Hydrology Report Bulldog Floodway and Apache Junction	1985
Ebasco Services Inc.	Bulldog and Apache Junction FRS and Outlet	1985
	Apache/Bulldog Survey, Hydrology, Soils	
Soil Conservation Service - SCS	Geological Investigation Report Apache Junction FRS, Floodway, Bulldog Floodway	1983
Soil Conservation Service - SCS	Apache Junction Hydrology Design	1983
Soil Conservation Service - SCS	Buckhorn-Mesa Watershed Review of Design Precipitation for Principal, Emergency and Freeboard Hydrographs	1983
Soil Conservation Service - SCS	Buckhorn-Mesa WPP Computer Printouts TR-20 and Resource Sites Program Apache Junction Dam, Pass Mt. Dam, Signal Butte Dam, TR-20	1973

Soil Conservation Service - SCS	SCS Design Folder Apache Junction FRS and Floodway Bulldog Floodway A&E Contract	
Soil Conservation Service - SCS	Apache Junction FRS and Floodway and Outlet and Bulldog Wash Floodway	
Soil Conservation Service - SCS	Buckhorn-Mesa Landscaping Design	1983
Soil Conservation Service - SCS	Buckhorn-Mesa Drop Structure Design	1982
Rogers, Gladwin & Harmony, Inc.	Landscape Rehabilitation Final Design Report "Pass Mt. Diversion and Outlet Signal Butte FRS and Floodway"	1985
Rogers, Gladwin & Harmony, Inc.	Landscape Rehab Final Design Report "Apache Junction Floodway and FRS Apache Junction Outlet and Bulldog Floodway"	1986
Flood Control District	Construction Specs for the Landscaping of the Buckhorn-mesa Structures	1989
Soil Conservation Service - SCS	Sedimentation Buckhorn-Mesa Watershed 1974 Supplement	
Soil Conservation Service - SCS	Buckhorn-Mesa Watershed Apache Junction Floodway Book #9	1974
Soil Conservation Service - SCS	Buckhorn-Mesa Watershed Apache Junction Floodway Book #8	1974
Del Georgio & Associates	Apache Junction Del Georgio Survey	1983
Ebasco Services Inc.	Phase IV.2 Final Design Report Apache Junction FRS, Floodway Volume I	1986
Ebasco Services Inc.	Phase IV.2 Final Design Report Apache Junction FRS, Floodway Volume II	1986
Ebasco Services Inc.	Phase IV.1 - Final Design Report Bulldog Floodway and Apache Junction Outlet Volume I	
Ebasco Services Inc.	Phase IV.1 - Final Design Report Bulldog Floodway and Apache Junction Outlet Volume II	
Soil Conservation Service – SCS	Construction Completion Report "Apache Junction FRS, Apache Floodway, Apache Junction Outlet and Bulldog Floodway"	1989
Soil Conservation Service – SCS	NO TITLE - Pay Estimates and Quantities	1987
Soil Conservation Service - SCS	Material Submittals	1989
Soil Conservation Service - SCS	Williams-Chandler WPP Apache Junction FRS Buckhorn-Mesa Watershed - Preliminary Plan and Profile of RWCD Floodway Buckhorn-Mesa WPP	
Ebasco Services Inc.	Supplement to Phase II - Soil Mechanics Report Bulldog Floodway and Apache Junction Flood Control Project	1986
Ebasco Services Inc.	Phase II Soil Mechanics Report Bulldog Floodway and Apache Junction Flood Control Project	1985
Soil Conservation Service - SCS	Plan and Profile for Geologic Investigation Apache Junction FRS	1983
Soil Conservation Service - SCS	Bulldog Floodway Hydrology	1983
Soil Conservation Service - SCS	Buckhorn-Mesa Hydrology	1973

Construction Plans

Soil Conservation Service - SCS	Spook Hill Flood Retarding Structure and Floodway Landscape Treatment	June 1977
Soil Conservation Service - SCS	Plans for the Construction of Spook Hill Floodway	June 1977
Soil Conservation Service - SCS	Plans for the Construction of Bulldog Floodway and Apache Junction FRS	Feb 1987
Soil Conservation Service - SCS	Plans for the Construction of Signal Butte Floodway	Mar 1983
Soil Conservation Service - SCS	Plans for the Construction of Apache Junction Floodwater Retarding Structure and Floodway	Feb 1987
Soil Conservation Service - SCS	Plans for the Construction of Signal Butte Floodway	May 1983
Flood Control District of Maricopa County	Spook Hill FRS 100 Year Floodplain Delineation	1980
Dibble & Associates	Utility Relocation Plans Signal Butte Floodway	Mar 1980
Soil Conservation Service - SCS	Signal Butte Floodway Plan of Dam Site and Storage Area	Oct 1974
Soil Conservation Service - SCS	Site No. 1 Apache Junction Dam Plan of Dam Site and Storage Area	Oct- 194
Soil Conservation Service - SCS	Land Rights Plan Apache Junction FRS	Jun 1983
Dibble & Associates	Right of Way Plans Signal Butte Floodway	Nov 1979
Soil Conservation Service - SCS	Land Rights Work Maps for Signal Butte Floodway	Mar 1978
Soil Conservation Service - SCS	Plans for the Repair of Expansion Joints East Maricopa Floodway Reach-4 and Signal Butte Floodway	May 1988
Soil Conservation Service - SCS	Plan and Profile of Signal Butte Floodway	Oct1 976
Soil Conservation Service - SCS	Signal Butte FRS Survey Subsidence Survey 1987	Mar 1987
Parsons Brinkerhoff	Master Drainage Plan for the Spook Hill FRS Watershed Phase 1	Sep 1985
Soil Conservation Service - SCS	Plans for the Modification of Side Inlets Signal Butte Floodway	Mar 1990

General References

Arizona Department of Transportation; 1992; Development of Seismic Acceleration Contour Maps for Arizona-Final Report; Arizona Department of Transportation Report No. AZ92-344; 328 p.; 5 map sheets, Scale 1:1,000,000.

Arizona Public Service Company; 1974; Palo Verde Nuclear Generating Station, Preliminary Safety Analysis Report with Amendments; Vol 2 and .

Burford & and Gilmore; 1982; Vertical Tectonics, in Summaries of Technical Reports; Vol. 14; United States Geological Survey; Open-File Report 82-840; pp. 29-31.

Cooley, M.E.;1977; Map of Arizona Showing Selected Alluvial Structures and Geomorphic Features; United State Geological Survey; Open-File Report 7733; 29 p.

Dubois, S.M., Smith, A.W., Nye, N.K., and Nowak, T.A.; 1982; Arizona Earthquakes 1776-1980; Arizona Bureau of Geology and Mineral Technology Bulletin 193; 456 p.; 1 map sheet, Scale:1:1,000,000.

Ertec-Western Inc.; 1981; Phase I Inspection Report for Spook Hill Retarding Dam, I.D. No. AZ00175, Maricopa County, Arizona; as part of National Program for Inspection of Dams; consultant report prepared for Arizona Department of Water Resources; August 1981; 36 p.

Menges, C.M. and Pearthree, P.A.; 1983; Map of Neotectonic (latest Pliocene-Quaternary age) Faults.

Pewe, T.L. and Larson, M.K.; 1982; Origin of Land Subsidence and Earth Fissures in Northeastern Phoenix, Arizona; Arizona Bureau of Geology and Mineral Technology Open-File Report 82-09, 169 p.

Schell, B.A. and Wilson, K.L.; 1981; Regional Neotectonic Analysis of the Sonoran Desert; United States Geological Survey; Open-File Report 82-00057; 61 p.

Soil Conservation Service; 1975; Report of Geologic Investigation, Buckhorn-Mesa Watershed, Spook Hill Damsite; 4 p with photographs, site plans, logs of test holes, field permeability test results, and material testing results.

Soil Conservation Service; 1975; Design Report, Spook Hill Dam & Floodway, Buckhorn-Mesa WPP, Maricopa County, Arizona; PL 566, Preliminary Design.

Soil Conservation Service; 1976; Design Report, Spook Hill Dam & Floodway, Buckhorn-Mesa WPP, Maricopa County, Arizona; PL 566, Phase II Final Design.

United States Department of the Interior, Bureau of Reclamation; 1982; Salt-Gila Aqueduct Reach-4 Solicitation No. 2-SB-30-00010; Specification No. DC-7668; Central Arizona Project, Arizona.

United States Geological Survey; 2000; National Earthquake Information Center; Earthquake Research Results, Earthquake Data Base 1980 through May 11, 2000.