MARICOPA RECHARGE FEASIBILITY INVESTIGATION
MARICOPA COUNTY FLOOD CONTROL DISTRICT

Technical Memorandum

EVALUATION AND RANKING OF THE MOST FEASIBLE POTENTIAL RECHARGE SITES

CH2M Hill - Nov. 3, 1987

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TECHNICAL MEMORANDUM

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SUBJECT: Maricopa Recharge Feasibility Investigation
Maricopa County Flood Control District
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INTRODUCTION

This memorandum documents preliminary evaluations of nine potential recharge sites for Flood Control District of Maricopa County (FCD) facilities. Based on previous evaluations and on discussions during the August 13, 1987 meeting, the following nine sites were selected by the Review Committee:

- o Saddleback Dam Detention Area
- o Centennial Wash from Levee to Mullens Cut
- o McMicken Dam Detention Area
- o Cave Buttes Dam to CAP Aqueduct
- o Cave Creek from CAP to 7th Street
- o New River from Skunk Creek to Agua Fria
- o Lower Agua Fria from New River to I-10
- o Queen Creek from CAP to Rittenhouse Road
- o Queen Creek from Rittenhouse to RWCD

The evaluations herein are based on previously selected criteria. The most important criteria for ranking of sites were recharge water availability, water quality impacts, and hydrogeologic conditions. The other criteria used to evaluate the sites include: flood control considerations, soils and intake rates, and land use and environmental impacts.

SUMMARY OF POTENTIAL SITES

Table 1, Technical Rating Sheet for Recharge Potential of the Nine Selected Sites, summarizes the preliminary evaluations for the major criteria. A more detailed discussion of the suitability of each potential recharge site is found in the Recharge Site Evaluations section of this memorandum.

New River and Lower Agua Fria Sites

These two sites represent approximately 12 miles of stream channel which have favorable hydrogeologic conditions, suitable soils, and available land for recharge. Potential water quality problems due to landfills and contaminated groundwater would require additional investigation. Potential for a cooperative project participant has been identified. Supplemental recharge water is available by delivery via SRP canals, and present and proposed locations of wastewater treatment facilities located in the vicinity of the sites.

Cave Buttes Dam Sites

Sufficient data are not available to determine water quality, hydrogeologic, and soils conditions at these sites. Indications are that the sites are limited by small aquifer storage capacity. There is high potential for a cooperative project for recharge and recovery of effluent at these sites, but the storage capabilities of the sites will be a limiting factor.

Queen Creek Sites

These sites comprise approximately 16 miles of the Queen Creek channel and flood plain below the CAP aqueduct. The last 4 miles of Queen Creek are not suitable for recharge by spreading methods due to perched groundwater conditions. An active sanitary landfill is located within 1.5 miles of the downstream site. The potential for a cooperative project at this site is considered marginal since the potential participant identified is currently pursuing a recharge project at location on the Salt River.

McMicken Dam Site

The retention area behind McMicken Dam is approximately 8 miles long. The soils at the north half of the site are marginal for surface recharge and the southern half has favorable soils, although soil conditions are less favorable than most of the other sites. Supplemental water sources can be delivered via the Beardsley Canal or through future wastewater reuse facilities.

Centennial Wash Site

This site includes about 7 miles of Centennial Wash below the levee. Because fluoride content for the groundwater in this area exceeds federal drinking water standards, recharge operations could be considered for this area if dilution of the existing groundwater to drinking water standards could be achieved. A potential participant in a cooperative project cannot be identified at this time.

Saddleback Dam Site

The five miles of retention area behind Saddleback Dam appear to be favorable for recharge; however, depth to groundwater level is greater than 400 feet. A potential participant for a cooperative project cannot be identified at this time.

CONCLUSIONS

1. New River from the confluence with Skunk Creek to Agua Fria and the lower Agua Fria reach are assigned the highest favorability for continued investigations for potential recharge projects by surface methods. Favorable criteria for recharge sites were identified as those where: an available water source occurs within two miles of the site, a potential participant for a cooperative project has been identified, depth to groundwater level is more than 50 but less than 200 feet, and thickness of the upper alluvium unit is more than 200 feet. Additional investigations are required for both sites to determine the potential for recharged water to move or mingle with reported contaminated groundwater.

2. Cave Creek from Cave Buttes Dam to 7th Street could be considered for a short-term recharge and recovery operation by surface methods. Available data suggest that the volume of aquifer storage is small.

3. Queen Creek from the CAP canal to Rittenhouse Road, Saddleback Dam, and McMicken Dam are assigned the highest favorability for continued investigations for large volume, long duration recharge projects. The depth to groundwater level for these sites is generally greater than 400 feet. Because the amount of infiltrated water which may be required or "invested" in the vadose zone prior to reaching a water content equal to the specific retention may be large, areas where average depth to

groundwater level is more than 200 feet are generally less favorable for recharge operations by surface methods. The hydraulic loading rates (acre-feet per year per acre of spreading area) for recharge operations and the estimated life of the recharge project must also be known for the final evaluation of a potential site with depth to groundwater level more than 200 feet.

In the early years of a project, the ratio of invested water to recoverable water could be large. For subsequent years of recharge operations with appreciable loading rates, the ratio of invested water to recoverable water would decrease, and would continue to decrease for the life of the project. For potential recharge projects with large total volume of water available for recharge and of long duration in years, the ratio of invested water to recoverable water may be large in the early years of a project, but in subsequent years the loss to invested water would become small.

RECHARGE WATER AVAILABILITY

Excess Floodwaters

The ability to recharge excess floodwaters is the primary basis for FCD recharge activities. The relative availability of floodwaters has been used to screen the potential recharge sites. To date, the relative availability of excess floodwater yield is based on size of drainage area, projected precipitation events, conditions of the watershed, and estimates of streamflow losses (Dames & Moore, 1987). Additional investigations for the nine remaining sites have included the research of a limited amount of available U.S. Geological Survey (USGS) stream flow gauging data, site visits, and the discussions with local residents who have observed flooding events.

The watersheds with continuous streamflow gauge records kept by the USGS include: Centennial Wash, New River, Skunk Creek, and Cave Creek. A summary of the streamflow data for these watersheds is shown on Table 2.

Table 2
SUMMARY OF AVAILABLE STREAMFLOW DATA

Watershed	Years of Record	Average Annual (af/yr)	Median of Annual Mean (af/yr)
Centennial	23	2,800	1,300
New River	16	9,060	2,500
Skunk Creek	16	1,320	550
Cave Creek	26	2,950	630

Source: USGS Data Storage and Retrieval System

The average annual streamflow includes all flows past the gauge including infrequent large events which tend to raise the average. The median of the annual mean flows is more representative of the annual flows for recharge purposes. The Avondale stream gauge on the Agua Fria River was maintained by the USGS for recording maximum discharges from

1960 through 1980 water years. During 20 years of record at the Avondale gauge measurable flows occurred once in 1970 due to large storm events upstream which caused extensive flooding, and in three consecutive years, 1978, 1979, and 1980, due to large releases at Waddell Dam.

Stream gauge data for Queen Creek downstream from the CAP aqueduct is not available. Discussions with local landowners and gravel pit operators indicate that the creek generally flows once or twice a year for several hours, sometimes full from bank to bank. Based on reported observations of local residents, floodflows seldom reach the RWCD floodway. This conclusion is also consistent with conditions observed during the field review.

Previous investigations have been made concerning the availability of excess floodwaters and the feasibility of capturing these waters for recharge purposes. The U.S. Army Corps of Engineers (COE) conducted an in-house study in 1977, as part of the Phoenix Urban Study, to determine the feasibility of capturing floodflows at the confluence of New River and Skunk Creek for recharge purposes. This site would receive floodwaters from the watersheds of New River, Skunk Creek, Cave Creek, and the Arizona Canal Drainage Channel (ACDC). Plans to implement extensive modifications at the flood detention dams to provide retention and controlled release of flood flows were outlined in the report. The conceptual plan for recharge facilities was to construct 180 acres of spreading basins at the site. The report concluded that a floodwater recharge project constructed at the confluence of New River and Skunk Creek would conserve less than 1,000 acre-feet per year on the average (COE, 1977). The report did conclude, however, that such a project "... recharging imported water along with floodflows may be highly valuable."

It is clear that it will be difficult to construct recharge facilities solely for the purpose of recharging floodwaters for two principal reasons: First, available data on stream flows suggests that for the potential recharge sites investigated, a significant portion of stream flows from the more frequent flood events are being recharged naturally and that "excess" floodwaters or those stream flows available for artificial recharge are infrequent; and secondly, detention/retention facilities are needed to capture and recharge significant amounts of floodwater from the high discharge, short duration runoff events that are typical of the study area.

Other Recharge Water Sources

The potential for recharging other recharge water sources has been determined for the remaining recharge sites. Other water sources include: CAP water, sewage effluent, Salt River Project (SRP) water, and Maricopa Water District (MWD) water. The quantities available and delivery schedules have not been determined. The specific requirements or facilities needed to convey the recharge water to the recharge sites are only conceptually determined. The quantities, delivery schedules, and conveyance facilities will be addressed during the facilities planning stage of the investigation.

The major source of recharge water that is a readily available source is CAP water. The existing means of conveyance are the Beardsley Canal, SRP canals, and ephemeral stream channels. New facilities required for conveyance could include canals, pipelines, turnouts, and pumping plants. Salt River Project and Maricopa Water District are currently preparing estimates of the excess capacity in their canals to carry water for recharge purposes. MWD has a CAP turnout in operation and SRP will have a CAP turnout operational by early 1990.

Although sewage effluent is not currently available near the potential recharge sites, as urbanization of these areas continues sewage collection systems and wastewater treatment plants will be constructed. The treatment and reuse of sewage effluent is currently in the planning stages in the developing areas near the potential sites and therefore, the quantities available, delivery schedules, and conveyance facilities are as yet undefined. It has been determined however, that significant amounts of seasonal storage of treated effluent will be needed in reuse delivery systems to store effluent flows in the winter to meet summer irrigation demands. Artificial groundwater recharge and recovery of effluent is one of the most viable alternatives to provide the seasonal storage requirements.

RECHARGE METHODS

Recharge of excess floodwaters is given first priority during the investigation. The potential for recharging other supplemental sources of water, i.e., CAP water and sewage effluent is considered so far as these sources of water may be available and cooperative project participants can be identified. Water may be recharged by surface methods through basins and channels, or by subsurface injection through wells. Recharge by injection wells is limited to water that has been treated to drinking water quality standards to avoid clogging of the wells by bacterial growths, suspended solids, and to avoid contamination of existing groundwater. Surface spreading is the only viable method of recharging floodwaters. Cooperative projects using injection wells have not been identified because floodwaters are not a suitable source water. Sources of treated water are, therefore, limited to water produced from municipal water treatment plants. For these reasons recharge by surface spreading methods predominates the evaluations. The City of Phoenix is currently investigating the feasibility of using existing production wells for recharge of treated CAP water during off-peak water demand periods.

FLOOD CONTROL CONSIDERATIONS

Flood Control Benefits

Flood control benefits are derived from both direct and indirect benefits. Direct benefits are the savings from reduced flood damage costs resulting from implementation of a project. Indirect benefits are less tangible. Economists categorize indirect benefits into four accounts:

- National economy
- Local economy

- Environmental
- Social well-being

Through work done by CH2M HILL on large flood control studies in other parts of the country, the U.S. Army Corps of Engineers has adopted this criteria and specific methodologies for derivation of flood control benefits.

Direct benefits from a given recharge project will result from operations/flows that produce less damage or maintenance cost. Most notable will be reduced removal of silt and debris from roadways, bridges, and culverts. Reduction of stream channel maintenance will also benefit from reduced flows.

Indirect benefits are those that enhance the national and local economies, the local environment, and the mental well-being of the citizens. The most notable indirect benefits derived from potential recharge projects in Maricopa County are improvement of transportation facilities. Roads will remain open for longer time periods following storm events for better access, allowing for improvement to the national and local economy. This in turn can allow for improved utility maintenance and access (i.e., landfills, electrical, gas, sewerage, water, and phone). Environmental benefits are usually from multi-purpose flood control projects that enhance recreation and aesthetics. Social well-being is having a satisfied public.

Generally, to derive a flood control benefit there should be reduction in either, or both, flow rate and duration. The greatest opportunity to develop flood control benefits on Maricopa County's Flood Control Facilities is by management of the smaller, but more frequent, flood flows. Three distinct possibilities exist for doing this. First is utilization of existing sediment storage to regulate the smaller storm events. Second is diversion of flow (usually small) from the stream channel to recharge basins or pits. Finally, if recharge in existing flood channels is enhanced, flood flow rates and durations will be reduced.

Flood control benefits will have to be developed for each specific project. Hydrologic and hydraulic analyses are necessary to evaluate reduced flow rates, water velocity, and duration of flooding. Increasing the detention times of the more frequent floods behind existing facilities and releasing at lower rates of flow will produce flood control benefits. This potential exists at all nine project sites.

Nearly all of the streams in Maricopa County experience heavy sediment and debris movement during flooding. The higher and longer the duration of flow, the more severe the problem. Reduced flows will reduce maintenance cost, improve transportation, and provide higher satisfaction to the community.

Adaptation of Existing Facilities

The potential adaptations of existing flood control facilities to accomplish recharge can be addressed in three categories: 1) Modify the outlets of flood detention structures for revised regulation of discharge rates,

2) Construct shallow recharge basins behind existing structures, and 3) Construct levees within existing stream channels to retard flows and enhance natural recharge.

Flood control dams with large storage capacities would be the most favorable candidates for outlet modifications. It may be feasible to allocate the sediment storage volume plus some additional space for storage/regulation of moderate flow events for recharge purposes. The dilemma will be to provide greater detention times and reduced flow rates for recharge without severely impacting the important flood control functions of the facility, particularly for the large flood events. One approach would be to revise the outlet structures and construct outlet towers which have smaller discharge orifices at the lower elevations. This would allow small to moderate flood events to be detained and recharged while providing higher discharge rates needed during higher reservoir elevations caused by the more severe flood events.

Another option is to put gates on the outlets for manual or automated controls that would allow discharge rates to be regulated for both recharge and flood control purposes. Automatic overrides which respond to rising reservoir levels and other fail safe mechanisms would be required to insure the gates would be opened during severe flood events. Modifying the discharge outlets will require that other design considerations be evaluated. Increased sediment loads in the reservoir caused by longer detention times may require periodic removal of sediment buildup. The ability of the dams to withstand periods of inundation and the potential impacts on long-term structural integrity would also need to be examined. Table 3 summarizes the storage capabilities and existing discharge characteristics of the three major flood control dams operated by the FCD.

Table 3
SUMMARY OF STORAGE AND DISCHARGE CHARACTERISTICS OF THREE MAJOR DAMS

Facility Name	Total Storage Capacity (af)	Sediment Storage Capacity (af)	Peak Discharge Rate (cfs)	Reservoir Drawdown Time (days)	Recharge Discharge Rate (cfs)	Sediment Storage DD Time (days)
New River	43,520	4,920	2,665	13	140	18
Adobe	18,350	2,700	1,890	5	140	10
Cave Buttes	46,600	5,700	500	48	140	21
McMicken	23,800	-	2,600	5	-	-

The time to completely discharge the floodwater stored in the sediment pool at a selected recharge rate is shown for comparison purposes. The selected rate of 140 cfs is sufficient to recharge 100,000 acre-feet per year if the facility is operated year-round.

Conducting recharge with spreading basins behind the major flood detention facilities is generally not practical since in most cases the dams are founded on bedrock and the hydrogeologic conditions immediately upstream are not conducive to recharge. However, many of the flood retarding dikes, i.e., McMicken Dam and Saddleback Dam have detention areas which are suitable for surface recharge facilities. The inlet structures could be raised slightly to retain small flows for recharge and increased detention times for moderate flows could be maintained with controlled outlets provided to release the water at a controlled rate for recharge purposes. Shallow recharge basins could be constructed within the sediment pool of these structures without reducing the flood control capabilities. Recharge basins behind the detention structures could recharge both floodwaters and supplemental recharge waters. To determine the feasibility of this approach the structural impacts of long-term inundation on earthen dikes would have to be investigated and procedures for handling the increased sediment loads determined.

Perhaps changes in the approach taken during ongoing channel widening and floodway enhancement projects could increase natural recharge from small to moderate flood events. Earthwork performed in stream channels and floodways to reduce flooding and erosion hazards could include deliberate efforts to increase flow paths and detention times of flood flows to enhance recharge.

Operational Changes

Under present conditions operational changes to accomplish recharge are practically non-existent. Existing flood control facilities are uncontrolled and thus, are not subject to operations. Should the flood control facilities be modified, as suggested by some of the examples in the previous section, then an appropriate operations and maintenance plan would need to be developed to meet recharge and flood control objectives. Where recharge facilities are actively managed, additional work items will include: operation and maintenance of flow control structures, sediment removal, ripping operations to improve soil infiltration rates, construction and maintenance of small dikes, data collection, and maintenance of monitoring equipment; and other recharge related activities. If the conservation of floodwaters and recharge of supplemental waters becomes an integral part of FCD responsibilities, then numerous, but often subtle, changes in operation and management of facilities and adjustments in responsibilities of FCD personnel will be needed to meet these objectives.

WATER QUALITY IMPACTS

CHEMICAL QUALITY OF GROUNDWATER

Recharge operations are not acceptable and should not be conducted where the aquifer presently contains groundwater which does not meet drinking water standards due to poor chemical quality. Maps of specific electrical conductance, fluoride, nitrate, chromium, arsenic, and sulfate content for groundwater have been prepared for Maricopa Association of Governments, Arizona Department of Water Resources, and the U.S. Geological Survey (Reeter and Remick, 1986; Long, 1983; Schmidt, 1981; Graf, 1980; Schmidt, 1978). These maps have been used to identify chemical quality of groundwater for potential recharge sites. Data indicate that fluoride content in groundwater near Centennial Wash exceeds the federal drinking water standard of 4.0 mg/l (milligrams per liter).

Existing Groundwater Contamination

Recharge operations are not acceptable and should not be conducted where the recharge water may induce movement of contaminants which originate from activities of man. Areas where contaminated groundwater occurs have been identified from maps prepared by Salt River Project and Arizona Department of Health Services (Graf, 1986; Salt River Project, 1985). Areas of existing groundwater contamination are reported to occur near the New River and Agua Fria potential recharge sites.

Presence of Landfills

Recharge operations are not acceptable and should not be conducted where the recharge water may saturate an active or abandoned landfill and cause formation and movement of leachate from the landfill to the aquifer. Locations of landfills have been identified from maps prepared by Maricopa County Landfill Department. Landfills are reported to occur near McMicken Dam, and near the potential recharge sites along the Agua Fria, Cave Creek from the CAP aqueduct to 7th Street, and Queen Creek from Rittenhouse Road to the RWCD.

Depth to Groundwater Level

Because available volume for groundwater storage is small where depth to groundwater is small, areas where average depth to groundwater level is less than 50 feet are generally unfavorable for recharge operations. Small average depth to groundwater level may occur along Cave Creek from Cave Buttes Dam to 7th Street. Because the amount of infiltrated water which may be required or "invested" in the vadose zone prior to reaching a water content equal to the specific retention may be large, areas where average depth to groundwater level is large may be unfavorable for recharge operations by surface methods. For the purposes of this investigation large average depth to groundwater has been defined as more than 200 feet. Large average depth to groundwater level occurs for Saddleback Dam, McMicken Dam, and for both reaches of Queen Creek. Depth to groundwater level has been compiled from maps prepared by Arizona Department of Water Resources, and U.S. Geological Survey (Reeter and Remick, 1986; Long, 1983; Graf, 1980).

Thickness of Upper Alluvium Unit

The Upper Alluvium unit consists of sand, gravel, cobbles, and boulders, with thin interbeds of silt and clay, and comprises floodplain and alluvial fan deposits. The Upper Alluvium unit constitutes the medium for receiving recharge from most recharge operations by surface methods. The coarse-grained fabric of the unit accommodates the percolation of water into the underlying saturated zone, and permits easy lateral groundwater movement. Because the hydraulic conductivity of the Upper Alluvium Unit is generally large compared to the underlying Middle Alluvium unit, areas where average thickness of the Upper Alluvium unit is large are generally more favorable for recharge operations by surface methods. Thickness of the Upper Alluvium unit has been compiled from maps prepared by the U.S. Bureau of Reclamation and U.S. Geological Survey (Laney and Hahn, 1986; U.S. Bureau of Reclamation, 1977).

Depth to Basement Complex

Because more groundwater can be held in storage in the vadose zone where thickness of alluvial deposits is large, areas where average depth to basement complex is large are generally more favorable for recharge operations. Depth to basement complex has been compiled from maps prepared by Arizona State Land Department and the U.S. Geological Survey (Laney and Hahn, 1986; Cooley, 1973; Denis, 1971). Shallow depth to bedrock is suggested for both reaches of Cave Creek.

Occurrence of Perched Groundwater

Presence of shallow groundwater conditions beneath a potential surface recharge operation is considered to be unfavorable. For purposes of this report, shallow perched groundwater conditions are identified where depth to perched groundwater is less than 100 feet below land surface. Shallow perched groundwater conditions separate infiltrating water from the regional aquifer system and the infiltrated water may not be available for recovery. Potential for perched groundwater conditions has been identified from areas where perched groundwater conditions have been reported and from areas where extensive clay deposits have been described in the upper 100 feet below land surface. Data for the presence of, or potential for, perched groundwater conditions have been identified from maps prepared by Maricopa Association of Governments, Arizona Department of Water Resources, and U.S. Geological Survey (Laney and Hahn, 1986; Long, 1983; Schmidt, 1981; Graf, 1980). Perched groundwater conditions are reported to occur along four miles of Queen Creek from Rittenhouse Road to the RWCD.

SOILS AND INTAKE RATES

Soil survey and mapping reports prepared by the Soil Conservation Service (SCS) were reviewed for suitability of soils for recharge at the nine potential recharge sites. Soils mapping was available for every potential recharge site except for the Cave Buttes sites. The discussion of soils is limited primarily to the off-channel areas contained within the flood plain for two reasons. First, the area needed for spreading basins will often exceed the area of the channel; and secondly, the permeability of the stream channel deposits will almost certainly exceed that of the soils in the surrounding area. The soil survey report classifies stream channel deposits as torrifluvents consisting of unconsolidated, gravelly, cobbly, and stony alluvium which is highly stratified and varies widely in texture. It is likely that the alluvial deposits are often shallow and the characteristics of underlying soils will control intake rates. Therefore, the descriptions of the soils at the sites and not the shallow stream channel deposits are used to characterize the recharge potential.

Typically the areal extent of the sites is quite large and therefore, the soils information was reviewed on a generalized scale. Characteristics of soils can vary dramatically even within small areas. Soils at the sites were generally characterized by the SCS for pond or reservoir areas as "moderately permeable to very rapidly permeable".

The existence of significant restricting layers in the soil profile or adverse soil chemistries were not reported in the soil profile descriptions for any of the soil types encountered at the sites. The areal extent of suitable soils at the sites is generally extensive and there appears to be adequate areas suitable for constructing spreading basins. Soil conditions at all sites could be rated as good to excellent for recharge.

Due to the large areal extent of sites and the variability of soils within a given site, estimates of intake rates cannot be made until the basin locations are defined. Another caution regarding estimates of intake rates is that past experience in the design and operation of recharge facilities near stream channels indicate that soil conditions onsite can vary dramatically across the site and may significantly differ from the SCS soil survey descriptions. Experience has shown that conditions at the selected locations are often less permeable and have less favorable characteristics than was projected from the SCS soil survey information. The methods used to prepare the SCS soil survey maps are often not definitive enough for the final planning and design of a recharge project. Onsite soil surveys and pilot infiltration tests are needed to develop adequate design criteria for a large-scale recharge project. Consequently, when preparing the facilities plans for the selected recharge sites appropriate safety factors need to be applied to the SCS soil survey data on intake rates when developing the land requirements for spreading basins.

LAND USE AND ENVIRONMENTAL IMPACTS

Aerial photographs of the sites have been reviewed to determine general availability of land for constructing recharge basins and compatibility with surrounding land uses. All of the sites have extensive areas of undeveloped property that could be used for constructing recharge facilities. In a few instances there are conflicting land uses, i.e., gravel pits and farming operations, but generally there appears to be enough suitable land available to work around these conflicts. Base maps for the State Land Department were reviewed for land ownership. Property ownership varies from site to site with private land being the most predominant. Several sites have a significant amount of State land.

RECHARGE SITE EVALUATIONS

This section reviews application of the criteria discussed in the preceding section to each of the nine specific recharge projects being evaluated. These projects are shown on Figures 1 through 3.

Saddleback Dam Detention Area

Seven depth to groundwater level measurements were made in 1979 and 1980 within about one-half mile of the Saddleback Dam. The measurements are for wells completed in the alluvial deposits. Depth to groundwater level ranged from 426 to 510 feet below land surface (Graf, 1980). Groundwater samples for laboratory chemical analyses were obtained in 1979 and 1980 for three wells located about two miles west of Saddleback Dam. Fluoride content for groundwater samples obtained from wells ranged from 2.8 to 3.1 mg/l (milligrams per liter), and total dissolved solids content estimated from specific electrical conductance ranged from about 470 to 570 mg/l (Graf, 1980). Direction of groundwater flow in 1980 was southwest from the dam toward the Harquahala Plains.

The Saddleback Dan and retention area is outside of the generalized limit of fine-grained beds of the upper alluvium unit and known perched groundwater which eliminated the other flood retention structures in the Harquahala Plains from additional consideration (Graf, 1980). Thickness of the upper alluvium unit is estimated to range between 300 and 600 feet for the northern half of the Saddleback Dam retention area (Bureau of Reclamation, 1977). Depth to the basement complex is estimated to range from 300 to 1,120 feet (Denis, 1971).

CAP water is available to this site with two possible modes of conveyance. A new turnout from the aqueduct could discharge CAP water into the existing stream channel about 2 miles upstream from the flood retarding structure. Another option is to deliver CAP water through the Harquahala Valley Irrigation District (HVID) canal system at a location near the north end of the dike. Canal capacity is about 100 cfs at that location.

The availability of sewage effluent at this site is enhanced by the use of effluent at the nearby Palo Verde Nuclear Generating Station (PVNGS). Arizona Public Service (APS) has an effluent delivery pipeline from the 91st Avenue Wastewater Treatment Plant (WWTP). The initial leg of the pipeline flows by gravity from the 91st Avenue WWTP to a pump station near the Hassayampa River and Buckeye-Salome Road (See Figure 1). The pressure pipeline from the pump station to the PVNGS is used to full capacity year-round. The gravity pipeline however, has unused capacity. The gravity pipeline and pump station were constructed while the PVNGS was still in the planning stages. After the pipeline was constructed several planned nuclear reactors were not constructed at PVNGS. The pipeline has the capacity to carry about 170,000 acre-feet of effluent annually, but the PVNGS will use less than 70,000 acre-feet per year under full operating conditions. A letter from APS has indicated that the extra capacity could be made available for carrying effluent for recharge and that the pumping plant has forebays prepared to accept additional pumping facilities. Delivery of effluent to Saddleback Dam from the APS Hassayampa pumping plant would require 23 miles of pipeline and additional pumping facilities installed at the existing plant site.

Discussions were held with parties that could possibly participate in a cooperative project, but none were identified as having an immediate interest. APS would be amenable to transporting effluent through their pipeline to the Hassayampa pumping plant, but they have little interest in participating in a recharge project. Apparently, there is no need to use recharge for additional or backup water supplies for the PVNGS. CAP (formerly CAWCD) is conducting a study of potential sites along the aqueduct which they could cooperatively develop for recharge purposes. In a recent draft of the study report the Tonapah area, roughly six miles east from Saddleback Dam, was identified as a favorable recharge site (Ungerman, 1987).

Soils in the vicinity are generally a gravelly sandy loam and are classified by the SCS as "moderately rapidly permeable to moderately permeable". Land ownership of the detention area behind the dam is about equally divided between State land, Bureau of Land Management (BLM), and private land.

Centennial Wash from Levee to Mullens Cut

Depth to groundwater level in the area of Centennial Wash from the levee to Mullens Cut ranged from 174 feet to about 400 feet below land surface as measured in 1979 and 1980 (Graf, 1980). One measurement is for a well adjacent to Centennial Wash and six measurements are for wells within one mile of the Wash. In general, the depth to groundwater level is more than 400 feet below land surface in the area of the levee, and rises to less than 200 feet near Mullens Cut. Groundwater samples for laboratory chemical analyses were obtained from four wells within about one mile of Centennial Wash in 1979 and 1980. Fluoride content for groundwater samples obtained from wells ranged from 3.3 to 4.8 mg/l, and total dissolved solids estimated from specific electrical conductance ranged from about 810 to 880 mg/l (Graf, 1980). No laboratory chemical quality data were reported by Graf for the area where the depth to groundwater level was less than 400 feet. Denis (1971) reported fluoride content between 4 and 5 mg/l for the groundwater in the area of Centennial Wash from the levee to about three miles downstream.

In the 1950's, prior to extensive groundwater development in the Harquahala Plains area, the direction of groundwater flow was from the northwest to the southeast with groundwater discharging from the area at Mullens Cut. In 1980, direction of groundwater flow was northwest from Mullens Cut into cones of depression in the Harquahala Plains. Centennial Wash from the levee to Mullens Cut overlies the main water-bearing alluvial unit of the Harquahala Plains where the unit consists mainly of sand and gravel (Graf, 1980). The thickness of the upper alluvium unit in this area ranges from about 200 to 500 feet (Bureau of Reclamation, 1977). The depth to groundwater level in the area roughly parallels the depth to the base of the upper alluvium indicating that the available storage for recharged water would be in the upper alluvium unit. Depth to the basement complex is estimated to range from less than 300 to about 700 feet (Denis, 1971).

Because fluoride content for the groundwater in this area exceeds federal drinking water standards, the Centennial Wash area is marginally unfavorable for the recharge of CAP water. Recharge operations could be considered for this area if dilution of the existing groundwater to drinking water standards could be achieved. Additional collection of groundwater samples and recharge source water for laboratory chemical analyses, a well inventory for current use of groundwater, and hydrologic studies for placement and operation of recharge and pumping facilities would be required.

CAP water could be delivered to this site by constructing a turnout on the aqueduct near the tunnel on Burnt Mountain and discharging into the stream channel which flows into the Saddleback Dam detention area. From the aqueduct, the CAP flows would travel 15 miles around the dam and through the Saddleback Diversion Channel to Centennial Wash. Another opportunity to convey CAP water to the site is to use a wasteway spill from the HVID canal system which could deliver about 30 cfs to the stream channel three miles upstream from the recharge site. Effluent could be delivered to the site from the APS Hassayampa pump station with additional pumping facilities and 19 miles of pipeline.

The discussions with potential cooperative project participants for Saddleback Dam also apply to this site.

Soils in the vicinity are generally a loamy sand to gravelly sandy loam and are classified by the SCS as "very rapidly permeable to moderately rapidly permeable". The most permeable materials are located near the upper end of the site. Land ownership is principally private with two miles of State land at the upper end of the site.

McMicken Dam Detention Area

Depth to groundwater level was measured for nine wells within about one-half mile east of the levee in 1982. Depth to groundwater level ranged from 465 to 504 feet below land surface (Reeter and Remick, 1986). Depth to groundwater level was 329 feet below land surface in 1982 at a well located less than one mile west of the dam (Reeter and

Remick, 1986). No depth to groundwater level measurements were made within the area of the southern one-third of the levee and associated retention area. Groundwater samples for laboratory chemical analysis were obtained for eight wells located about one-half mile east of the levee in 1982 and 1983. Fluoride content for groundwater samples obtained from wells ranged from 0.1 to 1.5 mg/l, and total dissolved solids estimated from specific electrical conductance ranged from about 190 to 290 mg/l (Reeter and Remick, 1986).

An active solid waste landfill operated by Maricopa County is located about two miles west of McMicken Dam. Direction of groundwater flow in 1982 in the area of McMicken Dam and retention area was from the northwest to the southeast. The majority of the McMicken Dam and associated retention area is located where thickness of the upper alluvium unit ranges from 500 to 700 feet and where the middle alluvium unit is not present (Bureau of Reclamation, 1977). Depth to basement complex in the area is estimated to be greater than 1,200 feet (Cooley, 1973).

CAP water could be conveyed to the southern portion of McMicken Dam through the Beardsley Canal. The capacity of the canal to delivery CAP water in addition to the regular irrigation deliveries is not yet available. The Maricopa Water District has conducted a water conservation and a wastewater reuse planning study for their service area which has lands in the vicinity of McMicken Dam. There is a possibility of a cooperative project recharging the District's surface water supplies or recharge and recovery of treated effluent to provide seasonal storage for proposed wastewater reuse facilities. The District's interest in a cooperative project has not yet been determined.

The most suitable soils for recharge at this site are located at the south half of the site. These soils are sandy loam to gravelly sandy loam and are classified by the SCS as "moderately rapidly permeable". Soils at the north half of the site are only marginally favorable for recharge activities due to presence of loam or gravelly clay loam soils with slow permeabilities. Land ownership is private except for the southern two miles of State land which comprises about one-third of the site.

Cave Buttes Dam to CAP Aqueduct

Sufficient data are presently not available to determine the hydrogeologic conditions in the vicinity of Cave Buttes Dam. Depth to bedrock in the vicinity of the dam is about 30 feet (U.S. Army Corps of Engineers, 1983). The location of Cave Buttes Dam is a narrow valley edged with volcanic rocks suggests shallow depth to bedrock, and small available storage volume for recharged water.

Raw CAP water could be delivered to this site by constructing one mile of pipeline and a pumping plant at the aqueduct. Treated water could be brought from the Phoenix Union Hills Water Treatment Plant (WTP) with similar facilities. Recharge of CAP water is not likely to be feasible at this site due to the limited storage capacity. However, this site may be hydrogeologically suitable and ideally located for a put and take operation for seasonal storage of treated effluent. The City of Phoenix is preparing a master plan for 70,000 acres of land surrounding this site, known as peripheral areas C and D (Harza, 1987). Water resource planning for this area includes an extensive amount of wastewater reuse. Seasonal storage of effluent through recharge and recovery could be a feasible component of the reuse system. The City is also studying the options for surface water storage near Cave Buttes Dam.

Soils information for this site is only available for Cave Creek at 7th Street. These soils are classified by the SCS as "very rapidly permeable to moderately rapidly permeable". Observed conditions during a field survey indicate the soils are suitable for recharge. The land ownership at this site is State land.

Cave Creek from CAP to 7th Street

Sufficient data are presently not available to determine the hydrogeologic conditions in the vicinity of Cave Creek from the CAP aqueduct to 7th Street. Depth to groundwater level was 68 feet below land surface in 1982 at a well located at Cave Creek and 7th Street (Reeter and Remick, 1986). A construction debris landfill is reported to occur less than one mile downgradient from Cave Creek at 7th Street (Maricopa County Landfill Department). The thickness of the upper alluvium unit and the depth to bedrock in the area are less than 400 feet (Cooley, 1973). The outcrops of volcanic rock along Cave Creek in this area, the depth to bedrock less than 400 feet, and the shallow depth to groundwater level at

7th Street suggest small available storage volume for recharged water.

The CAP aqueduct is immediately upstream from this site and a turnout exists for the Union Hills Water Treatment Plant. Both raw or treated CAP water could be made readily available for this site. As with the site immediately downstream from the dam, the opportunity exists for recharge and recovery of effluent for the City of Phoenix wastewater reuse program.

Soils survey data which ends at the south end of the site indicate sandy loam soils underlain by gravelly loamy sand with SCS classifications of "moderately rapidly permeable to very rapidly permeable". State land owns most of the land at this site.

New River from Skunk Creek to Agua Fria

Depth to groundwater level was measured for six wells in 1982 for New River from the confluence with Skunk Creek to the confluence with Agua Fria. Depth to groundwater level ranged from 144 to 278 feet below land surface (Reeter and Remick, 1986). Fluoride content for groundwater samples obtained from wells ranged from 0.2 to 0.5 mg/l and total dissolved solids estimated from specific electrical conductance ranged from 260 to 1,030 mg/l (Reeter and Remick, 1986). A construction debris landfill is reported to occur on the Agua Fria about one-half mile downstream of the confluence with New River (Maricopa County Landfill Department). A municipal landfill is reported to occur about one mile west of New River and in a downgradient direction for groundwater flow. The West Maryvale area identified by Arizona Department of Health Services is located about one and one-half miles east and in the upgradient direction of groundwater flow from the confluence of New River and Agua Fria. Concentrations of volatile organic compounds above the Arizona Department of Health Services action limits have been measured for the groundwater in the West Maryvale area (Graf, 1986).

Direction of groundwater flow in 1982 along this reach of New River was generally from the east to the west. For the northern portion of the reach, the direction of flow is from the southeast to the northwest. Thickness of the upper alluvium unit ranges from 650 to 800 feet (Bureau of Reclamation, 1977). Depth to bedrock in the area is more than 1,200 feet (Cooley, 1973). Although the depth to groundwater, depth to bedrock, thickness of the upper alluvium unit, and reported chemical quality of groundwater in the vicinity of New River indicate favorable conditions for the recharge of CAP water, additional investigations are required to determine the potential for recharged water to move or mingle with potential contaminants.

CAP water could be conveyed to this site by using the New River stream channel above the dam and conveying it through the dam and into the downstream channel for a total of 10 miles. Incidental recharge would be performed during conveyance and the opportunity exists for providing recreational opportunities and open-space enhancements with water flowing through natural channels and modest size impoundments behind the dam and in the existing channel. Another way to convey CAP water to the site is through the SRP's Arizona Canal which has a drain that discharges into Skunk Creek immediately upstream from the site.

The City of Glendale has expressed an interest in a cooperative project at this site recharging CAP water. They are still formulating their plans, but it is possible that they will embark on a program to recharge CAP water in the near future. Glendale has a wastewater treatment plant near Skunk Creek and there is a possibility of implementing a wastewater reuse program and using aquifer storage and recovery to meet seasonal demands at this site. Peoria has expressed an interest in conducting recharge of CAP water, but they have not formulated any definite plans as yet.

Soils at this site are gravelly sandy loam to loam and the SCS classification ranges from "moderately permeable to very rapidly permeable". There is high degree of spatial variability of soils at this site. The land is all privately owned and much of the land adjacent to the stream channel is irrigated farmland.

Lower Agua Fria from New River to I-10

Depth to groundwater level was measured for four wells in 1982 within one-half mile of the Agua Fria from the confluence with New River to Interstate 10. Depth to groundwater level ranged from 95 to 153 feet below land surface (Reeter and Remick, 1986). Groundwater samples for laboratory chemical analyses were obtained for three wells located within one-half mile of the Agua Fria. Fluoride content ranged from 0.3 to 1.4 mg/l and total dissolved solids estimated from electrical conductance ranged from 380 to 980 mg/l (Reeter and Remick, 1986). A construction debris landfill is reported to occur along this reach of the Agua Fria (Maricopa County landfill Department). The West Maryvale area identified by Arizona Department of Health Services is located about one and one-half miles east and in the upgradient direction of groundwater flow from the confluence of New River and Agua Fria. Concentrations of volatile organic compounds above the Arizona Department of Health Services action limits have been measured for the groundwater in the West Maryvale area (Graf, 1986).

Direction of groundwater flow in 1982 for this reach of the Agua Fria is from the east and southeast to the west and northwest. Thickness of the upper alluvium unit is estimated to range from 600 to 750 feet (Bureau of Reclamation, 1977). Depth to the basement complex is greater than 1,200 feet (Cooley, 1973). Although the depth to groundwater, depth to bedrock, thickness of the upper alluvium unit, and reported chemical quality of groundwater in the vicinity of Agua Fria indicate favorable conditions for the recharge of CAP water, additional investigations are required to determine the potential for recharged water to move or mingle with potential contaminants.

CAP water could be delivered to this site through SRP's Grand Canal. The Grand Drain at the end of the canal discharges directly to the site. Preliminary discussions with SRP canal operations staff indicate that the capacity exists to delivery 50 to 100 cfs of CAP water at the Grand Drain.

SRP operations staff are presently working on estimates of the carrying capacity available in the Grand Canal for conveying CAP water for recharge. This option is not immediately available since the intertie between the CAP aqueduct and the SRP canals is not due to be operational until early 1990.

Glendale is conducting a wastewater master planning study for a large study area which runs adjacent to the site. Plans for wastewater reclamation and reuse is major component of the study. Wastewater treatment facilities are likely to be constructed near the southern portion of the site. A cooperative project with Glendale to recharge and recovery treated effluent for meeting seasonal demands of the reuse system is a definite possibility.

Soils in the flood plain are primarily a loamy sand with rapid permeability to very rapid permeability. The steam channel is more than 1,000 feet wide over most of this site which would allow extensive development of spreading basins in the alluvial deposits. Most of the land is undeveloped and privately owned. There are a few gravel companies operating in the channel. State land and Bureau of Land Management own several scattered parcels less than 80 acres each in the stream channel.

<u>Queen Creek from CAP to Rittenhouse Road</u>

Depth to groundwater level was measured in 1982 for eight wells located within about one-half mile of Queen Creek for the reach from the CAP aqueduct to Rittenhouse Road. Depth to groundwater level ranged from 436 to 500 feet below land surface (Reeter and Remick, 1986). Fluoride content for groundwater obtained from three wells ranged from 0.5 to 0.7 mg/l and total dissolved solids estimated from specific electrical conductance ranged from 370 to 520 mg/l (Reeter and Remick, 1986). Direction of groundwater flow for this reach of Queen Creek in 1982 was from the east to the west.

Thickness of the upper alluvium unit ranges from 200 to 300 feet (Laney and Hahn, 1986). Depth to bedrock complex is estimated to be more than 1,200 feet (Cooley, 1973).

A turnout could be constructed on the CAP aqueduct to discharge water directly into the upper end of the site. Other potential sources of supplemental recharge water have not been identified for this site. The City of Mesa is presently pursuing a cooperative project with SRP to recharge CAP water in the upper Salt River. If this project does not prove feasible, then indications are that Queen Creek would be their second choice for a CAP recharge site.

Soils in the vicinity of this site vary from fine sandy loam to a loamy sand which are classified by the SCS as "moderately rapidly permeable to very rapidly permeable". Underlying soils have a mixture of gravel and cobbles. In general, the upstream portions of th site tend to be more permeable than the downstream areas. The first one-half mile of this site is State land and the rest is privately owned. The existence of gravel pit operations in the area would require siting of recharge facilities to avoid inundation of the pits.

Queen Creek from Rittenhouse Road to RWCD Floodway

Depth to groundwater was measured in 1982 for eight wells within one-half mile of Queen Creek from Rittenhouse Road to the Roosevelt Water Conservation District (RWCD) Floodway. Depth to groundwater level ranged from 254 to 444 feet below land surface (Reeter and Remick, 1986). Groundwater samples for laboratory chemical analyses were obtained in 1982 and 1983 for 11 wells within about one-half mile of Queen Creek. The fluoride content for the groundwater ranged from 0.4 to 1.0 mg/l and total dissolved solids estimated from specific electrical conductance ranged from about 550 to 2,080 mg/l (Reeter and Remick, 1986). The two groundwater samples with the highest specific electrical conductance of 2,150 and 3,200 micromhos per centimeter were obtained from wells located in an area of known perched groundwater. The downstream four miles of Queen Creek from Rittenhouse Road to the RWCD Floodway are in an area of known perched water (Laney and Hahn, 1986). Laney and Hahn (1986) indicate that the perched water may originate as applied irrigation water or as flow from Queen Creek. An active county landfill is reported to occur about one and one-half miles in the downgradient groundwater direction from Queen Creek (Maricopa County Landfill Department). Direction of groundwater flow in 1982 for this reach of Queen Creek was north to south.

Thickness of the upper alluvium unit for this reach of Queen Creek ranges from about 200 to 300 feet (Laney and Hahn, 1986). Depth to basement complex is estimated to be more than 1,200 feet (Cooley, 1973). Because of the presence of perched water in the lower half of the reach of Queen Creek from Rittenhouse Road to the RWCD Floodway, this portion of the reach is considered unfavorable for recharge operations by surface methods.

CAP water could be conveyed to this site through 6 miles of the upper reaches of the Queen Creek channel. Other supplemental recharge water sources have not been identified.

Soils at this site range from loam to loamy fine sand with moderately rapid permeability. These soils are less permeable than those found in the upper reaches of Queen Creek. All land ownership is private. The stream channel is narrower in this lower reach and residences and farm structures are commonly found near the stream channel.

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Table 1

TECHNICAL RATING SHEET FOR RECHARGE POTENTIAL OF SELECTED MARICOPA COUNTY FLOOD CONTROL DISTRICT SITES

Name	Depth to Groundwater Level (feet)	Thickness of Upper Alluvium (feet)	Depth to Basement Complex (feet)	Proximity to Landfills or Contaminated Groundwater[a]	Chemical Quality of Groundwater: Fluoride mg/l[b]	Chemical Quality of Groundwater: Total Dissolved Solids (TDS[c]) mg/l	Water Availability: Water Source . Distance . Conveyance	Potential Cooperative Project Participant
Saddleback Dam detention area	426 - 510	300 - 600	300 - 1120		2.8 - 3.1[d]	470 - 570[d]	CAP . 2 miles . stream channel Effluent . 23 miles . pipeline	
Centennial Wash from Levee to Mullens Cut	174 - 400	200 - 500	<300 - 700		3.3 - 4.8[d]	810 - 880[d]	CAP . 15 miles . stream channel Effluent . 19 miles . pipeline	
McMicken Dam detention area	329 - 504	500 - 700	>1200	A	0.1 - 1.5	190 - 290	CAP . --- . Beardsley Canal Effluent[f]	Maricopa Water District
Cave Buttes Dam to CAP Aqueduct	ND[e]	<400	<400		ND	ND	CAP . 1 mile . Pipeline Effluent[f]	City of Phoenix
Cave Creek from CAP to 7th Street	68[d]	<400	<400	C	ND	ND	CAP . 0.25 mile . Effluent[f]	City of Phoenix
New River from Skunk Creek to Agua Fria	144 - 278	650 - 800	>1200	A, C, V	0.2 - 0.5	260 - 1030	CAP . 10 miles . stream channel CAP . ---[f] . Arizona Canal Effluent[f]	City of Glendale City of Peoria
Lower Agua Fria from New River to I-10	95 - 153	600 - 750	>1200	C, V	0.3 - 1.4	380 - 980	CAP. ---[f]. Grand Canal Effluent[f]	City of Glendale
Queen Creek from CAP to Rittenhouse Road	436 - 500	200 - 300	>1200		0.5 - 0.7	370 - 520	CAP . 0.25 mile . stream channel	City of Mesa
Queen Creek from Rittenhouse to RWCD	254 - 444	200 - 300	>1200	A	0.4 - 1.0	550 - 2080	CAP . 6 miles . stream channel	

[a] A - active landfill
C - construction debris landfill
V - groundwater contaminated with volatile organic compounds

[b] mg/l - milligrams per liter

[c] Estimated from measurements of specific electrical conductance (EC) and approximate relation: total dissolved solids (mg/l) = 0.65 x EC (micromhos per centimeter)

[d] One data point onsite, or 4 or less data points offsite

[e] ND - no data

[f] Wastewater reuse program in planning stages; no estimate of distance available

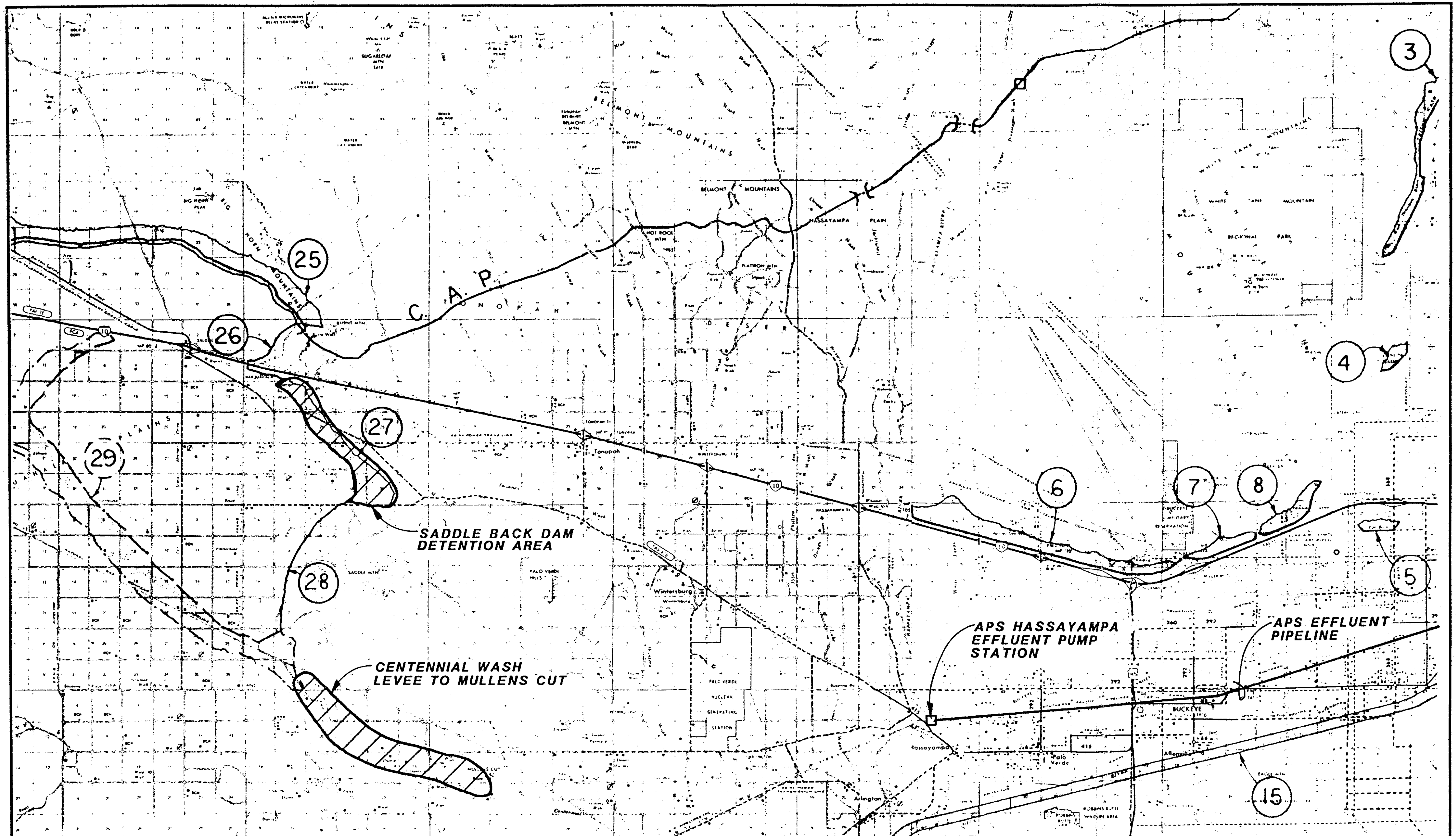

FIGURE 1
SADDLEBACK DAM AND CENTENNIAL WASH RECHARGE SITES

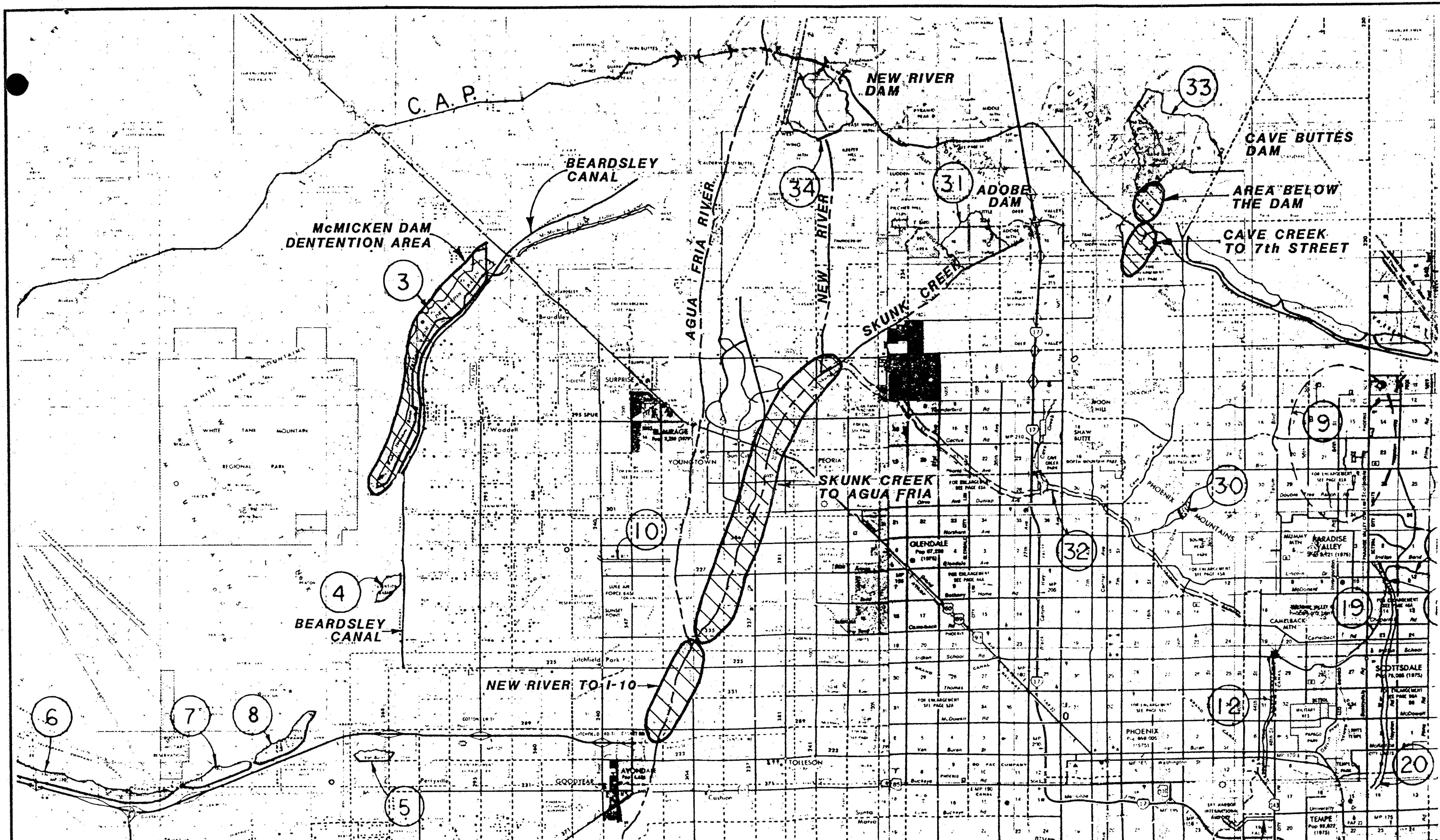

FIGURE 2

McMICKEN DAM, NEW RIVER, AGUA FRIA, AND CAVE BUTTES RECHARGE SITES

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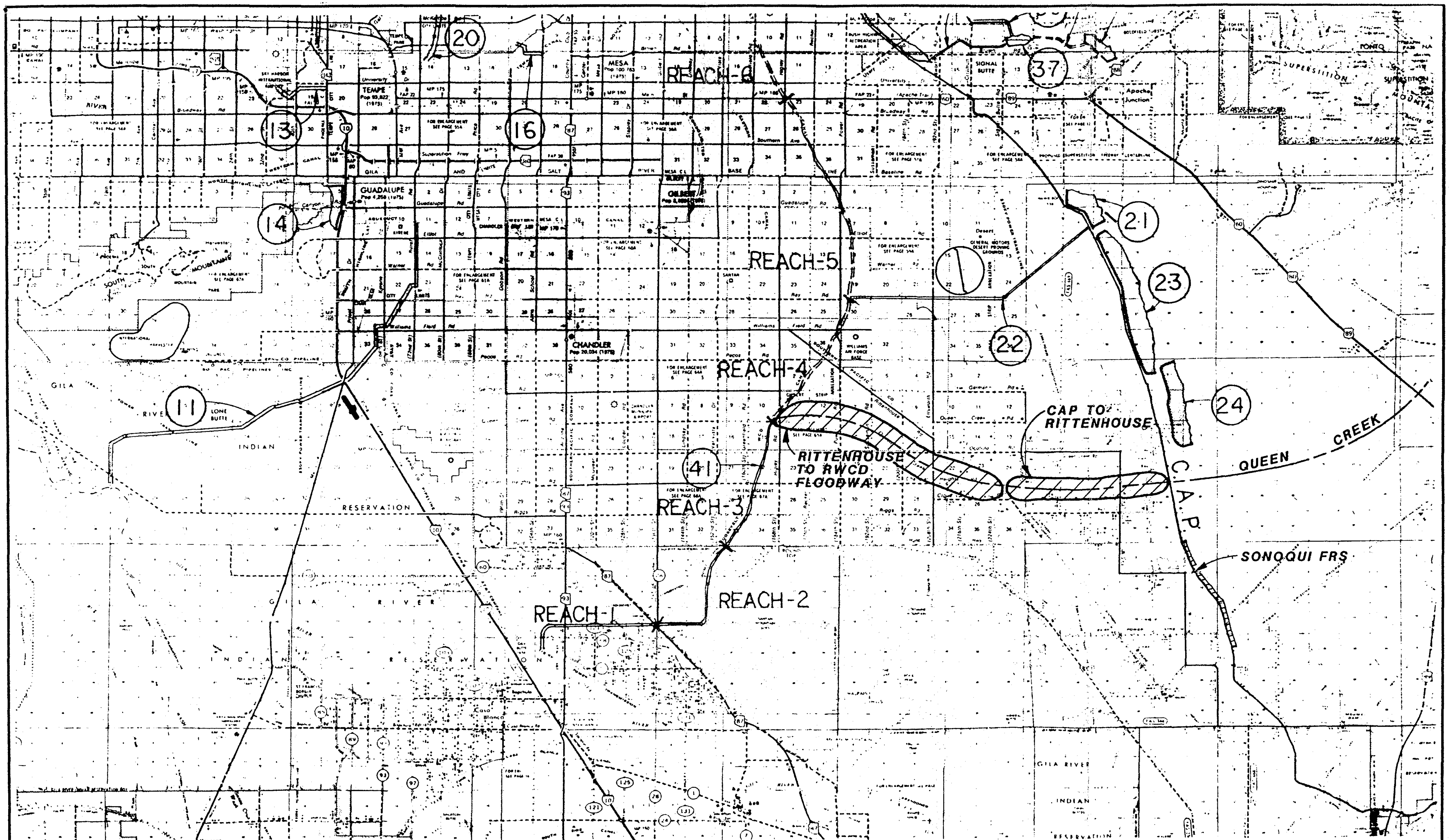

FIGURE 3
QUEEN CREEK RECHARGE SITES

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