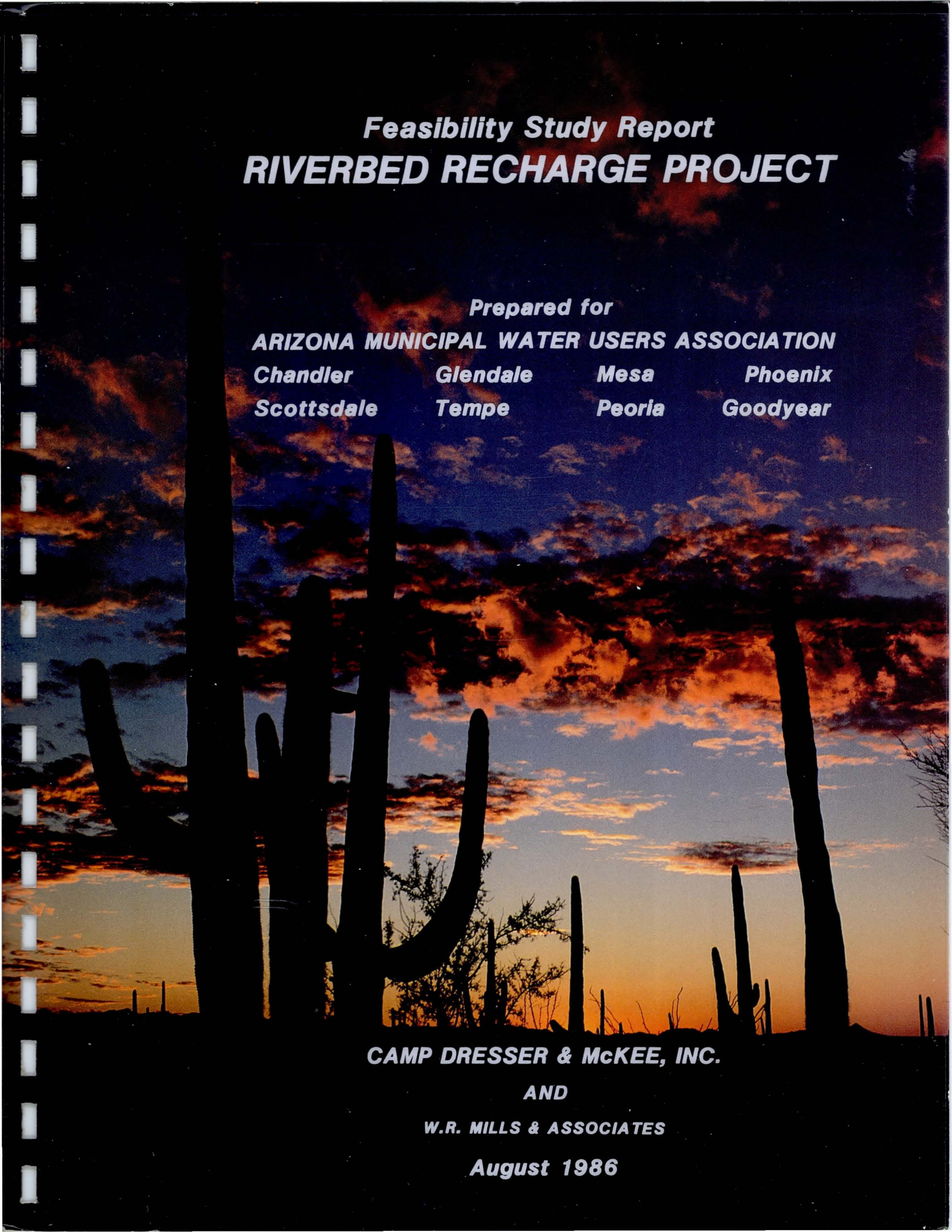

Feasibility Study Report
RIVERBED RECHARGE PROJECT

Prepared for

ARIZONA MUNICIPAL WATER USERS ASSOCIATION

Chandler Glendale Mesa Phoenix

Scottsdale Tempe Peoria Goodyear

CAMP DRESSER & McKEE, INC.

AND

W.R. MILLS & ASSOCIATES

August 1986

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Prepared for

ARIZONA MUNICIPAL WATER USERS ASSOCIATION

Chandler	**Glendale**	**Mesa**	**Phoenix**
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RIVERBED RECHARGE PROJECT

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August 1986

CDM
environmental engineers, scientists,
planners, & management consultants

CAMP DRESSER & McKEE INC.

Cambridge Court
2701 North 16th Street
Phoenix, Arizona 85006
602 277-9966

August 8, 1986

Mr. Roger S. Manning
Executive Director
Arizona Municipal Water Users Association
505 North 2nd Street
L'Aiglon Court Suite 385
Phoenix, Arizona 85004

Dear Mr. Manning:

Camp Dresser & McKee Inc. is pleased to submit the final report on the feasibility study for recharge of Colorado River water in the Phoenix metropolitan area groundwater aquifers.

The report, prepared in accordance with our contract dated March 20, 1986, presents a comprehensive review of technical factors associated with groundwater recharge at ten proposed riverine sites on a conceptual basis; and on a preliminary design basis for two specific sites located on the Upper Agua Fria River and Salt River systems. The investigative results indicate that recharge is possible and economically feasible. Implementation of recharge programs will be an important element of Arizona's long-term water supply strategy.

We wish to express our deepest appreciation for the cooperation and assistance generously offered by you, your staff, and the AMWUA members during the course of study and preparation of the report.

Thank you for the opportunity to be of service.

Sincerely,

CAMP DRESSER & McKEE INC.

Jeffrey K. Kracht, P.E.
Vice President

JKK/jco

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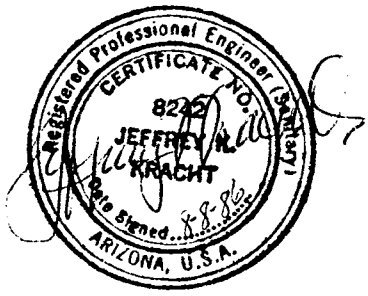

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INTRODUCTION 1.0

1.1 BACKGROUND

Beginning in 1986, Colorado River water will be transported via the Central Arizona Project (CAP) to CAP sub-contractors in Maricopa County. At the present time, the delivery potential of the CAP far exceeds the water demands which may be placed on the system by the CAP water users, which makes surplus water available for storage and later retrieval. Early delivery of surplus water to the Phoenix area will enhance future conjunctive management of present and future water supplies if the surplus water can be stored underground in large quantities. In the Phoenix Active Management Area (AMA), tremendous amounts of water can be stored by recharging the alluvial groundwater basins that underlie the greater Phoenix Metropolitan area.

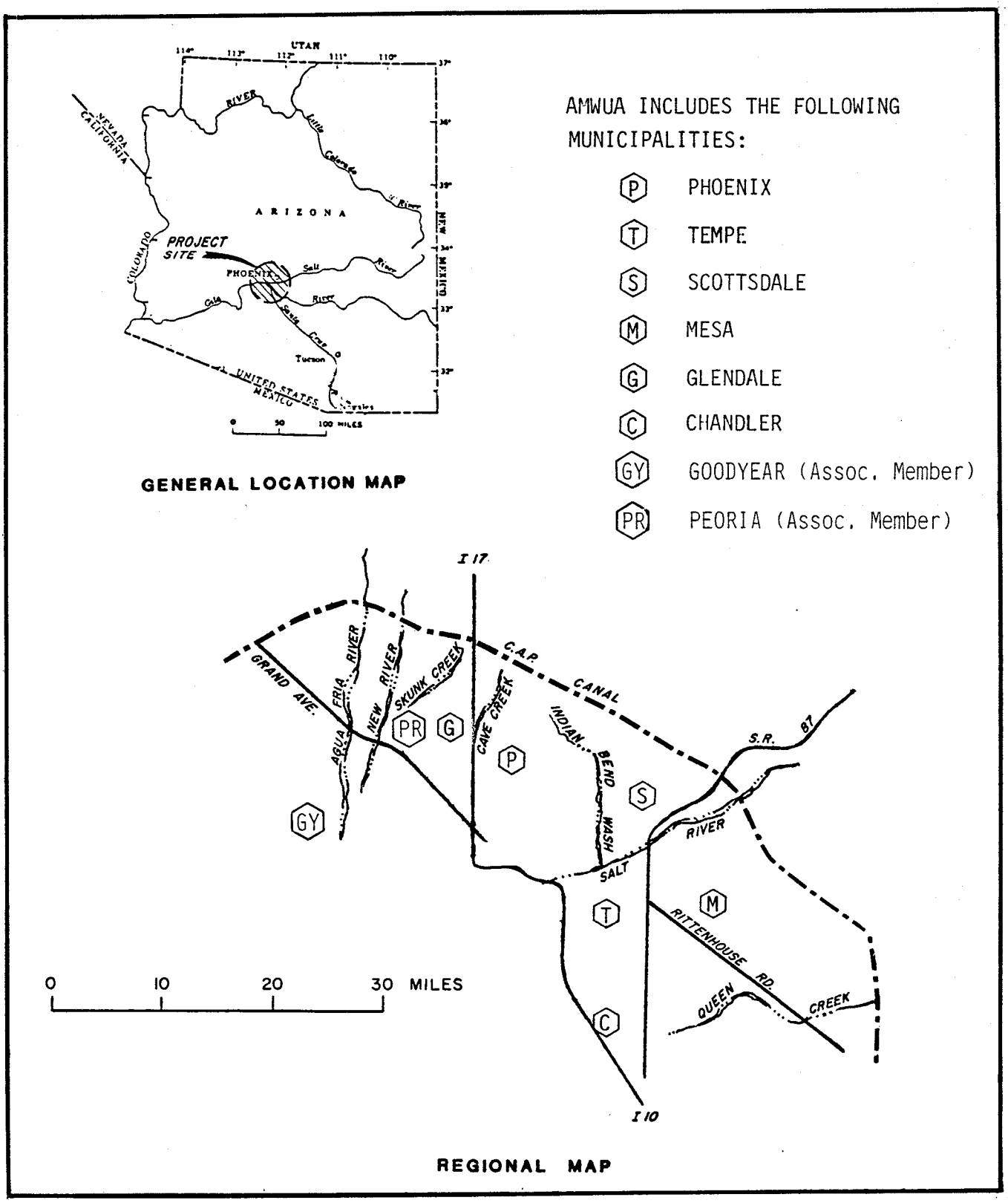
Because of the regional nature of such an ambitious program, an organization representing regional interests is well suited to undertake the required feasibility studies. The Arizona Municipal Water Users Association (AMWUA) is a private, non-profit corporation established for the purposes of developing and coordinating regional urban water policies. The AMWUA member agencies include the cities of Chandler, Glendale, Mesa, Phoenix, Scottsdale, Tempe, Goodyear and Peoria, which together represent over 80 percent of both the population, and municipal and industrial water use in Maricopa County.

AMWUA retained Camp Dresser & McKee Inc. (CDM) to evaluate the feasibility of recharging and storing surplus CAP water in the East and West Salt River Valley groundwater subbasins of the Phoenix AMA. The location of the study area is shown on Figure 1. The specific areas that were considered included the river channel areas downstream of the Granite Reef/Salt-Gila Aqueduct for (1) the Agua Fria River to Grand Avenue, (2) New River to the Agua Fria River, (3) Skunk Creek to the New River, (4) Cave Creek to the Arizona Canal, (5) Indian Bend Wash to the Salt River, (6) the Salt River from the Granite Reef Dam to Tempe Buttes, and (7) Queen Creek to the Roosevelt Canal.

FIGURE 1

LOCATION OF AMWUA RIVERBED RECHARGE PROJECT

Feasibility Study Report — AMWUA Riverbed Recharge Project



The information presented in this report discusses the progress of the study from the site screening stage through development of preliminary designs for the two best sites. Each stream course under investigation was evaluated for the technical feasibility of recharging and storing CAP water. A feasibility-level technical and economic evaluation of 10 sites was conducted. Based on this evaluation, the 10 sites were screened to the two most favorable sites. Preliminary designs were then developed for these sites.

1.2 METHODS OF RECHARGE

Artificial recharge involves releasing water over the ground surface and allowing it to infiltrate into the ground and percolate to the subsurface aquifers. Spreading methods include flooding, ditch and furrow, irrigation, natural channel, inflatable dams, shallow spreading basins, and deep basin or pit techniques. In addition, artificial recharge may also be accomplished using injection wells or shallow basins augmented by shafts or recharge wells. Currently, the most common methods of artificial recharge are shallow spreading basins and deep basins or pits.

Siting constraints originally established for the study narrowed potential sites to the river channel areas. In addition, methods are required which will recharge large quantities of water quickly. Because of these two constraints, only surface recharge methods have been considered during the study. The following is a brief description of the recharge facilities that were evaluated to recharge CAP water.

1.2.1 SHALLOW SPREADING BASINS

Shallow spreading basins are usually the most economical and the most commonly used method of artificial recharge. They also are easy to build and maintain. In general, water is released into one- to ten-foot deep basins which are formed by the construction of dikes or levees, or by excavation. Ponded water infiltrates through the ground surface and percolates to the water table. During this process, silt and micro-organisms are filtered out by the soil, thus providing a degree of treatment. However,

this treatment mechanism also tends to reduce infiltration rates by clogging the soil surface. Successful spreading operations require good maintenance techniques to minimize clogging. Location of the spreading grounds, with respect to subsurface geology, is also important to allow unimpeded travel of the water from the ground surface to the water table.

Two types of shallow basins are commonly utilized: temporary shallow basins, sometimes referred to as "T" or "L"-levees, and permanent shallow basins. An "L" shaped levee preceeded the "T" levee. However, the "L" levee does not provide positive control of the water flow into the downstream "L" basin. Consequently, water would sometimes "short circuit" in the "L" basin without fully wetting the basin. To correct this, a downstream training levee was added, changing the shape from an "L" to a "T".

The "T"-levees are constructed within the active river channel and are subject to periodic washout from flood flows. This type of system consists of a series of levees that are constructed perpendicular to the river flow direction. One end of this levee is tied into an existing riverbank or channel improvement. Short levees parallel to river flow direction are built at the end of the transverse levee, thus creating a "T"-shaped, 3-sided shallow basin. Controlled releases of recharge water or storm flows at low flow rates are stored or captured behind each "T"-levee. The levee system creates a series of basins that "spill" to the down-gradient basins as the depth of water increases to allow flow around the parallel levee segment. The "T"-levees are usually constructed so that the depth of water does not exceed 5 or 6 feet and the backwater in each levee reaches the toe of the upstream transverse levee, thus maximizing the wetted surface area.

Shallow basins of a more permanent type are also constructed within or adjacent to the river channel. Normally, these facilities are constructed outside the active river channel and are thus protected from washout. If the basins are constructed within an unimproved river channel, some type of erosion protection is usually provided. These basins are normally about 10 to 20 acres in size with water depths of 5 to 10 feet.

Operation and maintenance costs for these types of facilities are considered minimal in comparison to the volume of water recharged. However, land acquisition costs can be high if the purchase of private land is necessary.

1.2.2 ABANDONED GRAVEL PITS (DEEP BASINS)

Abandoned gravel pits have been used in several locations for groundwater recharge. In general, these pits or deep basins are more expensive to maintain than shallow spreading basins. Infiltration rates are more difficult to maintain in deep pits because of the difficulty in periodically drying the pit bottom and sides to allow silt and bacterial clogging to break up. Thus, long-term average infiltration rates for deep basins will be less than those for shallow basins, given the same soil characteristics.

The principal advantage of deep pits is their storage capacity for storm runoff, which increases the amount of infiltration between storms. In addition, deep pits can allow water to reach more permeable sediments in areas where clays or hardpans near the ground surface restrict downward percolation of groundwaters.

Where private land acquisition is necessary, abandoned gravel pits are generally acquired at a cost substantially below the cost of vacant, undisturbed land.

1.3 RECHARGE SITE IDENTIFICATION

The objective of the AMWUA Riverbed Recharge Study is to identify and evaluate the recharge and storage capabilities of the river segments located within the East and West Salt River Valley groundwater subbasins adjacent to and downstream of the Granite Reef and Salt-Gila Aqueduct, including the following: the Agua Fria River, New River, Skunk Creek, Queen Creek, the Salt River, Cave Creek, and Indian Bend Wash.

Recent aerial photographs (1985) of all the drainage courses were studied to locate presently undeveloped lands within the study areas and near the Central Arizona Project or other major water conveyance facilities which are connected to the CAP, such as the Arizona Canal. This review process identified a total of 13 areas in which CAP water could potentially be recharged. These general areas are shown on Plate 1. The following are brief descriptions of each area.

1.3.1 AGUA FRIA RIVER

The flood plain of this river contains substantial areas of presently undeveloped lands. Potential recharge sites can be supplied recharge water from both the Granite Reef Aqueduct and the Beardsley Canal. Three sites were selected on this river system: the Upper Agua Fria site which is situated between Deer Valley and the CAP, the Middle Agua Fria site which is located between Jomax Road and Deer Valley Road, and the Lower Agua Fria, which is located between Deer Valley and Grand Avenue. The Upper Agua Fria site overlies a relatively small groundwater body that is not in significant hydraulic continuity with the regional aquifer. The area of this potential recharge site encompasses about three square miles. This recharge site could be easily supplied water from either the Granite Reef Aqueduct or the Beardsley Canal. Use of the Beardsley Canal would be predicated upon receiving permission from the Maricopa Water District, the canal owner and operator.

The Middle and Lower Agua Fria sites extend a distance of about 8 miles south of Jomax Road to Grand Avenue and comprises an area of approximately 6 square miles. The flood plain of this river segment is very wide and CAP water could be delivered to this site via the Beardsley Canal. The recharge potential of this area is much greater than the amount of surplus water which will probably be available from the CAP. CDM estimated that 200,000 acre- feet per year of water released into spreading facilities would be fully percolated by the time it reached Deer Valley Road, located only about 3 miles south of Jomax Road. For this reason, evaluation was conducted for only the Middle Agua Fria site area. Should additional capacity be needed, in-stream recharge facilities could easily be extended into the Lower Agua Fria area.

1.3.2 NEW RIVER

Two potential recharge sites were located along the New River. The Upper New River recharge site encompasses an area of about one square mile and is adjacent to the CAP. This facility also overlies a small groundwater body, similar to the Upper Agua Fria recharge area. As mentioned previously, this smaller groundwater basin is not in substantial hydraulic continuity with the regional aquifer.

The Lower New River recharge site extends from just below the Upper New River Dam, between Jomax and Deer Valley Roads, a distance of about 4 miles. The total surface area within the site is about 500 acres. Recharge water for this site would be obtained directly from the Granite Reef Aqueduct. CAP water could be discharged directly into the natural drainage course of the New River and travel a distance of about 1.5 miles to reach the upper end of this recharge facility.

1.3.3 SKUNK CREEK

Two potential recharge sites were identified along this drainage system. The first of these, the Upper Skunk Creek recharge site, lies within 1/2 mile of the Granite Reef Aqueduct and encompasses an area of approximately 800 acres. This area, similar to the upper areas of the Agua Fria and New Rivers, overlies a small groundwater basin that is not in substantial hydraulic continuity with the regional aquifer.

The Lower Skunk Creek site is a 520-acre area situated behind Skunk Creek Dam, located at 35th Avenue and Deer Valley Road. Recharge facilities at this site would occasionally become inundated by flood waters.

1.3.4 CAVE CREEK

Two nearly adjacent recharge sites were identified along Cave Creek. The Upper Cave Creek site, located between Deer Valley Road and Union Hills Drive, is situated about 1.5 miles from the CAP and comprises an area of about 240 acres.

The Lower Cave Creek site is situated between Bell Road and Greenway, about 1/2 mile downstream of the Upper Cave Creek site. This site covers about 400 acres.

1.3.5 INDIAN BEND WASH

Most of the lands along the Indian Bend Wash have already been developed in some form of public or private recreational facility. A large area of currently undeveloped land, although not within the flood plain boundary of Indian Bend Wash, was identified adjacent to the Granite Reef Aqueduct. This 1,400-acre facility is identified as the Upper Indian Bend Wash recharge site on Plate 1.

A relatively small, 90-acre site was identified within the flood plain and adjacent to the Arizona Canal. The recharge water would be diverted from the CAP at Granite Reef Dam into the Arizona Canal for delivery to the recharge site.

1.3.6 SALT RIVER

Two major recharge sites were identified along the Salt River drainage course. The upper site consists of about 800 acres of riverbed lands and is located immediately downstream of the Granite Reef Dam. Recharged water could be conveyed directly to this facility from the Granite Reef Aqueduct of the CAP.

The Lower Salt River recharge site adjoins the upper site and extends another 6 miles downstream. Nearly 2,600 acres of flood plain could be supplied recharge water via the Southern Canal or from the CAP turnout at the Granite Reef Dam.

1.3.7 QUEEN CREEK

The entire 5.5-mile-long flood plain of Queen Creek, located between the Salt-Gila Aqueduct and the Southern Pacific Railroad, was identified as the potential recharge facility. This site covers an area of approximately 800 acres.

1.4 INITIAL SCREENING PROCESS

Because of the large number of recharge sites that were identified on a preliminary basis, and also because the total recharge area encompassed several thousand acres, the 13 sites were initially screened to eliminate the least attractive sites and to allow a more concentrated study effort to be conducted on the remaining sites. The following criteria were used for this initial screening process:

- The site must be near the CAP canal or another water conveyance facility through which CAP water could be delivered. This criterion potentially eliminates the need to construct extensive conveyance facilities and allows for rapid implementation that can satisfy recharge facility needs in the near term.

- The groundwater reservoir at the site must be in substantial hydraulic continuity with the major groundwater producing body for the AMWUA member agencies. This criterion precludes the recharge of CAP water in areas that do not directly affect the groundwater storage conditions in the East and West Salt River Valley groundwater subbasins of the Phoenix AMA. Several such areas exist in the West Basin where bedrock highs separate small alluvial subbasins from the main groundwater basin to the south.

On the basis of these screening criteria, three sites were placed in the "least desirable" category. These sites are the Upper Agua Fria site, the Upper New River site, and the Upper Skunk Creek site. As previously mentioned, these sites are located immediately adjacent to the CAP Canal but overlie small groundwater bodies that are not in substantial hydraulic continuity with the main groundwater basin in the area. Thus, it would be difficult for the AMWUA member agencies to obtain any significant benefit from the groundwater recharge in these basins as the recharge water would not directly affect the groundwater levels in the main basins, nor would the water be readily available for extraction and subsequent use without the construction of new production and conveyance facilities.

EVALUATION CRITERIA 2.0

2.1 INTRODUCTION

Final site selection, as well as the method by which water will be recharged, has been evaluated with regard to the following specific selection criteria:

- Infiltration rates
- Mounding potential
- Available storage capacity
- Groundwater quality
- Perched water table conditions
- Proximity to residential neighborhoods
- Proximity to landfills and waste disposal sites
- Environmental factors
- Land ownership

A qualitative rating system, using the above criteria, was used to select suitable alternative recharge sites. The general implication of each criterion relative to recharge site selection and the methodology by which these criteria were derived are discussed in this section. The application of these criteria to individual site screening is presented in Section 3, "Technical Evaluation of Recharge Sites."

2.2 INFILTRATION RATES

The infiltration rate is the rate that water passes through the soil surface and enters the unsaturated zone of the soil. Infiltration rates vary not only areally because of variations in soil and other subsurface conditions, but will vary at any one location with time due to silt and biological clogging of the recharge ponds. Sustained or long-term infiltration rates reflect subsurface flow impediments, such as fine-grained silt and clay lenses that may exist beneath the site. Normally, infiltration rates are highest where fine-grained soils have been removed, such as along stream channels. Because the area required for groundwater recharge is directly related to the infiltration rate, recharge sites with

relatively high infiltration rates are considered more favorable than those having lower infiltration rates.

Several studies have been done in the Phoenix area on recharge rates by storm and controlled runoff events. Briggs and Werho (1966) studied infiltration losses from a controlled release by the Salt River Project into the Salt River. The average infiltration rate for the 19-mile reach between Granite Reef Dam and 48th Street in Phoenix was over 2.5 ft/day. This was the instantaneous rate for a four-day period. Farther downstream, four-day rates in gravel pits averaged about 1.5 ft/day. Sustained infiltration rates declined to 1.1 ft/day after two weeks. Babcock and Cushing (1941) determined a range of infiltration rates for a 20-mile reach on Queen Creek. Rates were from 0.14 to 2.09 ft/day, with an average of 1.08 ft/day for floods of varying magnitude. Infiltration rates in upstream areas were as high as 7 ft/day, but rapidly decreased downstream as sediment load increased in the stream water. Infiltration rates in pools of runoff remaining in the channel averaged 0.91 ft/day. Because these rates were only measured over a short period of time, sustained rates could not be determined for Queen Creek.

Other data show a sustained infiltration rate on the Salt River below Granite Reef Dam to be about 1 ft/day, based on flows from 1978 to 1980, with sustained flows during the spring of each year (Mann and Rohne, 1983). Generally, a long-term infiltration rate of 1 ft/day is a conservative measure of the ability of normally dry stream beds to recharge water (Arizona Department of Water Resources, 1986).

Infiltration rates were derived for potential AMWUA recharge sites by interpreting U. S. Soil Conservation Service (SCS) soils maps to estimate infiltration rates over large areas, primarily in the stream channels. From observations of recharge operations along the Santa Ana River, sustained recharge rates were found to be about ten times less than instantaneous infiltration rates derived from soils data. Therefore, for the purposes of this initial screening, sustained infiltration estimates for potential AMWUA recharge sites were assumed to be one-tenth of the instantaneous values derived from the SCS soils maps.

For the individual recharge sites, the adjusted SCS infiltration rates obtained from soils maps were estimated for each 640-acre section within the potential recharge area on the basis of a weighted mean. This procedure provided a representative overall infiltration rate for each section within the recharge site area.

Each section within the potential recharge sites were then planimetered to obtain the actual acreage of each section within the recharge site. Finally, a weighted mean for sustained infiltration rate, based on acreage of section within the recharge site, was calculated for each site. It should be noted that infiltration rates determined by this method could vary substantially from those observed during actual operations. To more accurately assess this design parameter, in-situ infiltration tests should be conducted prior to preparing final designs.

2.3 MOUNDING POTENTIAL

In evaluating recharge sites, it is important to determine the amount of groundwater rise that will result from long-term recharge. This rise in water level due to recharge (mounding) is compared to the depth to water beneath the proposed recharge facilities. Recharge operations should not cause groundwaters to rise to the ground surface, which would result in interference with infiltration. Rising groundwater could also penetrate the base of nearby landfills, resulting in contamination of the recharged water. If the proposed recharge site is subject to mounding which nears the ground surface, the site rating is lower.

Mounding potential for AMWUA recharge areas was derived as a function of infiltration rates, aquifer transmissivity and specific yield, width of the recharge basin, and the period of recharge. Therefore, these variables were estimated for each potential recharge site. Most of the transmissivity and specific yield data were obtained from the Arizona Department of Water Resources groundwater model for the Salt River Basin (Long, et al., 1982). The transmissivity and specific yield data from the model relied upon available aquifer tests, specific capacity information, and geologic and drillers' logs, and were compiled on a (640-acre) section by section

basis. Other data from available aquifer tests and Corps of Engineers reports (U.S. Army Corps of Engineers, 1981) compared quite favorably. Width and total area of the recharge sites were planimetered. For purposes of the mounding analysis, it was assumed that the basins within the recharge facility would be operated on an alternating wet-dry basis. Period of recharge was held constant for 30 days before application of a 30-day dry cycle. Other wet-dry cycles have been used at other recharge sites to address local operational conditions. However, the 30-day wet-dry cycle was selected to maintain high sustained infiltration rates, to mitigate midge fly problems, and to allow dispersement of the underlying groundwater mound. Actual wet-dry cycle durations should be adjusted once the facilities are in operation. These variables are listed and summarized in tables for each site later in the text.

Using these data, a computation was made of the amount of groundwater rise that would result from extended recharge operation at each site. The method used for the analysis, is described in an EPA Process Design Manual (Treatment of Municipal Wastewater, October, 1981). If it was determined that the infiltration rate would result in mounding at a recharge site, a determination was made of the sustained average infiltration rate that could be expected at the site.

2.4 AVAILABLE STORAGE CAPACITY

The importance of depth to groundwater was mentioned in the previous section. In addition, the available storage capacity in the unsaturated zone beneath some recharge sites may be less than others due to the depth to groundwater and/or the specific yield of the sediments in the unsaturated zone. In general, the greater the available storage capacity beneath a recharge site, the better the site.

Storage capacity is calculated by taking the product of the depth to water, the area of the recharge site, and the specific yield. These calculations assume that the underlying geologic materials are at field capacity.

A depth to water and groundwater elevation map was developed for the Salt River Basin based on 1984 Arizona Department of Water Resources water level data (Plate 2). This map served as the basis for determining the average water level beneath each potential recharge site. Water levels were estimated on a section by section basis, and then a weighted average was computed based on the portion of each section within the recharge site. It should be noted that storage capacity gives a general indication of the amount of water stored beneath a site. But because water moves laterally from a site, the amount of water being recharged can be larger than the storage capacity which exists directly beneath the site.

2.5 GROUNDWATER QUALITY

Ideally, the quality of groundwater beneath recharge sites should meet drinking water standards. If CAP water is allowed to comingle with poor quality groundwaters, the resulting mixture of CAP and native groundwaters, when withdrawn, may require costly treatment to meet drinking water standards. In general, potential sites overlying groundwaters of poor quality were ranked lower on the rating matrix.

Groundwater quality conditions which may affect the operation of recharge facilities were evaluated using historic groundwater quality data, as well as land use data which may indicate the possibility of degradation, such as existing or historic agricultural activity in the area of recharge facilities. A regional groundwater quality map was developed describing conditions near the potential AMWUA recharge sites (Plate 3). Information from this map was based on data from EPA STORET, USGS WATSTORE, Arizona Department of Health Services reports (Eberhardt 1984; Arizona Department of Health Services, 1985; Love, 1979), MAG 208 reports (Maricopa Association of Governments, 1979), and USGS reports (U.S. Geological Survey, 1974).

Areas where groundwater quality constituents (such as nitrates) exceed primary or secondary drinking water standards, and areas where the pesticide, DBCP, and volatile organic compounds (VOCs), such as TCE, have been detected, are delineated on the regional groundwater quality map (Plate 3).

2.6 PERCHED WATER CONDITIONS

Recharge operations conducted in areas above perched water tables or continuous horizontally stratified, low permeability geologic materials close to the ground surface may inhibit deep percolation of recharge water. In this situation, percolating water will accumulate on the perching zone, producing a mound which could rise to the ground surface, which effectively stops further percolation of recharge water. Also, perched water table conditions can direct recharged water away from points of desired use. In general, areas with existing or potential perched water conditions are unfavorable for continuous, large-scale recharge operations.

Determination of potential or actual perched water conditions was based on data obtained from existing reports (MAG, 1981; U.S. Geological Survey 1978), water level data, and geologic cross sections constructed for each potential site. The regional water level map (Plate 2) indicates areas previously identified as having major perched water conditions. The reports reviewed, coupled with Arizona Department of Water Resources 1984 water level data, describe either areas with wells exhibiting cascading water or shallow water levels above the regional water table. The geologic cross sections presented in Section 3, which were constructed for each site area show where perched water conditions could occur beneath each site if large amounts of water were recharged.

2.7 PROXIMITY TO RESIDENTIAL NEIGHBORHOODS

A problem commonly encountered with water spreading operations is the propogation of an insect commonly known as the midge fly. The insect resembles the mosquito, but does not bite, as does the mosquito. Studies have been conducted to determine the most effective control for this insect and to determine its expected travel distance from the spreading basins.

Interruption of the insect's life cycle through periodic drying of the spreading basins has been found effective in its control, but is operationally more difficult. However, midge travel distance from recharge basins has been found to be minimal. Thus, the location of spreading basins at

distances from residential neighborhoods may be more desirable than operational control measures. Thus, potential recharge sites near developed residential land or undeveloped, but zoned residential land, were rated less favorably than those sites on undeveloped publicly owned lands.

Zoning information was collected for each potential recharge site to evaluate proximity or future proximity to residential neighborhoods. Site specific maps for each potential recharge site indicate areas of residential zoning which are less than 20,000 ft^2 (1/2 acre) per dwelling. This cutoff was selected because areas greater than 20,000 ft^2 per dwelling allow rural conditions with horses and livestock, which already attract nuisance pests.

2.8 PROXIMITY TO LANDFILLS AND WASTE DISPOSAL SITES

Landfills and illegal waste disposal sites may pose groundwater contamination problems, because of the possible generation and downward migration of landfill leachates and wastes into underlying groundwater. Thus, groundwater recharge facilities should not be constructed near these sites because the elevated groundwater table may intercept any downward migrating contaminants.

Data from a MAG 208 point source report and aerial photos provided the basis of a regional map showing landfills and sewage treatment facilities (Plate 4). These areas are also shown on site specific maps of the potential recharge sites.

2.9 ENVIRONMENTAL FACTORS

Biological and archaeological factors were identified and evaluated for each alternative recharge site. Most of the study area channels are devoid of vegetation, but some vegetation exists and serves as a habitat for wildlife. Published reports indicate that several wildlife species which live in the general area of the potential recharge sites are on the endangered species list or other lists that require special protection. In addition, several archaeological sites near some of the recharge sites have

been identified in previous reports. If these sensitive areas cannot be protected from the recharge operation, the recharge location was eliminated from consideration.

Areas which generally may be considered environmentally sensitive by the Arizona State Parks Department are also shown on Plate 4. These areas are shown on site-specific maps delineating the potential recharge sites (Figures 3, 5, 7, 8, 10, 12, 14, and 17).

2.10 LAND OWNERSHIP

This non-technical suitability criteria is important as a cost consideration and as a potential implementation constraint. Privately held lands may be more costly to obtain than publically owned lands, which may only require conditional use permits. Consequently, potential recharge sites on public lands were ranked more favorably than those on privately held lands.

Land ownership information was collected from the Bureau of Land Management Surface Management maps for the Salt River Basin (Bureau of Land Management, 1979). These data provided the basis of the land ownership map (Plate 5) which describes patented (private land), federal, military, state, recreational, and Indian lands. This information is also provided on the site specific maps for the potential recharge areas.

TECHNICAL EVALUATION OF RECHARGE SITES 3.0

3.1 INTRODUCTION

This section examines the ten potential recharge areas on the basis of the specific selection criteria discussed in Section 2. This evalution forms the basis for the recharge site matrix and final technical ranking of the sites, and includes infiltration rates, mounding potential, storage capacity, perched water conditions, groundwater quality, proximity to landfills, waste disposal sites and other non-point pollution sources, proximity to residential neighborhoods, environmental factors, and land ownership.

3.2 AGUA FRIA

As discussed earlier, because only the Middle Agua Fria site is required to recharge the available CAP water, henceforth, this site area will be referred to as the Agua Fria. The Middle Agua Fria recharge site appears to be the most technically adequate area among the potential sites. For the amount of CAP water which may be available for recharge, the site area required extends south of Jomax Road several miles to Deer Valley Road and is about three square miles in area (Plate 1). If more CAP water becomes available, then the site can be extended as far south as Grand Avenue. The flood plain is very wide, providing a large area for recharge along the river bottom. Both "T"-levees and shallow basins appear suitable.

Sustained infiltration rates along the Agua Fria recharge site are the highest among all the recharge areas under consideration. Infiltration rates range from 2.1 ft/day to 3.8 ft/day, with an area weighted mean of 3.2 ft/day. The highest infiltration rates are within the stream channel itself, in Sections 6, 7, and 18 of Township 4S and Range 7E (Table 1). In addition, infiltration rates appear to decrease from about 3.5 ft/day in the northern portion of the site to 2.1 ft/day in the southern portion of the area.

TABLE 1

PHYSICAL CHARACTERISTICS, AGUA FRIA RECHARGE AREA

Feasibility Study Report — AMWUA Riverbed Recharge Project

TOWNSHIP AND SECTION	DEPTH TO WATER (a) (feet)	INFILTRATION RATE (ft/day)	TRANSMISSIVITY (kgpd/ft)	SPECIFIC YIELD	STORAGE CAPACITY (b) (af)	AREA OF SECTION WITHIN RECHARGE AREA (ac)	PRESENCE OF PERCHING ZONE	WATER QUALITY PROBLEMS (c)
A(4,1) 5	110	2.5	10	.05	1,100	200	yes	ND
6	200 *	3.3	10	.05	4,000	400	possible	ND
7	290	3.8	5	.10	13,340	460	possible	ND
8	290	3.1	5	.10	725	25	possible	ND
18	280	3.7	45	.10	11,200	400	possible	ND
19	300	3.4	80	.05	2,550	170	possible	ND
30	350	NA	30	.10	0	0	NA	ND
A(5,1) 29	200 *	NA	ND	NA	0	0	NA	ND
30	100 *	NA	ND	ND	0	0	NA	ND
31	100 *	NA	ND	ND	ND	20	ND	ND
32	200 *	NA	ND	ND	ND	25	possible	ND
B(4,1) 13	250	NA	45	.10	1,250	50	ND	ND
24	280	2.1	60	.10	11,200	400	ND	possible
25	300	NA	75	.10	0	0	NA	possible
RANGE NA	100 - 350	2.1 - 3.8	5 - 80	.05 - .10	NA	NA	NA	NA
MEAN (d) NA	280	3.2	35	.09	NA	NA	NA	NA
TOTAL NA	NA	NA	NA	NA	54,000**	2,150	NA	NA

a Measured to the nearest 10 feet; 1984 data.
b Approximate amount of water that can be stored above the 1984 water table.
c Exceeds one of the primary or secondary drinking water standards, or other problems in proximity of the recharge area.
d Area weighted; considered representative value for recharge site
* Estimated.
** Determined from mean value and may not agree with column total.
ND No data.
NA Not applicable.

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Using the mean infiltration rate of 3.2 ft/day, the Agua Fria recharge area is one of the three sites investigated which may have a potential mounding problem. Recharge potential is thus reduced because of mounding.
With its high infiltration rates, large width of recharge basin, relatively low transmissivities and specific yields, and a moderate depth to water, the Agua Fria initial mounding calculations resulted in a mound of over twice the depth to water. The estimated basin width is 3,200 feet. Transmissivities range from 5,000 gallons per day per foot of aquifer width (gpd/ft) to 80,000 gpd/ft, with an area weighted mean of 35,000 gpd/ft (Table 1). Lower transmissivities occur in the upper half of the recharge area, while the larger values occur in the lower half of the study area, presumably because depth to bedrock increases further downstream toward the center of West Basin. Specific yield varies from 0.05 to 0.10, with an area weighted mean of 0.09 (Table 1). The lower values reflect more fine-grained clays and silts. Depth to water ranges from 110 feet below land surface in the northern-most section of the recharge site to 350 feet just south of Deer Valley Road. Average depth to water within the recharge site is 280 feet (Table 1, Plate 2).

Because mounding at the site would reduce the long-term infiltration rate, a computation was made, using the procedures described in Section 2.1.3 (Mounding Potential) of this report, to compute the recharge rate that would not cause mounding. As a result, the recharge rate was adjusted to 1.0 ft/day.

Based on an adjusted recharge rate of 1.0 ft/day (which will limit the rise in the groundwater recharge mound to below land surface) and a recharge area of 2,150 acres, the maximum potential annual recharge rate at the Agua Fria site is 785,000 ac-ft/yr (Table 12). (It should be noted that this figure presumes recharge at 365 days/yr for the entire 2,150 acres.)

Available storage capacity was calculated to be 54,000 ac-ft using the area weighted depth to water, the average specific yield, and the total area of the recharge site (Table 1). This value represents a storage capacity of 25 ac-ft/acre, considered low in comparison to the other recharge sites.

But, because of the large area of the recharge site, 2,150 acres, and lateral subsurface movement, annual recharge rates will be high.

Presence of perched water may occur in the northern portion of the Agua Fria site, as shown by an elevated water level of 110 feet (Plate 2). Geologic cross sections (Figure 2) indicate the presence of fine-grained sediments layered through the unsaturated zone in Sections 6, 7, 8, and 24 of T4N and R1E, which comprises a large portion of the study area.

Generally, groundwater quality is good in the vicinity of the Agua Fria recharge site. However, water quality data were insufficient to definitively describe groundwater quality beneath the Agua Fria recharge site. One groundwater quality sample, taken about one-half mile west of the northern boundary of the study area, shows the water to be of good quality, with an electrical conductivity of 475 umhos/cm (Plate 2). However, more data are needed within the Agua Fria site to adequately describe water quality at this site.

Landfills, wastewater treatment facilities, and farming areas comprise point and non-point potential groundwater pollution sources which could effect the recharge areas. No landfills were identified near the Agua Fria site. The Sun City Wastewater Treatment Facility is located near Deer Valley Road in the southeast corner of the study area (Figure 3), but should not pose a problem.

The Agua Fria site is outside residential zones which are less than 20,000 ft^2 per dwelling (Figure 3). There are some residential areas which border the Agua Fria site east of the southern half of the recharge area, but their proximity will probably not be a problem.

Several environmentally sensitive areas have been identified along the eastern and western borders of the Agua Fria site (Figure 3). However, recharge basins can be designed to avoid sensitive areas.

Some areas within the Agua Fria site are privately owned. The northern half of the Agua Fria site is mostly privately owned, while the southern half of the study area is mostly publicly owned (Figure 3).

In summary, the Agua Fria site appears to satisfy most of the recharge criteria, and is a promising site. The limiting recharge criterion for the Agua Fria site is mounding. Recharge rates will have to be adjusted by limiting the width of the recharge basins and the duration of recharge in order to prevent mounding to the land surface. These adjustments can be made while the facility is in operation. The site is large enough to percolate large amounts of CAP water, and it is near a potential conveyance structure.

3.3 NEW RIVER

The New River recharge site technically has recharge capabilities with a few major drawbacks. The recharge area, several miles east of the Agua Fria site, is a long, narrow river reach about four miles long (Plate 1). Although it is a large facility, extensive conveyance facilities may have to be built from Granite Reef Aqueduct to minimize losses to the small, hydraulically isolated groundwater basin near the aqueduct. Land acquisition and water quality problems also exist and will be discussed in more detail with the other recharge criteria.

Estimated sustained infiltration rates along the New River recharge area range from 1.2 to 3.2 ft/day, with an area weighted mean of 2.5 ft/day (Table 2). This rate was higher than most of the other sites. The highest infiltration rates are in the southern portion of the study area, where surficial sands and gravels predominate.

Depth to groundwater in the study area ranges from 250 to 500 feet (Table 2). Mounding does not appear to be a problem at the New River site. Based on a 30-day wet-dry cycle, the groundwater will probably mound to a depth of about 100 feet beneath the proposed recharge area, which is adequate for long-term recharge opeations. A localized cone of depression is apparent in the southern portion of the study area, and depth to water

TABLE 2

PHYSICAL CHARACTERISTICS, NEW RIVER RECHARGE AREA

Feasibility Study Report — AMWUA Riverbed Recharge Project

TOWNSHIP AND SECTION	DEPTH TO WATER (a) (feet)	INFILTRATION RATE (ft/day)	TRANSMISSIVITY (kgpd/ft)	SPECIFIC YIELD	STORAGE CAPACITY (b) (af)	AREA OF SECTION WITHIN RECHARGE AREA (ac)	PRESENCE OF PERCHING ZONE	WATER QUALITY PROBLEMS (c)
A(4,1) 1	350	1.2	ND	ND	ND	25	possible	ND
2	350	2.4	ND	ND	ND	90	possible	ND
11	450	2.5	ND	ND	ND	40	possible	ND
12	450	1.9	ND	ND	ND	60	possible	ND
13	480	2.0	25	.07	1,350	40	no	ND
14	500	2.6	30	.07	3,850	110	no	DBCP
23	500	3.2	100	.12	7,200	120	no	DBCP
26	450	ND	75	.08	0	0	possible	DBCP
27	440	ND	200	.12	0	0	possible	DBCP
A(5,1) 26	300	ND	ND	ND	0	0	possible	ND
27	300	ND	ND	ND	0	0	possible	ND
34	250	ND	ND	ND	0	0	possible	ND
35	300	ND	ND	ND	0	10	possible	ND
RANGE NA	250 - 500	1.2 - 3.2	25 - 200	.07 - .12	NA	NA	NA	NA
MEAN (d) NA	450	2.5	60	.09	NA	NA	NA	NA
TOTAL NA	NA	NA	NA	NA	20,000**	495	NA	NA

a Measured to the nearest 10 feet; 1984 data.
b Approximate amount of water that can be stored above the 1984 water table.
c Exceeds one of the primary or secondary drinking water standards, or other problems in proximity of the recharge area.
d Area weighted; considered representative value for recharge site
* Estimated.
** Determined from mean value and may not agree with column total.
ND No data.
NA Not applicable.

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is well over 500 feet beneath the depression (Plate 2). In the northern part of the New River site (T4N, R1E, Sections 1 and 2) the depth to water is about 350 feet (Table 2).

Transmissivity data are lacking in the northern portion of the study area. The central portion of the recharge area averages about 25,000 gpd/ft, while the southern part is as high as 200,000 gpd/ft (Table 2). Average transmissivity is 60,000 gpd/ft, based on an area weighted mean. Specific yield varies from 0.07 to 0.12 with a weighted mean of 0.09 (Table 2). Again, the southern portion of the site has the highest value of 0.12. The width recharge area averages about 800 feet throughout the river reach.

Storage capacity at New River is estimated to be about 20,000 ac-ft. based on a specific yield of 0.09, a depth to water of 450 feet, and a total recharge area of 495 acres (Table 2). This is about 40 ac-ft/acre, which is considered high in comparison to the other recharge sites. Although storage capacity is an indicator of recharge capability, water will move laterally from the site, allowing for more recharge than the indicated value. Total annual recharge is estimated to be 215,000 ac-ft/year, based on a recharge area of 495 acres and a sustained infiltration rate (from a 1:1 wet-dry cycle) of 1.2 ft/day (Table 12).

Perched water has not been detected at the New River site. A geologic cross section (Figure 4) indicates the potential for perched water if recharge is initiated in the northern and central portion of the study area, where fine-grained materials are extensive.

Groundwater quality beneath the New River site is unknown in the northern portion of the study area, and is degraded in the southern portion. Data are lacking in the northern portion of the study area, primarily because of the lack of wells in the area. The southern areas of the New River site show a potential problem with DBCP contamination of groundwater (Plate 3). In the past, this area was heavily cropped with citrus (MAG, 1979). At the time, application of DBCP was common for control of nematodes in citrus groves. Under these circumstances there should be concern about the possibility of contaminating CAP water with DBCP. In addition, mounding or

downward percolation from recharge of CAP water could possibly cause DBCP retained in the unsaturated soil zone to become soluble, and increase the DBCP content in groundwater. For these reasons, recharge near the areas of DBCP contamination may need to be modified or avoided.

Landfills and sewage treatment facilities are not present within or near the New River site. However, a gravel pit in the southern portion of the study area should be checked for the illegal disposal of hazardous or toxic wastes.

Environmentally sensitive areas are present within the New River recharge site, primarily in the southern two sections of the area (Figure 5). Archaeological clearances would probably be necessary before recharge in the area commences.

The New River site is in proximity to some residential areas where zoning is less than 20,000 ft^2/dwelling. The southern third of the site is mostly zoned residential, and may be a potential problem (Figure 5). The northern two-thirds of the New River site is relatively free of residential zoning less than 20,000 ft^2/dwelling.

Much of the land in the New River site is privately owned (Figure 5). The northern-most mile of the river reach is not private land and would provide a slight relief to expensive land acquisition. But, overall, land acquisition for recharge at New River could be quite costly.

In conclusion, the New River recharge site appears to have several major obstacles. Groundwater quality in the southern portion of the area is poor due to DBCP contamination. Proximity to residential areas is prevalent in the southern part of the site where land ownership is primarily private, making land acquisition potentially costly. The northern portion of the study area does look much more promising than the southern portion for CAP water recharge. The downstream length of any future recharge site could be shortened to avoid the above-mentioned problems at the cost of reducing the amount of water which could be recharged. Conveyance structures are also a problem which could prove costly. Unlike those other sites which are near

the CAP Aqueduct, the New River site is not in close proximity to an existing conveyance facility which can transport CAP water to the site. All these drawbacks may limit the New River site as a recharge area.

3.4 SKUNK CREEK

The Skunk Creek site is located about four miles east of the New River site, one mile west of Interstate 17, and just north of Deer Valley Road (Plate 1). This large site is a desirable recharge area with some major drawbacks. It is not near the CAP aqueduct and may require a conveyance facility to prevent percolation of recharge water into the small groundwater basin adjacent to the aqueduct and to avoid the possibility of contamination of the water by the landfill located upstream of the site. There are also some problems with land ownership, possible and potential water quality degradation, and residential proximity.

Infiltration rates within the Skunk Creek site are low in comparison to the other sites. Infiltration ranges from 0.2 to 0.3 ft/day, with an area weighted mean of 0.3 ft/day (Table 3). Most of the recharge site lies within Township T4S, R2E, Section 15, behind a flood control dam where the infiltration rate is estimated to be 0.3 ft/day. Infiltration near the mountainous area in the southeast portion of the study area is as low as 0.2 ft/day.

Mounding does not appear to be a problem at the Skunk Creek site. Estimated transmissivities range from 10,000 to 75,000 gpd/ft, with an area weighted mean of 64,000 gpd (Table 3). Specific yield ranged from 0.10 to 0.15, with an area weighted mean of 0.10 (Table 3). The estimated average width of the recharge basin is 2,000 feet. From these values, the calculated mound would rise to a depth of 150 feet beneath the Skunk Creek facility, based on a 30-day wet-dry cycle. With the average depth to water over 500 feet beneath the site (Plate 2, Table 3), mounding will not interfere with recharge opeations.

TABLE 3

PHYSICAL CHARACTERISTICS, SKUNK CREEK RECHARGE AREA

Feasibility Study Report — AMWUA Riverbed Recharge Project

TOWNSHIP AND SECTION	DEPTH TO WATER (a) (feet)	INFILTRATION RATE (ft/day)	TRANSMISSIVITY (kgpd/ft)	SPECIFIC YIELD	STORAGE CAPACITY (b) (af)	AREA OF SECTION WITHIN RECHARGE AREA (ac)	PRESENCE OF PERCHING ZONE	WATER QUALITY PROBLEMS (c)
A(4,2) 10	480	NA	75	.15	0	0	no	ND
14	480	NA	50	.10	0	0	no	ND
15	500	0.3	75	.10	19,000	380	no	ND
16	500	0.2	50	.10	4,500	90	no	possible nitrate
21	500	0.3	10	.10	2,500	50	no	ND
22	530	NA	50	.10	0	0	no	ND
RANGE NA	480 - 530	0.2 - 0.3	10 - 75	.10 - .15	NA	NA	NA	NA
MEAN (d) NA	500	0.3	64	.10	NA	NA	NA	NA
TOTAL NA	NA	NA	NA	NA	26,000**	520	NA	NA

a Measured to the nearest 10 feet; 1984 data.
b Approximate amount of water that can be stored above the 1984 water table.
c Exceeds one of the primary or secondary drinking water standards, or other problems in proximity of the recharge area.
d Area weighted; considered representative value for recharge site
* Estimated.
** Determined for mean value and may not agree with column total.
ND No data.
NA Not applicable.

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Water recharged at the Skunk Creek site could be easily recovered downgradient of the site. Two miles south of the Skunk Creek site is a large groundwater depression caused by groundwater withdrawals (Plate 2). An ancillary benefit of recharge would be reduced pumping lifts in this area of active groundwater production.

Since depth to groundwater is substantial at the Skunk Creek site, storage capacity is large. Based on a 500-foot depth to water, a specific yield of 0.10, and a total area of 520 acres (Table 3), the storage capacity is 26,000 ac-ft, or about 50 ac-ft/acre. This is the largest storage capacity per acre of all ten sites. Lateral movement from the site would allow up to about 40,000 af/year of CAP water to be recharged, based on a recharge rate of 0.2 ft/day, over an area of 520 acres, and a 30-day wet-dry cycle.

Perched water will probably not be a problem at the Skunk Creek site. A geologic cross section (Figure 6) shows few lenses of fine-grained material above the 1984 water table, indicating perched conditions would probably not result from CAP water recharge. More fine-grained material occurs downgradient of the site, which could perch recharged water moving laterally toward the downgradient cone of depression.

Groundwater quality in the vicinity of the Skunk Creek site may pose a problem. Water quality data in the Skunk Creek site area are lacking, but well water about 1.5 miles west and 2 miles northeast indicate elevated nitrate concentrations (Plate 3). The groundwater west of the site contains nitrate with concentrations exceeding the public drinking water limit of 45 milligrams per liter (mg/l). Agricultural lands are absent upgradient of the recharge site, so the elevated nitrates may be isolated to sources near these wells. More site-specific data are needed to adequately describe groundwater quality conditions beneath the recharge site.

Related to groundwater quality are the presence of landfills. A landfill in the flood plain of the creek is located about 1 mile upstream of the site. If CAP water is conveyed in the stream channel, significant amounts may percolate through the channel bottom. Because the landfill is so close

to the river channel, percolated water may move laterally into the landfill and produce leachate upgradient of the Skunk Creek site, posing a potential threat to recharge water quality. To overcome this problem, a lined conveyance channel may be necessary to transport water between the CAP aqueduct and the spreading facilities.

Environmentally sensitive areas are present in the southwest portion of the Skunk Creek recharge area (Figure 7). Archaeological clearances would probably be necessary before recharge commences.

Residential zones of less than 20,000 ft^2/dwelling are present one-half mile southeast and directly north of the Skunk Creek site (Figure 7). Wetting and drying cycles help to control the midge life cycle, but the site is considered less favorable because of its proximity to residential areas.

Over half of the Skunk Creek site is privately owned. Land acquisition for this site could be moderately expensive because of the private land.

In summary, the Skunk Creek recharge site may be feasible, but has some major obstacles. The site may require a 3.5 mile conveyance channel from the Granite Reef Aqueduct to avoid water intercepting the landfill in transit to the site. Groundwater quality needs to be assessed beneath the site, especially because groundwater from nearby wells has elevated nitrate concentrations. Finally, considerable land is privately owned, making land acquisition more costly. The advantages of recharging in this area include replenishing an area of severe groundwater overdraft and the lack of perched water problems. These advantages make the site more desirable than some of the others under consideration.

3.5 CAVE CREEK

Because of their close proximity, the Upper and Lower Cave Creek sites will be discussed together. Both sites have very similar physical and surficial characteristics, and both sites could be tied together in the conceptual designs for recharge facilities. The northern end of the combined sites is

about two miles south of Granite Reef Aqueduct. Each site is about 1.5 miles long and ranges between 1,000 feet and 2,000 feet wide. The sites are two miles east of Interstate 17, between Beardsley and Bell Roads (Plate 1, Figure 8). These sites are feasible with some major drawbacks which will be discussed in the following paragraphs.

Sustained maximum infiltration rates at both Cave Creek sites are similar. The upper site ranges from 0.1 to 2.1 ft/day with a weighted mean of 1.8 ft/day (Table 4). The lower sites ranges from 1.8 to 3.0 ft/day, with a weighted mean of 2.3 ft/day (Table 5). The highest infiltration rates occur in the middle portion of the study areas, while the lowest rates are in the northern area of the site.

Both Cave Creek sites have a potential mounding problem. The geologic cross section (Figure 9) reveals evidence of fine-grained layers which are fairly extensive at both sites. This problem can be mitigated if the estimated recharge rates are cut in half by adjusting the recharge period and/or the width of the recharge basins. Area-weighted transmissivities in the site area vary from about 10,000 gpd/ft to 30,000 gpd/ft. Similarly, the specific yield decreases from 0.05 to 0.10. Using this hydraulic data and reducing the infiltration rates to 0.9 ft/day and 1.2 ft/day for the upper and lower sites, respectively, the corresponding recharge mounds would be 138 feet and 380 feet above the water table. These values assume a 30-day wet-dry cycle. Depth to water is about 275 feet and 400 feet at the upper and lower sites, respectively (Plate 2).

The estimated annual recharge rates are 80,000 ac-ft/year for Upper Cave Creek and 175,000 ac-ft/year for Lower Cave Creek, based on the adjusted recharge rates of 0.9 ft/day and 1.2 ft/day, and recharge areas of 240 acres and 400 acres, respectively. Storage capacities for the sites are low due to the low total recharge areas. The upper site storage capacity is 6,600 ac-ft or about 27.5 ac-ft/acre, which is a low value compared to the other sites (Table 4). The lower site has a storage capacity of 11,200 ac-ft, or 28.0 ac-ft/acre, which is also comparatively low (Table 5).

TABLE 4

PHYSICAL CHARACTERISTICS, UPPER CAVE CREEK RECHARGE AREA

Feasibility Study Report — AMWUA Riverbed Recharge Project

TOWNSHIP AND SECTION	DEPTH TO WATER (a) (feet)	INFILTRATION RATE (ft/day)	TRANSMISSIVITY (kgpd/ft)	SPECIFIC YIELD	STORAGE CAPACITY (b) (af)	AREA OF SECTION WITHIN RECHARGE AREA (ac)	PRESENCE OF PERCHING ZONE	WATER QUALITY PROBLEMS (c)
A(4,3) 20	300	0.1	10	.07	840	40	possible	ND
21	300	NA	ND	ND	0	0	possible	ND
28	280	NA	ND	ND	0	0	possible	ND
29	270	2.1	15	.10	5,400	200	possible	ND
30	300	NA	30	.10	0	0	possible	ND
RANGE NA	270 - 300	0.1 - 2.1	10 - 30	.07 - .10	NA	NA	NA	NA
MEAN (d) NA	275	1.8	14	.10	NA	NA	NA	NA
TOTAL NA	NA	NA	NA	NA	6,600**	240	NA	NA

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a Measured to the nearest 10 feet; 1984 data.
b Approximate amount of water that can be stored above the 1984 water table.
c Exceeds one of the primary or secondary drinking water standards, or other problems in proximity of the recharge area.
d Area weighted; considered representative value for recharge site
* Estimated.
** Determined from mean value and may not agree with column total.
ND No data.
NA Not applicable.

TABLE 5

PHYSICAL CHARACTERISTICS, LOWER CAVE CREEK RECHARGE AREA

Feasibility Study Report — AMWUA Riverbed Recharge Project

TOWNSHIP AND SECTION	DEPTH TO WATER (a) (feet)	INFILTRATION RATE (ft/day)	TRANSMISSIVITY (kgpd/ft)	SPECIFIC YIELD	STORAGE CAPACITY (b) (af)	AREA OF SECTION WITHIN RECHARGE AREA (ac)	PRESENCE OF PERCHING ZONE	WATER QUALITY PROBLEMS (c)
A(3,3) 5	400 *	NA	10	.10	0	0	possible	TCE found .5 - 1 mile downgradient of recharge site
6	400	1.8	10	.05	5,000	240	possible	
A(4,3) 31	400 *	2.8	10	.10	1,200	30	possible	
32	400 *	3.0	10	.10	5,200	130	possible	
RANGE NA	400	1.8 - 3.0	10	.05-.10	NA	NA	NA	NA
MEAN (d) NA	400	2.3	10	.07	NA	NA	NA	NA
TOTAL NA	NA	NA	NA	NA	11,200**	400	NA	NA

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a Measured to the nearest 10 feet; 1984 data.
b Approximate amount of water that can be stored above the 1984 water table.
c Exceeds one of the primary or secondary drinking water standards, or other problems in proximity of the recharge area.
d Area weighted; considered representative value for recharge site
* Estimated.
** Determined from mean values and may not agree with column total.
ND No data.
NA Not applicable.

Groundwater quality beneath the Upper and Lower Cave Creek recharge sites is questionable because of the lack of data in the area. Although little is known about the groundwater quality beneath the site, downgradient quality is known. About one mile to the southwest and downgradient, groundwater is contaminated by volatile organic compounds (VOCs) and high nitrates. If the Cave Creek area was recharged with CAP water, it would eventually move downgradient into the areas where VOCs and high nitrates are present. This condition could possibly contaminate the recharge water.

A landfill was identified on Figure 8 in the northeastern part of the study areas. This landfill could possibly cause leachate problems if mounding from recharge water were to rise within the landfill. No sewage treatment facilities were identified in the study areas.

Several environmentally sensitive areas were identified in the Cave Creek study areas (Figure 8). Site inspections would be necessary to initiate recharge activities in this area.

One major drawback at the Cave Creek sites is the large amount of residentially zoned acreage within the area. With the exception of some non-residential areas in the southern portion of Lower Cave Creek, both sites are residentially dominated (Figure 8). Land in the Cave Creek areas is almost all privately owned land (Figure 8).

In conclusion, the Cave Creek sites are feasible, but have several fundamental problems. A conveyance structure is needed, without which CAP water could generate leachate as it passes through the landfill. Downgradient water quality is contaminated with VOCs and high nitrates. Finally, residential zoning and land ownership appear inappropriate for recharge. Private land is costly and residential areas near the recharge basins may be affected by midge generation.

3.6 UPPER INDIAN BEND

The Upper Indian Bend recharge site is directly south of the Granite Reef Aqueduct, northwest of the Scottsdale Municipal Airport, and north of Thunderbird Road (Plate 1, Figure 10). The site has technical merit

because it is large in area and is close to the aqueduct. But, the site also has some severe limitations.

Infiltration rates are 0.3 ft/day for all sections within the flood plain. Using the infiltration rate of 0.3 ft/day, the Upper Indian Bend site does not have a potential mounding problem. The maximum mound height above the water table is estimated to be 75 feet, which is less than the 430 feet depth to water. Estimated basin width is 5,000 feet. Transmissivities range from 5,000 gpd/ft to 15,000 gpd/ft, with a weighted mean of 11,000 gpd/ft. This is low when compared to the other study areas. Specific yield ranges from 0.05 to 0.10, with a weighted mean of 0.09 (Table 6).

Based on an average sustained infiltration rate of 0.2 ft/day, and a potential recharge area of 1,430 acres, the potential annual recharge rate is 105,000 ac-ft per year.

Available storage capacity was calculated to be 55,000 ac-ft based on the weighted depth to water and specific yield, and the total area of the recharge site (Table 6). This value represents a storage capacity of 38.7 ac-ft/acre (Table 11).

Perched water will probably occur in some portion of the Upper Indian Bend site. Based on the geologic cross section constructed for this site (Figure 11), continuous fine-grained material is present below and above the 1984 water level with the exception of the north-central area of the site. Because of the stratification of fine-grained material, perching could cause localized mounding in the area.

Groundwater quality appears good in the vicinity of the Upper Indian Bend site, with the exception of hexavalent chromium. A zone of excessive hexavalent chromium in groundwater is present beneath the southern portion of the study area and in groundwater downgradient of the site (Plate 3). This condition has been attributed to naturally occurring chromium. Higher chromium contents were found along the depositional axis of the basin, where finer-grained materials predominate (MAG, 1979). Higher chromium content has been found in the upper alluvial units than in the lower

TABLE 6

PHYSICAL CHARACTERISTICS, UPPER INDIAN BEND RECHARGE AREA

Feasibility Study Report — AMWUA Riverbed Recharge Project

TOWNSHIP AND SECTION		DEPTH TO WATER (a) (feet)	INFILTRATION RATE (ft/day)	TRANSMISSIVITY (kgpd/ft)	SPECIFIC YIELD	STORAGE CAPACITY (b) (af)	AREA OF SECTION WITHIN RECHARGE AREA (ac)	PRESENCE OF PERCHING ZONE	WATER QUALITY PROBLEMS (c)
A(3,4)	1	390	0.3	10	.10	4,000	105	yes	ND
	2	440	0.3	15	.10	20,250	460	yes	Cr = .010 ug/1
	3	440	0.3	15	.10	17,000	390	yes	ND
	10	420	0.3	5	.07	14,000	475	yes	Cr = .034 ug/1
	11	350 *	NA	10	.10	0	0	yes	ND
	14	300 *	NA	5	.10	0	0	yes	ND
	15	300 *	NA	5	.05	0	0	yes	ND
RANGE	NA	300 - 440	0.3	5 - 15	.05 - .10	NA	NA	NA	NA
MEAN (d)	NA	430	0.3	11	.09	NA	NA	NA	NA
TOTAL	NA	NA	NA	NA	NA	55,000**	1430	NA	NA

a Measured to the nearest 10 feet; 1984 data.
b Approximate amount of water that can be stored above the 1984 water table.
c Exceeds one of the primary or secondary drinking water standards, or other problems in proximity of the recharge area.
d Area weighted; considered representative value for recharge site
* Estimated.
** Determined from mean values and may not agree with column total.
ND No data.
NA Not applicable.

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conglomerate units (MAG, 1979). This may present a problem because the shallower units, those more likely to be effected by the recharged water, are higher in chromium than the other units. This condition could be a significant limiting factor when considering CAP recharge.

Landfills, sewage treatment facilities and non-point pollution sources, such as farmland, are not present in the vicinity of the Upper Indian Bend Wash site.

The Indian Bend site is almost entirely zoned residential for dwellings with less than 20,000 ft^2/dwelling. This factor is quite limiting when considering the recharge site. In addition, all of the land is privately owned, making land acquisition potentially costly.

In summary, the Upper Indian Bend Wash site is promising for recharge, but may have several major drawbacks. First, presence of naturally occurring excessive hexavalent chromium in groundwater in areas downgradient of recharge may contaminate recharge water. Secondly, zoning in the site area is all residential, providing potential nuisance pest problems. Finally, the land is privately held.

3.7 LOWER INDIAN BEND

The Lower Indian Bend Wash site is downstream from the juncture of the Arizona Canal and Indian Bend Wash, just north of McDonald Drive (Plate 1, Figure 12). The smallest site of the ten considered, it has indirect access to CAP water via the Arizona Canal. The largest drawback of this site is size and proximity to residential neighborhoods.

Low infiltration rates pose a problem for the Lower Indian Bend Wash site. The estimated maximum recharge rate is only 0.25 ft/day, which is among the lowest of all the recharge sites.

Mounding is not a problem at the Lower Indian Bend Wash site. The largest estimated mound, based upon the 0.25 ft/day recharge rate, was 30 feet. Area weighted depth to water is 340 feet (Table 7). Transmissivities range

TABLE 7

PHYSICAL CHARACTERISTICS, LOWER INDIAN BEND RECHARGE AREA

Feasibility Study Report — AMWUA Riverbed Recharge Project

TOWNSHIP AND SECTION	DEPTH TO WATER (a) (feet)	INFILTRATION RATE (ft/day)	TRANSMISSIVITY (kgpd/ft)	SPECIFIC YIELD	STORAGE CAPACITY (b) (af)	AREA OF SECTION WITHIN RECHARGE AREA (ac)	PRESENCE OF PERCHING ZONE	WATER QUALITY PROBLEMS (c)
A(2,4) 1	370	NA	70	.03	0	0	NA	yes
2	360	NA	100	.03	0	0	possible	yes
11	340	.25	40	.05	1,530	90	possible	yes
12	310	NA	30	.04	0	0	NA	yes
13	320	NA	50	.05	0	0	NA	TCE 0.5 miles down gradient
14	400	NA	20	.03	0	0	NA	
RANGE NA	340 - 400	.25	20 - 100	.03 - .05	NA	NA	NA	NA
MEAN (d) NA	340	.25	40	.05	NA	NA	NA	NA
TOTAL NA	NA	NA	NA	NA	1,530**	90	NA	NA

a Measured to the nearest 10 feet; 1984 data.
b Approximate amount of water that can be stored above the 1984 water table.
c Exceeds one of the primary or secondary drinking water standards, or other problems in proximity of the recharge area.
d Area weighted; considered representative value for recharge site
* Estimated.
** Determined from mean values and may not agree with column total.
ND No data.
NA Not applicable.

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from 20,000 to 100,000 gpd/ft. Specific yield ranges from 0.03 to 0.05, with a weighted mean of 0.05, indicative of fine-grained geologic material underlying the site.

The storage capacity of 1,530 ac-ft, is low because of the small size of the recharge area (Table 7). This value is translated to 17.0 ac-ft/acre, the lowest among the recharge sites. The annual recharge rate is calculated as a product of the sustained infiltration rate (0.1 ft/day) and the total area (90 acres), is about 5,000 ac-ft/year, the lowest among the potential sites.

Extensive fine-grained layering occurs beneath and in the vicinity of the recharge site (Figure 13). This may cause localized perching of CAP water recharged at this site. Perched water has been detected in the areas around the site, probably caused by the percolation of canal seepage.

There are water quality problems near the Lower Indian Bend site, but data is lacking directly beneath the site. Two miles south of the recharge site, VOCs are present and total dissolved solids (TDS) are elevated. This may not cause a problem because the site is up-gradient of a localized pumping depression (Plate 2). About one mile east, naturally occurring elevated hexavalent chromium is present.

No landfills or sewage treatment facilities are near the Lower Indian Bend site. Irrigated farmland is also not near the site. The land within the recharge site is zoned as a public park, but currently is undeveloped.

In conclusion, the Lower Indian Bend site may have problems from the perspective of recharging CAP water because of perched water, a small recharge site, proximity to residential neighborhoods, and potential water quality problems.

3.8 UPPER AND LOWER SALT RIVER SITES

The Salt River system is divided into the upper and lower sites. Because these two sites are adjoining, they will be discussed together.

The recharge sites are immediately downstream of the Granite Reef Diversion Dam (Plate 1). Both sites have direct access to the Southern Canal which runs along the southeastern border of the sites (Figure 14). Both sites are very large, covering 810 acres in the Upper Salt River area, and 2,515 acres in the Lower Salt River area. Because of their size and proximity to the CAP, these sites are promising CAP recharge locations.

Infiltration rates on the Salt River system are very similar. The upper site has a 1.9 ft/day value, while the lower site has a range of 1.9 to 2.5 ft/day, with a weighted mean of 2.5 ft/day (Tables 8 and 9). These values are similar to ones obtained from other studies along the Salt River, although sustained rates after a two-week period in gravel pits further downstream dropped to 1.1 ft/day (Briggs and Werho, 1966).

Mounding appears to be a potential problem on the Lower Salt River site because of its large width and high transmissivities and infiltration rates. Mounding calculations with the maximum infiltration rate of 2.4 feet/day, a mean transmissivity of 56,000 gpd/ft, and a specific yield of 0.09 (Table 9) resulted in a mound in excess of the depth to water. By adjusting the infiltration rate to 1.0 ft/day, the groundwater mound would be below the land surface. The groundwater mound at the upper site does not appear to be a problem. Based on a mean transmissivity of 80,000 gpd/ft, a specific yield of 0.08 (Table 8), and a 30 day wet-dry cycle, a groundwater mound of 260 feet is predicted, which is well below the weighted mean depth to water of 310 feet (Table 8).

Storage capacity is fairly large at both Salt River sites because of the large surface areas. The upper site has a storage capacity of 20,000 acre-feet, based on previously mentioned depth to water, specific yield, and surface area (Table 8). This value translates to 25 ac-ft/acre, a low value when compared to the other sites. The storage capacity at the lower site is much larger at 71,300 ac-ft based on similar depth to water and specific yield, but a much larger surface area (Table 9). This value is 28.4 af/acre, again a comparatively low value.

TABLE 8

PHYSICAL CHARACTERISTICS, UPPER SALT RIVER RECHARGE AREA

Feasibility Study Report — AMWUA Riverbed Recharge Project

TOWNSHIP AND SECTION	DEPTH TO WATER (a) (feet)	INFILTRATION RATE (ft/day)	TRANSMISSIVITY (kgpd/ft)	SPECIFIC YIELD	STORAGE CAPACITY (b) (af)	AREA OF SECTION WITHIN RECHARGE AREA (ac)	PRESENCE OF PERCHING ZONE	WATER QUALITY PROBLEMS (c)
A(2,6) 22	310	NA	110	.10	6,500	210	possible	TCE, DBCP
23	310 *	NA	ND	ND	ND	75	possible	F & Cl problems
27	310	NA	70	.07	4,550	210	possible	downgradient
28	310	1.9	70	.07	6,850	315	possible	
RANGE NA	310	1.9	70 - 110	.07 - .10	NA	NA	NA	NA
MEAN (d) NA	310	1.9	81	.08	NA	NA	NA	NA
TOTAL NA	NA	NA	NA	NA	20,000**	810	NA	NA

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a Measured to the nearest 10 feet; 1984 data.
b Approximate amount of water that can be stored above the 1984 water table.
c Exceeds one of the primary or secondary drinking water standards, or other problems in proximity of the recharge area.
d Area weighted; considered representative value for recharge site
* Estimated.
** Determined from mean values and may not agree with column total.
ND No data.
NA Not applicable.

TABLE 9

PHYSICAL CHARACTERISTICS, LOWER SALT RIVER RECHARGE AREA

Feasibility Study Report — AMWUA Riverbed Recharge Project

TOWNSHIP AND SECTION	DEPTH TO WATER (a) (feet)	INFILTRATION RATE (ft/day)	TRANSMISSIVITY (kgpd/ft)	SPECIFIC YIELD	STORAGE CAPACITY (b) (af)	AREA OF SECTION WITHIN RECHARGE AREA (ac)	PRESENCE OF PERCHING ZONE	WATER QUALITY PROBLEMS (c)
A(2,5) 24	310	NA	20	.05	0	125	possible	TCE, DBCP
25	310	2.5	20	.10	1,940	530	NA	and Cl problems
26	300	2.5	45	.10	16,500	225	NA	.5 - 1 mile
27	230	NA	50	.10	6,750	0	NA	downgradient
34	200	NA	60	.08	0	0	possible	for all
35	220	NA	100	.10	0	0	possible	sections
36	300	NA	100	ND	0	0	NA	
A(2,6) 19	320	NA	50	.10	7,840	245	NA	
20	320	NA	60	.10	6,880	215	NA	
28	310	1.9	70	.07	2,280	105	NA	
29	320	2.5	80	.10	16,000	500	NA	
30	320	2.5	80	.10	18,250	570	NA	
31	320	NA	70	.07	0	0	NA	
RANGE NA	180 - 320	1.9 - 2.5	20 - 100	.05 - .10	NA	NA	NA	
MEAN (d) NA	315	2.5	56	.09	NA	NA	NA	
TOTAL NA	NA	NA	NA	NA	71,300**	2,515	NA	

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a Measured to the nearest 10 feet; 1984 data.
b Approximate amount of water that can be stored above the 1984 water table.
c Exceeds one of the primary or secondary drinking water standards, or other problems in proximity of the recharge area.
d Area weighted; considered representative value for recharge site
* Estimated.
** Determined from mean values and may not agree with colum total.
ND No data.
NA Not applicable.

Due to lateral movement of recharge water, the total annual recharge rate can be higher than the storage capacity of each site. Based on a 30-day wet-dry cycle, a sustained average infiltration rate of 1.0 ft/day, and a recharge area of 810 acres, the annual recharge rate for the Upper Salt River site is 295,000 ac-ft/year. Based on a 30-day wet-dry cycle, a limited infiltration rate of 1.0 ft/day to prevent mounding to the land surface, and a surface area of 2,515 acres, the annual recharge rate for the Lower Salt River site could be as much as 920,000 ac-ft/year.

Perched water may be a problem for both Salt River sites. The Upper Salt site has extensive fine-grained layers throughout the area (Figures 15 and 16). No direct evidence of perched water has been documented in this area. The lower site has had documented areas of perched water beginning about one-quarter mile west of the west edge of the site and extending westward along the Salt River (Plate 2). In addition, some fine-grained layering was found in wells near the site (Figure 16). More data are needed within the site area to determine if these potential perching zones exist beneath the site. One well bordering the upper site shows fine-grained layering beneath the 1984 water table but not above it (Figure 15, well A (2, 6) 29cda). Data west of this well are lacking.

Groundwater quality in the vicinity of the Salt River sites is poor. Groundwater directly south and southeast, hydraulically downgradient of the sites, is contaminated with DBCP, VOCs, fluoride, and chloride (Plate 3). A zone of DBCP in groundwater begins south of the upper and lower sites and extends several miles to the south. The elevated DBCP has been attributed to deep percolation of irrigation water leaching solubilized DBCP residuals from nematicide application (Love, 1979). A zone of VOCs has been detected about 1/2 mile south and southeast of the upper and lower sites. The source is currently unknown. High fluorides in groundwater are southeast of the Upper Salt River site, and extend several miles south of the sites. Because groundwater movement is to the southeast (Plate 2), recharged CAP water will eventually mix with or displace contaminated groundwater downgradient.

Related to groundwater quality are landfills and wastewater treatment facilities. There is a proposed wastewater treatment plant site in the northwest Section 32 of T2N, R6E (Figure 14). Careful consideration to minimize mounding is important to avoid intercepting any downward migrating effluent. No landfills were identified in the area, but the possibility of unauthorized dumping should be investigated before recharge commences.

Environmentally sensitive areas are scattered along the Salt River recharge sites. Most of the sites are concentrated in the upper recharge area (Figure 14). Archaeological clearances will probably be necessary in these areas.

The Salt River sites are relatively free from zoning less than 20,000 ft^2/ dwelling (Figure 14). This is highly advantageous for the recharge site. In addition, most of the land is publicly owned, allowing for easier and less expensive site acquisition.

Overall, the Salt River system is a highly feasible site for CAP recharge. The sites are near CAP sources, they are very large areas, ownership is primarily public, there is almost no residential conflict, and recharge rates are good. The only major drawback is poor water quality of downgradient receiving water.

3.9 QUEEN CREEK

The Queen Creek recharge site is a promising site but has a few major drawbacks. The site has direct access to the Salt-Gila Aqueduct, and the total area is relatively large. The site is bound on the east by the Salt-Gila Aqueduct and on the west by Rittenhouse Road and the Southern Pacific Railroad (Plate 1, Figure 17). The site is 1,500 feet wide and about 5 miles long.

Estimated infiltration rates vary from 2.1 to 3.2 ft/day, with an area weighted mean of 2.7 ft/day (Table 10). This value is the second highest among the ten potential sites. These values are somewhat higher than the

TABLE 10

PHYSICAL CHARACTERISTICS, QUEEN CREEK RECHARGE AREA

Feasibility Study Report — AMWUA Riverbed Recharge Project

TOWNSHIP AND SECTION	DEPTH TO WATER (a) (feet)	INFILTRATION RATE (ft/day)	TRANSMISSIVITY (kgpd/ft)	SPECIFIC YIELD	STORAGE CAPACITY (b) (af)	AREA OF SECTION WITHIN RECHARGE AREA (ac)	PRESENCE OF PERCHING ZONE	WATER QUALITY PROBLEMS (c)
D(2,7) 25	450	2.7	80	.03	810	60	possible	ND
D(2,8) 20	480	NA	70	.08	NA	0	possible	no
21	450	2.8	110	.12	2,970	55	possible	no
22	430	2.5	110	.12	3,350	65	possible	no
23	430	2.5	60	.08	1,200	35	possible	no
26	450	2.7	110	.11	2,230	45	possible	ND
27	460	3.0	120	.12	6,350	115	possible	ND
28	460	2.6	110	.10	4,600	100	possible	ND
29	470	2.1	100	.10	7,520	160	possible	ND
30	460	3.2	150	.07	3,860	120	possible	ND
RANGE NA	430 - 480	2.1 - 3.2	60 - 150	.03 - .12	NA	NA	NA	NA
MEAN (d) NA	460	2.7	111	.10	NA	NA	NA	NA
TOTAL NA	NA	NA	NA	NA	34,400**	755	NA	NA

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a Measured to the nearest 10 feet; 1984 data.
b Approximate amount of water that can be stored above the 1984 water table.
c Exceeds one of the primary or secondary drinking water standards, or other problems in proximity of the recharge area.
d Area weighted; considered representative value for recharge site
* Estimated.
** Determined from mean values and may not agree with colum totals.
ND No data.
NA Not applicable.

0.9 ft/day rates obtained by Babcock and Cushing (1941), although their measurements were from sediment-laden pools after storm events.

Mounding does not appear to be a problem at the Queen Creek site. The estimated mound is 292 feet for a 30-day wet-dry cycle, well below the average depth to water of 460 feet (Table 10). Specific yields vary from 0.03 to 0.12, with a weighted mean of 0.10. Both transmissivity and specific yield for the site are the highest values of the ten recharge sites. These aquifer properties will allow for easier extraction of recharged CAP water if extraction wells are constructed. Direction of groundwater movement is to the southwest (Plate 2).

Available storage capacity is estimated at 34,400 ac-ft, or about 46.0 ac-ft/acre, based on an area of 755 acres, and the above mentioned average specific yield and depth to water (Table 10). The large per acre storage capacity makes Queen Creek a good possibility for recharge. In addition, the annual recharge rate, based on a 30 day wet-dry cycle, 755 acres of recharge area, and a sustained recharge rate of 1.4 ft/day is 385,000 ac-ft/year. This amount is third highest among the recharge sites after the Agua Fria and Lower Salt River sites.

Perched water could potentially become a problem at the Queen Creek recharge site. A documented zone of perched water is present about 2 miles west of the site. In addition, the geologic cross section (Figure 18) reveals extensive layering of fine-grained material beneath and near the site.

Groundwater quality does not appear to be a problem near the Queen Creek site. Although no groundwater samples were available directly beneath the site, several sample results were examined within one-half to two miles north and south of the site. Concentrations of total dissolved solids (TDS), nitrate, fluoride, and other inorganic constituents appear to be at acceptable levels (Plate 3). However, about two miles north of the western edge of the site, one well had an elevated concentration of nitrates (54 mg/l as NO_3) and TDS (700 mg/l). About four miles downgradient and west of the site, DBCP has been detected in groundwater.

Landfills and sewage treatment facilities are not located near the Queen Creek site. However, considerable agricultural activity has occurred north and west of the site. Groundwater monitoring near the site is advisable for this reason.

The Queen Creek site does not have problems with zoning or environmentally sensitive areas, but land ownership is a major drawback. The site is almost totally free from zoning of less than 20,000 ft^2 per dwelling. However, the site is almost all privately owned.

In summary, the Queen Creek site appears to be an excellent recharge area. The site is close to the CAP canal, it is large and has a large recharge potential, it is free of possible residential and environmental problems, and groundwater quality is good near the site. The major drawbacks include the possibility of perching water, and more importantly, private land ownership dominates the area.

3.10 SUMMARY OF TECHNICAL EVALUATION

Table 11 summarizes the physical characteristics of the ten potential AMWUA riverbed recharge sites. Depth to water for these sites varies from as low as 275 feet at the Upper Cave Creek site to 500 feet at Skunk Creek. This range of water levels is quite suitable for CAP water recharge. Infiltration rates vary from 0.25 ft/day at Lower Indian Bend Wash to 3.2 ft/day at the Agua Fria site. Most of the recharge rates are more than adequate for CAP water recharge. Average transmissivities ranged from 10,000 gpd/ft at Lower Cave Creek to 111,000 gpd/ft at Queen Creek. The values below 30,000 gpd/ft at the Cave Creek sites and Lower Indian Bend Wash are unusually low and could impede CAP recharge. Average specific yields are unusually low, ranging from 0.05 at Lower Indian Bend Wash to 0.10 at Skunk Creek, Upper Cave Creek, and Queen Creek. These low values are probably caused by fine-grained materials which lie beneath most of the recharge sites. Storage capacities vary from 17 ac-ft/acre at Lower Indian Bend Wash to 50 ac-ft/acre at Skunk Creek, where the depth to water was also greatest. Recharge areas vary from 90 acres at Lower Indian Bend Wash to 2,150 acres at Agua Fria and 2,515 acres at Lower Salt River. A site over 200 acres is

TABLE 11

SUMMARY OF PHYSICAL CHARACTERISTICS FOR POTENTIAL RECHARGE AREAS

Feasibility Study Report — AMWUA Riverbed Recharge Project

LOCATION	DEPTH TO WATER (a) (feet)		INFILTRATION RATE (ft/day)		TRANSMISSIVITY (kgpd/ft)		SPECIFIC YIELD		STORAGE CAPACITY (ac-ft) (b,c)	(af/ac) (b)	AREA FOR POTENTIAL RECHARGE (ac)	PRESENCE OF PERCHING ZONE	WATER QUALITY PROBLEMS
	RANGE / MEAN (c)		RANGE / MEAN (c)		RANGE / MEAN (c)		RANGE / MEAN (c)						
Agua Fria	100-350	280	2.1-3.8	3.2	5-80	35	.05-.10	.09	54,000	25.2	2,150	2 mi. south-west & down-gradient	F elevated 4 mi. SW TCE 3 mi. S
New River	250-500	450	1.2-3.2	2.5	25-200	60	.07-.12	.09	20,000	40.0	495	possible	DBCP in southern portion
Skunk Creek	480-530	500	0.2-0.3	0.3	10-75	64	.10-.15	.10	26,000	50.0	520	possible	High NO3 1 mi. upgradient
Upper Cave Creek	270-300	275	0.1-2.1	1.8	10-30	14	.07-.10	.10	6,600	27.5	240	possible	Data deficiences
Lower Cave Creek	400	400	1.8-3.0	2.3	10	10	.05-.10	.07	11,200	28.0	400	possible	TCE .5-1.0 mi. S.
Upper Indian Bend Wash	300-440	430	0.3	0.3	5-15	11	.05-.10	.09	55,000	38.7	1,430	possible	Elevated Cr does not exceed standards
Lower Indian Bend Wash	340-400	340	.25	.25	20-100	40	.03-.05	.05	1,530	17.0	90	yes	High Cr 1 mi. east
Upper Salt River	310	310	1.9	1.9	70-110	81	.07-.10	.08	20,000	24.8	810	possible	TCE, DBCP, F & Cl .5-1.0 mi. downgradi
Lower Salt River	180-320	315	1.9-2.5	2.5	20-100	56	.05-.10	.09	71,300	28.4	2,550	yes	TCE, DBCP, high Cl downgradient
Queen Creek	430-480	460	2.1-3.2	2.7	60-150	111	.03-.12	.10	34,400	46.0	755	possible	Elevated NO3, Cl

a Based on 50% wet-dry application cycle.
b Groundwater stored above the water table.
c Area weighted; considered representative for recharge site.

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usually more than adequate. Two sites, Lower Indian Bend Wash and Lower Salt River, have documented perched water conditions. The remaining sites have potential perched conditions, based on examination of geologic cross sections. Finally, most of the sites had associated groundwater quality problems either nearby or downgradient.

Most of the sites have substantial recharge potential. Table 12 summarizes recharge capabilities for all ten AMWUA sites. The annual recharge rates are based on estimated average sustained infiltration rates. Annual potential recharge rates range from 5,000 ac-ft/year at Lower Indian Bend Wash to 920,000 ac-ft/year at Lower Salt River. Agua Fria and Queen Creek also have high annual recharge rates of 785,000 af/year and 385,000 af/year, respectively. With the exception of the Lower Indian Bend Wash site, recharge potentials at all sites are excellent. Total potential annual recharge for all ten sites exceeds three million acre-feet per year.

Surficial characteristics varied considerably among the different recharge sites. Residential problems occur at all the sites except along the Salt River and Queen Creek. There are landfills or wastewater treatment facilities near the Middle Agua Fria, Skunk Creek, and Cave Creek areas. Environmentally sensitive areas are present at all sites except the Indian Bend Wash and Queen Creek sites. Land ownership is a problem at all sites except for the Salt River sites, where most of the land is publicly held.

3.11 TECHNICAL RANKING OF SITES

A comprehensive technical evaluation of each site was performed in the previous section of this report. The results of the evaluation are summarized in the evaluation matrix (Table 13). The potential recharge capabilities of each site (Table 12) were estimated to assist in site comparison. "Fatal flaws" were not discovered at any of the sites. Thus, all sites can be considered as feasible recharge sites on a technical basis, but some sites are more favorable than others.

TABLE 12

POTENTIAL RECHARGE CAPABILITIES OF
ALTERNATIVE RECHARGE SITES

Feasibility Study Report -- AMWUA Riverbed Recharge Project

Recharge Site	Area for Potential Recharge (ac.)	Estimated Average Sustained Infiltration Rate [a] (ft/day)	Potential Annual Recharge Rate (kaf/yr)
Agua Fria River	2,150	1.0[b]	785
New River	495	1.2	215
Skunk Creek	520	0.2	40
Upper Cave Creek	240	0.9	80
Lower Cave Creek	400	1.2	175
Upper Indian Bend	1,430	0.2	105
Lower Indian Bend	90	0.1	5
Upper Salt River	810	1.0	295
Lower Salt River	2,515	1.0[b]	920
Queen Creek	755	1.4	385
Totals	9,405		3,005

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(a) Based upon a 30-day wet-dry application cycle
(b) Recharge rate is limited by rise in groundwater recharge mound

TABLE 13

AMWUA RECHARGE SITE EVALUATION MATRIX

Feasibility Study Report — AMWUA Riverbed Recharge Project

RECHARGE SITE	INFILTRATION RATE (a)	MOUNDING PROBLEMS (b)	STORAGE CAPACITY (c)	QUALITY OF RECEIVING WATERS (d)	PERCHED WATER PROBLEM (e)	RESIDENTIAL PROBLEM (f)	LANDFILL OR WASTEWATER PROBLEM (g)	ENVIRONMENTAL CONSIDERATIONS (h)	LAND OWNERSHIP DIFFICULTY (i)
Agua Fria	high	yes	low	good	possible	yes	yes	yes	mod
New River	high	none	high	poor	possible	yes	no	yes	significant
Skunk Creek	low	none	high	good	possible	yes	yes	yes	mod
Upper Cave Creek	mod	none	low	good	possible	yes	yes	yes	significant
Lower Cave Creek	high	none	low	poor	possible	yes	yes	yes	significant
Upper Indian Bend Wash	low	yes	mod	poor	possible	yes	no	no	significant
Lower Indian Bend Wash	low	none	low	good	known	yes	no	no	significant
Upper Salt River	mod	none	low	poor	possible	none	no	yes	minor
Lower Salt River	high	yes	low	poor	known	none	no	yes	minor
Queen Creek	high	none	high	good	possible	none	no	no	significant

a. high > 2 feet/day; mod > 1, <2 feet/day; low < 1 foot/day.
b. none = depth to water - mound height > 20 feet; 20 > mod > 1 ft.; yes = mound hieght > depth to water.
c. high > 40 AF/acre; 40 > mod > 30 AF/acre; low < 30 AF/acre.
d. good = meets primary and secondary USPH & EPA drinking water standards; mod = meets secondary USPH & EPA drinking water standards; poor = exceeds USPH & EPA primary and secondary drinking water standards and may contain VOCs and pesticides.
e. none = middle fine-grained unit or extensive clay or caliche not present; possible = presence of middle fine-grained unit, extensive caliche or clay; known = identified perched water table.
f. none = residential land use more than 1/2 mile from project; yes = residential land use less than 1/2 mile from project.
g. none = none within influence of recharge area; yes = within influence of recharge area.
h. none = none within boundaries of recharge area; yes = within boundaries of recharge area.
i. minor = mostly publicly owned land; mod = some privately owned land; significant = mostly privately owned land.

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Substantial amounts of surplus CAP water (up to as much as 400,000 af-yr) are expected to be available in the Maricopa County area, and will continue to be available, at least in the near term. To recharge as much of this surplus water as possible while it is available will require that facilities with the highest potential recharge capacity be constructed as soon as possible. This is the highest criteria for site selection.

Less important criteria include the absence of potentially inhibiting characteristics (water quality problems in receiving waters, substantial data deficiencies, etc.). Therefore, important positive site characteristics that enhance implementation include:

- Large recharge capacity: This allows for economy of scale and minimizes the number of recharge sites.
- Convenient to CAP water supply: This eliminates the need to construct conveyance facilities and reduces the amount of potentially unrecoverable recharge water.
- Available public lands: This reduces the cost and time required to obtain the ability to construct and operate the recharge facilities.
- Absence of inhibiting characteristics: This provides for a higher assurance level that the recharge project can function as envisioned and that the recharge water can be extracted at some future time without the need to remove undesirable water quality constituents.

It follows that significant undesirable site characteristics include:

- Small annual recharge rate
- Need for private lands
- Need for conveyance facility to avoid unrecoverable infiltration losses or to prevent potential water contamination
- Poor water quality of receiving waters
- Identified perched water conditions

In consideration of these implementation criteria as well as the site physical characteristics, the ten sites were ranked, as follows:

Most feasible:

Agua Fria
Upper Salt River
Lower Salt River
Queen Creek

Feasible with major technical and implementation difficulties:

Skunk Creek
New River
Upper Cave Creek
Lower Cave Creek

Least feasible:

Upper Indian Bend Wash
Lower Indian Bend Wash

The major advantages and disadvantages of these sites are displayed on Table 14.

TABLE 14

RECHARGE SITE RANKING

Feasibility Study Report — AMWUA Riverbed Recharge Project

	ADVANTAGES					DISADVANTAGES					
	Large Facility	Near Supply Source	Public Lands Available	Receiving Water Quality Good		Private Lands Required	Conveyance Facility Needed	Known Perched Water Conditions	Small Facility	Receiving Water Quality Problems	Comments
MOST FEASIBLE											
1. Agua Fria (Middle)	●	●	●	●							
2. Salt River (Upper)	●	●	●							●	DBCP
3. Salt River (Lower)	●	●	●					◐		●	DBCP
4. Queen Creek	●	●		◐		●				◐	NO_3
FEASIBLE WITH MAJOR DRAWBACKS											
5. Skunk Creek	●					◐	●			◐	NO_3 and landfill
6. New River (Lower)	●					●	●			●	DBCP
7. Cave Creek (Upper)	●					●	●			●	VOC
8. Cave Creek (Lower)	●					●	●			◐	landfill
LEAST FEASIBLE											
9. Upper Indian Bend	●	●				●				●	Cr^{+6}
10. Lower Indian Bend		●				●		●	●		

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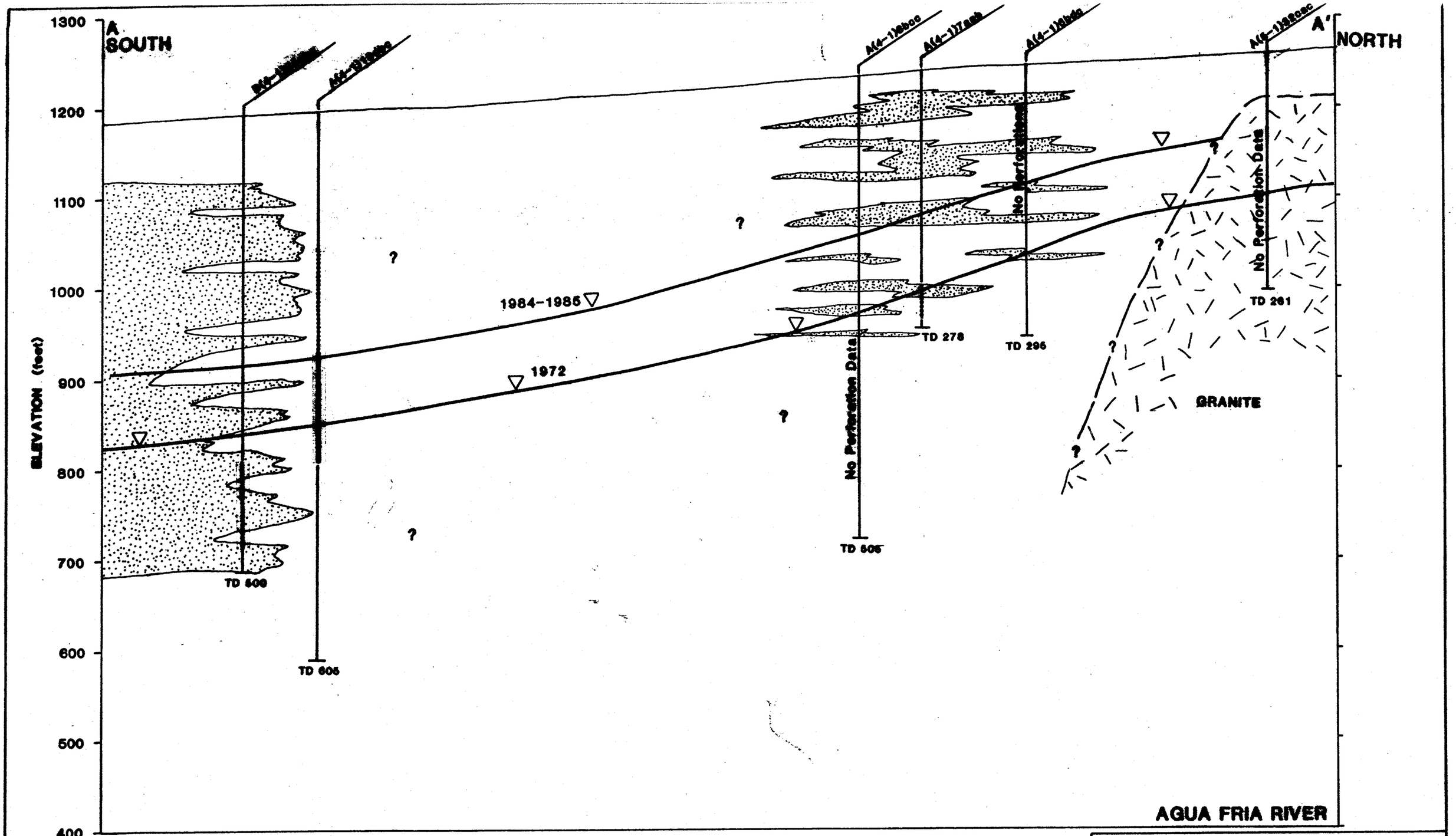
LEGEND

● Applies

◐ Partially Applies



LEGEND

Aquitard (Mostly Fine-grained Sediments)

Water Level

Water Well, Dotted Where Perforated, Showing Total Depth (TD) in Feet Below Ground Surface

TD 759

0 2000 4000 6000

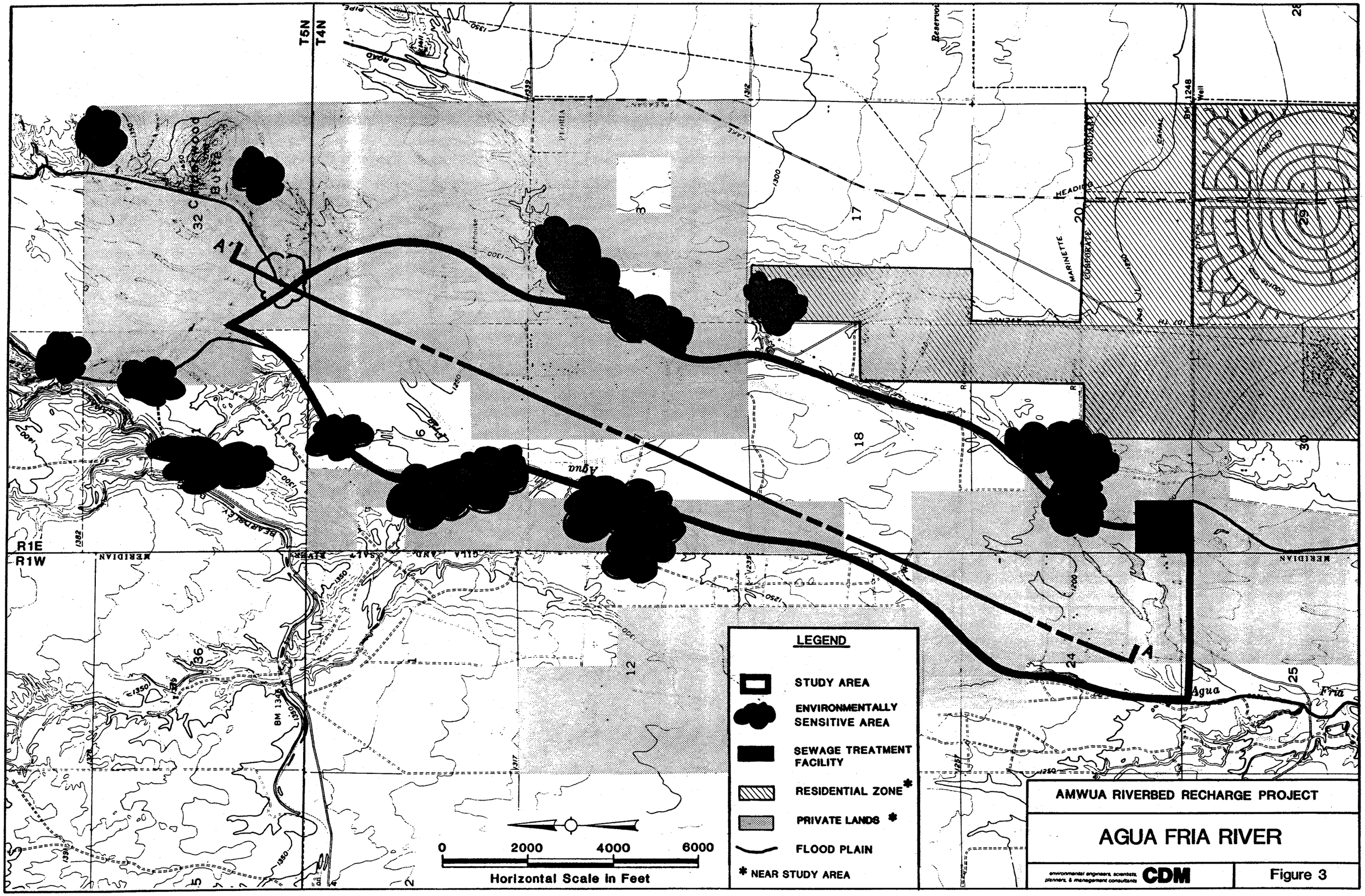
Horizontal Scale in Feet

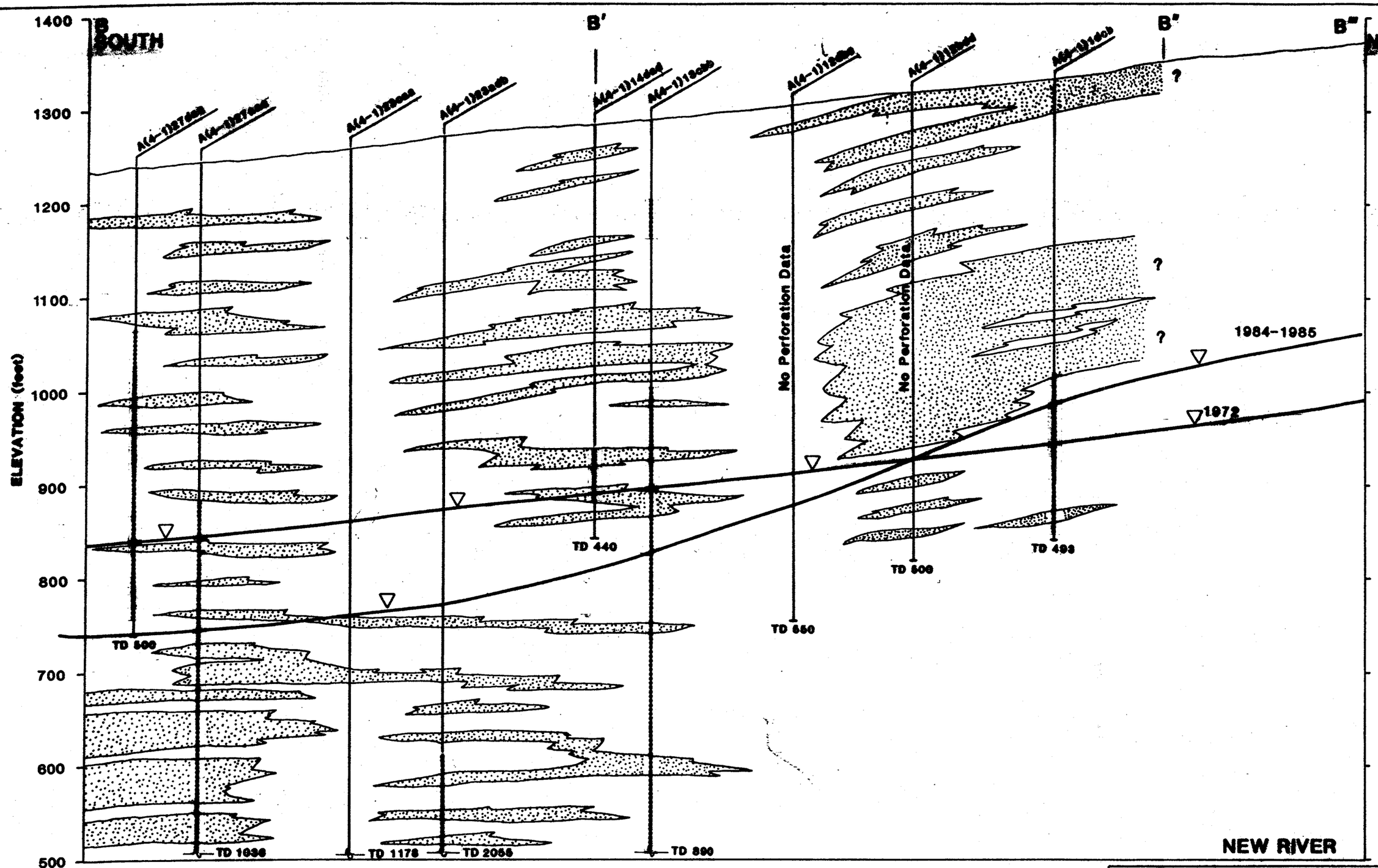
AMWUA RIVERBED RECHARGE PROJECT

SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION A-A'

CDM

Figure 2


T5N
T4N
R1E
R1W
A
A'
LEGEND
STUDY AREA
ENVIRONMENTALLY SENSITIVE AREA
SEWAGE TREATMENT FACILITY
RESIDENTIAL ZONE *
PRIVATE LANDS *
FLOOD PLAIN
* NEAR STUDY AREA
0
2000
4000
6000
Horizontal Scale in Feet
Agua
Fria
MARINETTE
CONTRACTS
HEADING
BOUNDARY
CANAL
Reservoir
Well
AMWUA RIVERBED RECHARGE PROJECT
AGUA FRIA RIVER
environmental engineers, scientists, planners, & management consultants
CDM
Figure 3



LEGEND

Aquitard (Mostly Fine-grained Sediments)

Water Level

Water Well, Dotted Where Perforated, Showing Total Depth (TD) in Feet Below Ground Surface

TD 759

0 2000 4000 6000

Horizontal Scale in Feet

AMWUA RIVERBED RECHARGE PROJECT

SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION B-B'''

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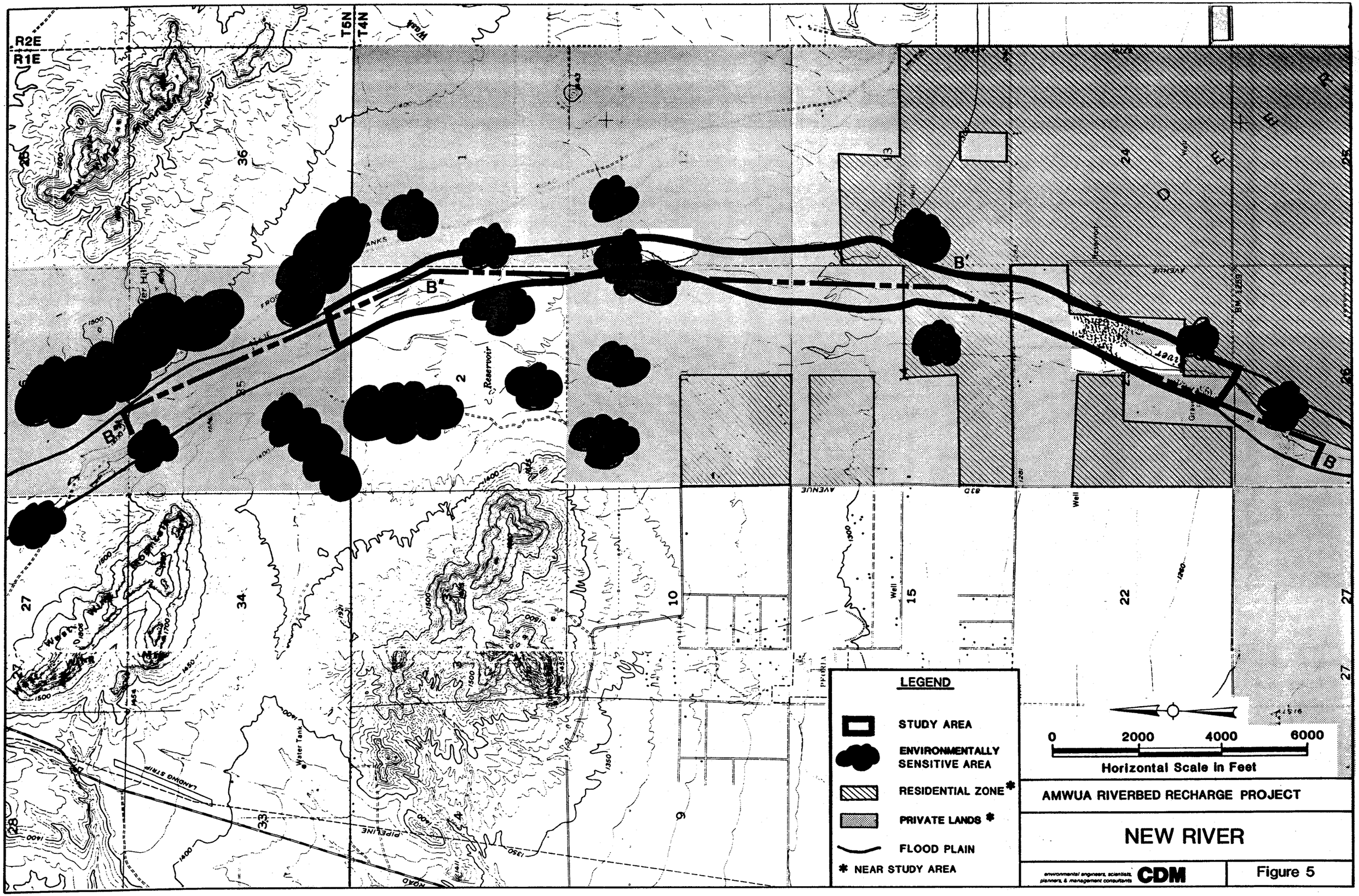
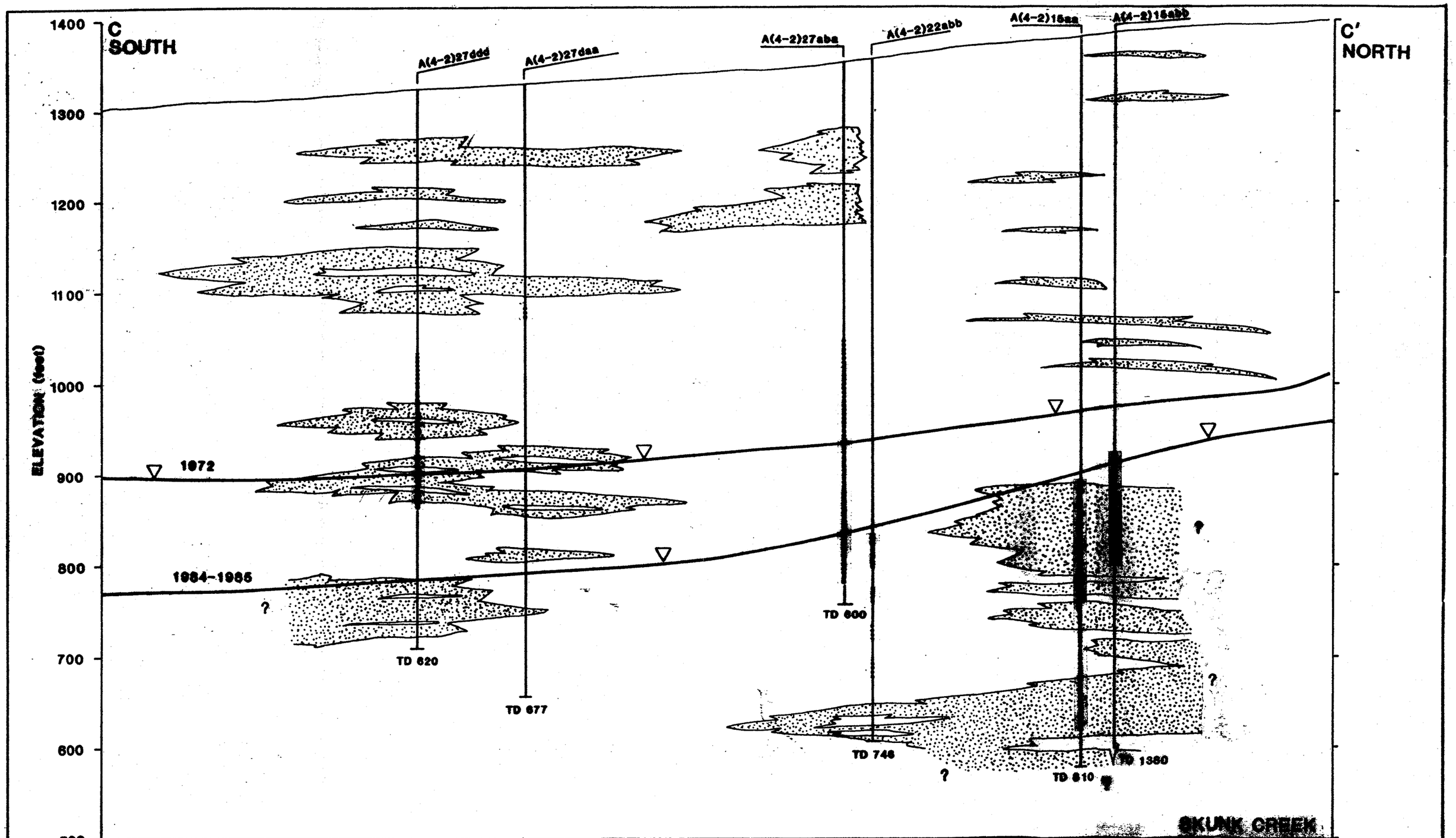
Figure 4


R2E
R1E
T5N
T4N
36
25
1
2
Reservoir
B
B'
24
19
30
13
Well
15
22
27
34
33
28
10
9
4
Water Tank
LANDING STRIP
PIPELINE
ROAD
AVENUE
LEGEND
STUDY AREA
ENVIRONMENTALLY SENSITIVE AREA
RESIDENTIAL ZONE *
PRIVATE LANDS *
FLOOD PLAIN
* NEAR STUDY AREA
0
2000
4000
6000
Horizontal Scale in Feet
AMWUA RIVERBED RECHARGE PROJECT
NEW RIVER
environmental engineers, scientists, planners, & management consultants
CDM
Figure 5



LEGEND

Aquitard (Mostly Fine-grained Sediments)

Water Level

Water Well, Dotted Where Perforated, Showing Total Depth (TD) in Feet Below Ground Surface

TD 759

0 2000 4000 6000

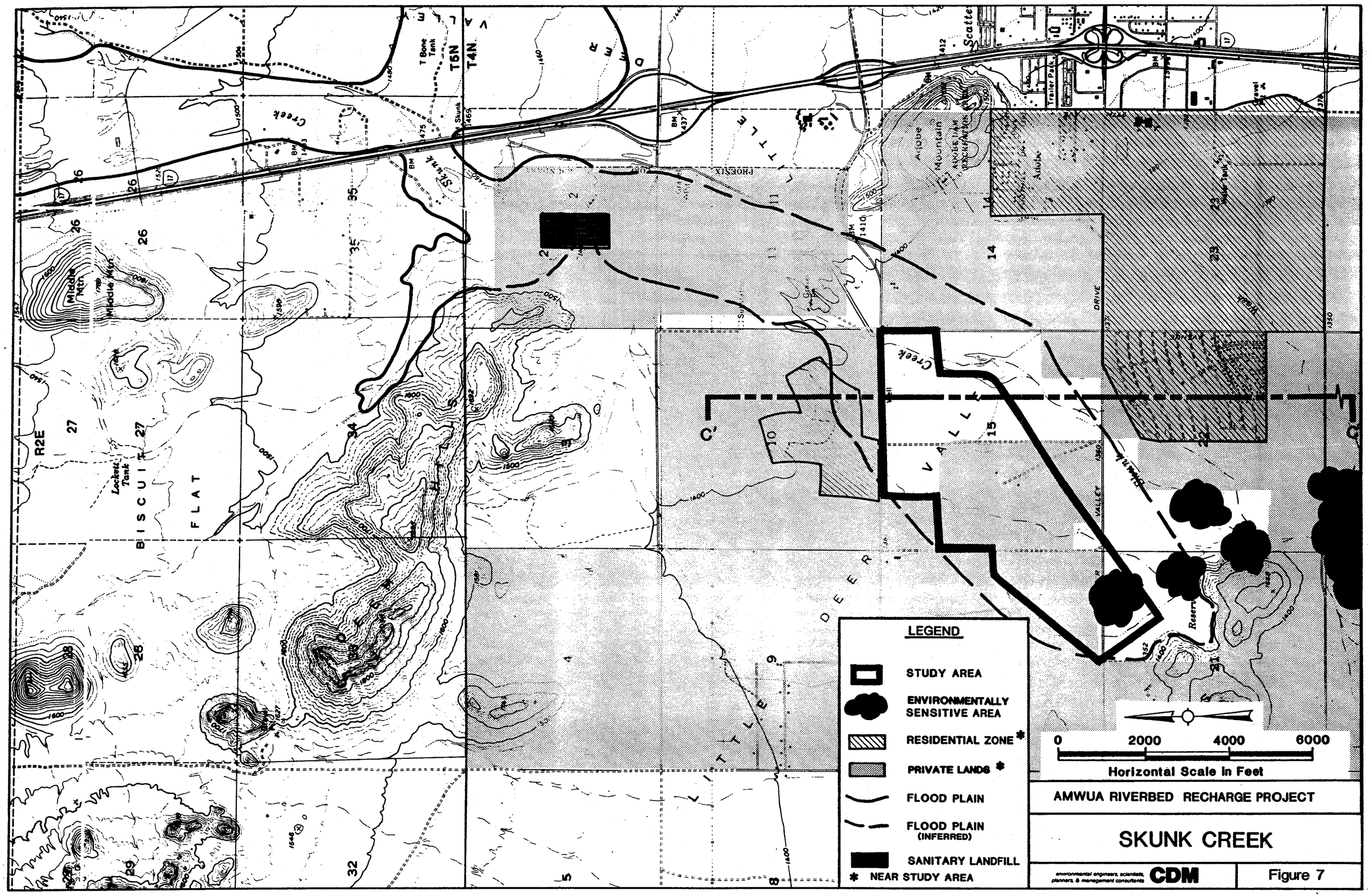
Horizontal Scale in Feet

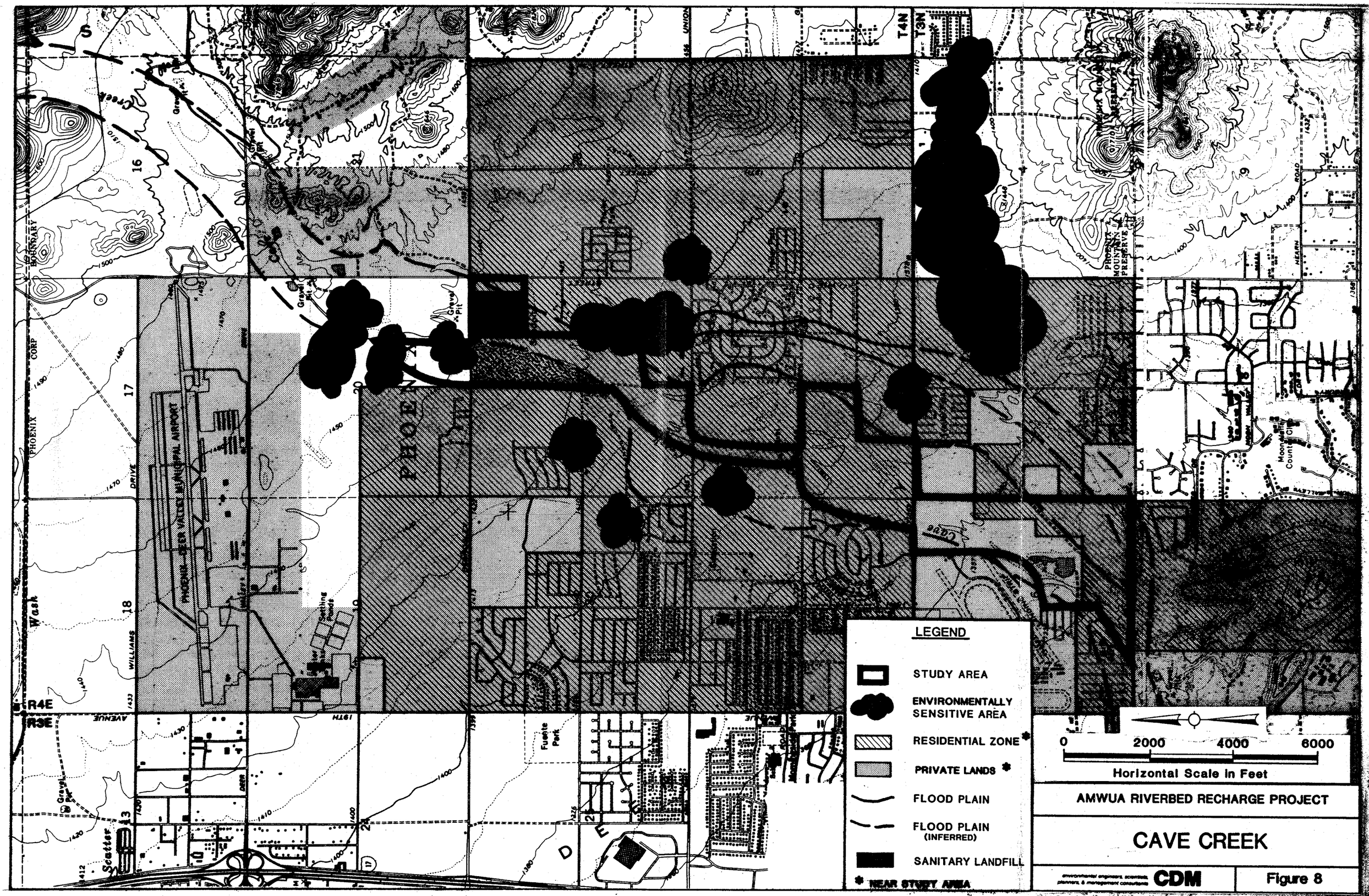
RIVERBED RECHARGE PROJECT

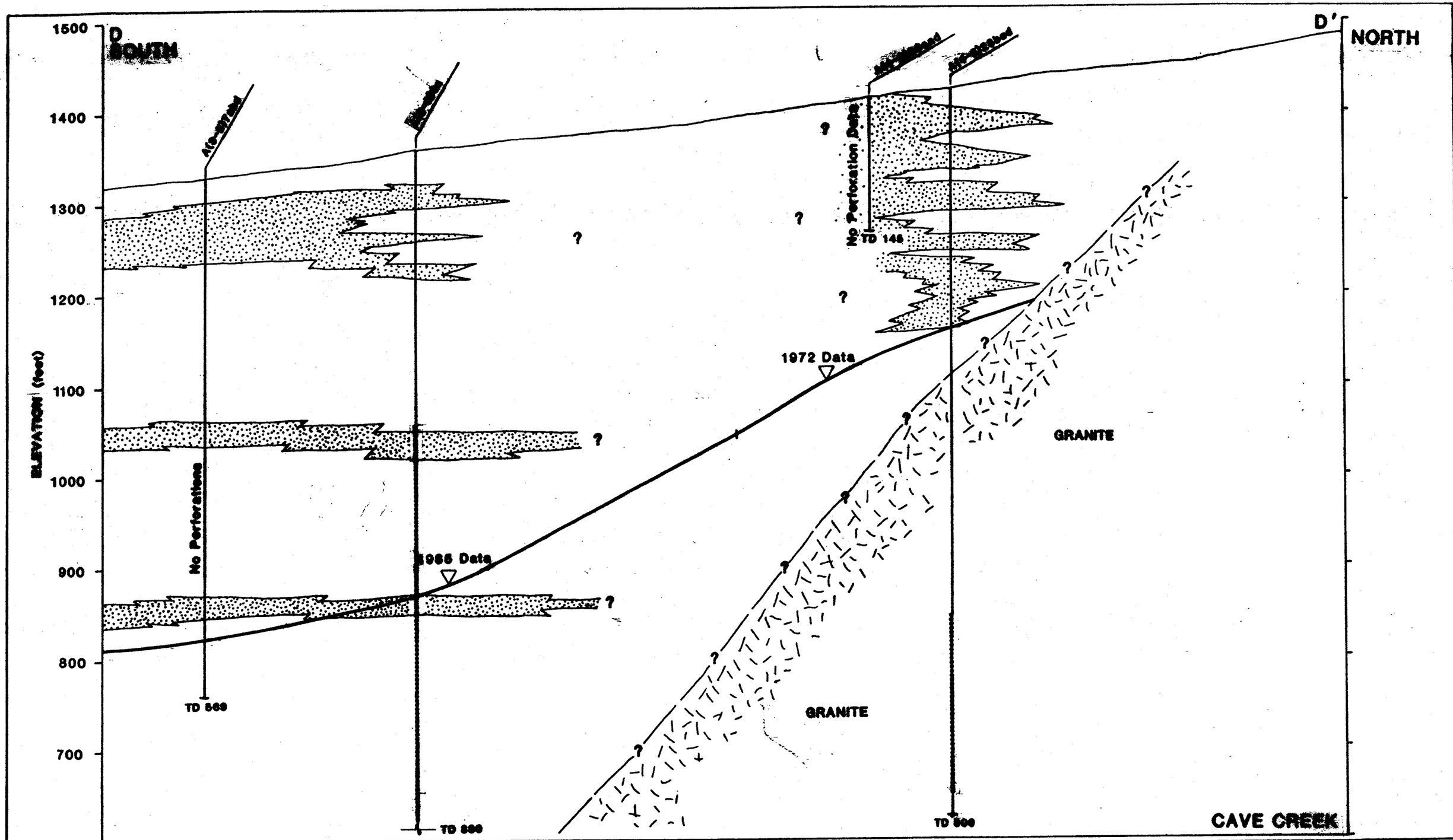
SECTION C-C'

CDM

Figure 6


LEGEND
STUDY AREA
ENVIRONMENTALLY SENSITIVE AREA
RESIDENTIAL ZONE *
PRIVATE LANDS *
FLOOD PLAIN
FLOOD PLAIN (INFERRED)
SANITARY LANDFILL
* NEAR STUDY AREA
0 2000 4000 6000
Horizontal Scale in Feet
AMWUA RIVERBED RECHARGE PROJECT
SKUNK CREEK
environmental engineers, scientists, planners, & management consultants CDM
Figure 7
BISCUIT FLAT
DEER VALLEY
Middle Mtn
Lockett Tank
T Bone Tank
Skunk Creek
Adobe Mountain
Trailer Park
Scattered
Shaw Butte
Reservoir
R2E
T6N
T4N
C
C'


LEGEND
STUDY AREA
ENVIRONMENTALLY SENSITIVE AREA
RESIDENTIAL ZONE *
PRIVATE LANDS *
FLOOD PLAIN
FLOOD PLAIN (INFERRED)
SANITARY LANDFILL
* NEAR STUDY AREA
0 2000 4000 6000
Horizontal Scale in Feet
AMWUA RIVERBED RECHARGE PROJECT
CAVE CREEK
CDM
Figure 8
PHOENIX MUNICIPAL AIRPORT
PHOENIX MOUNTAINS PRESERVE
Moon Valley Country Club
Fuente Park
Scottsdale Sand & Gravel
Gravel Pit
PHOENIX CORP BOUNDARY
WILLIAMS DRIVE
19TH AVENUE
HEARN ROAD
UNION
T4N
T3N
R4E
R3E
Wash
Creek
Cave
Scottsdale



LEGEND

Aquitard (Mostly Fine-grained Sediments)

Water Level

Water Well, Dotted Where Perforated, Showing Total Depth (TD) in Feet Below Ground Surface

TD 759

0 2000 4000 6000

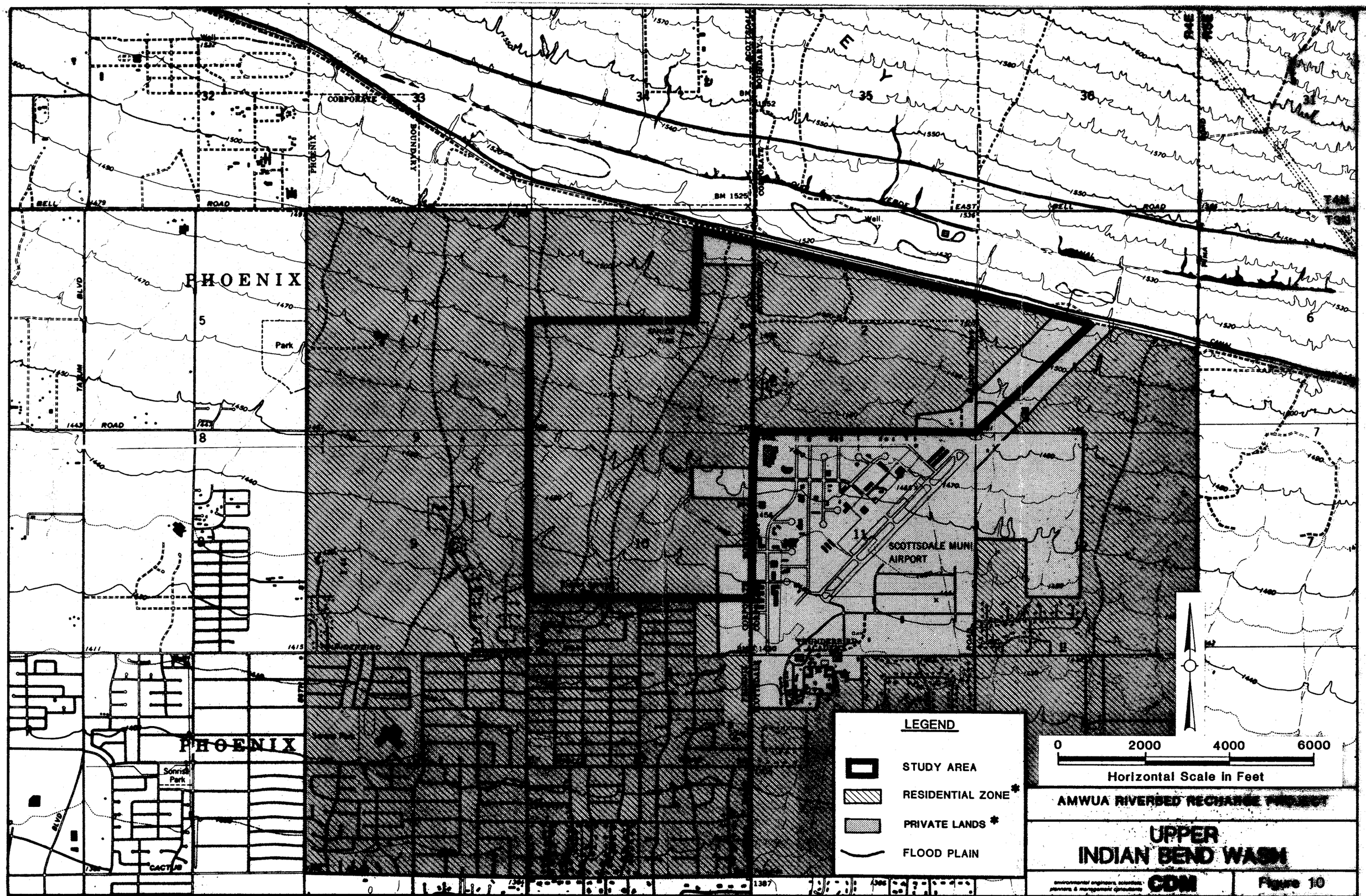
Horizontal Scale in Feet

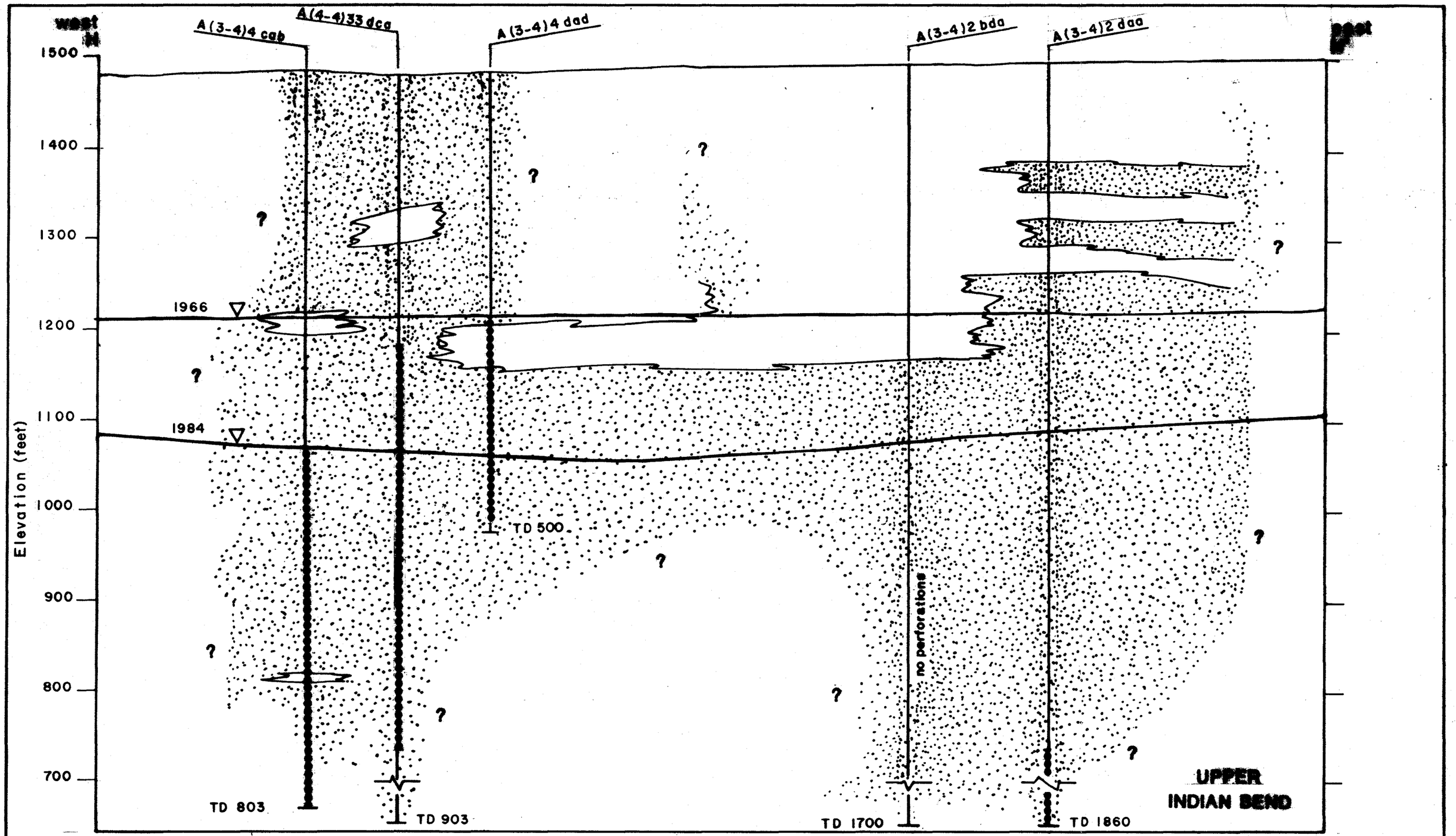
AMWUA RIVERBED RECHARGE PROJECT

SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION D-D'

CDM

Figure 9


PHOENIX
PHOENIX
SCOTTSDALE MUNI AIRPORT
CORPORATE BOUNDARY
BELL ROAD
ROAD
CANAL
T4N
T3N
LEGEND
STUDY AREA
RESIDENTIAL ZONE *
PRIVATE LANDS *
FLOOD PLAIN
0 2000 4000 6000
Horizontal Scale in Feet
AMWUA RIVERBED RECHARGE PROJECT
UPPER
INDIAN BEND WASH
CDM
Figure 10



LEGEND

Aquitard Mostly Fine-grained Sediments

Water Level

Water Well, Dotted Where Perforated, Showing Total Depth (TD) in Feet Below Ground Surface

TD 759

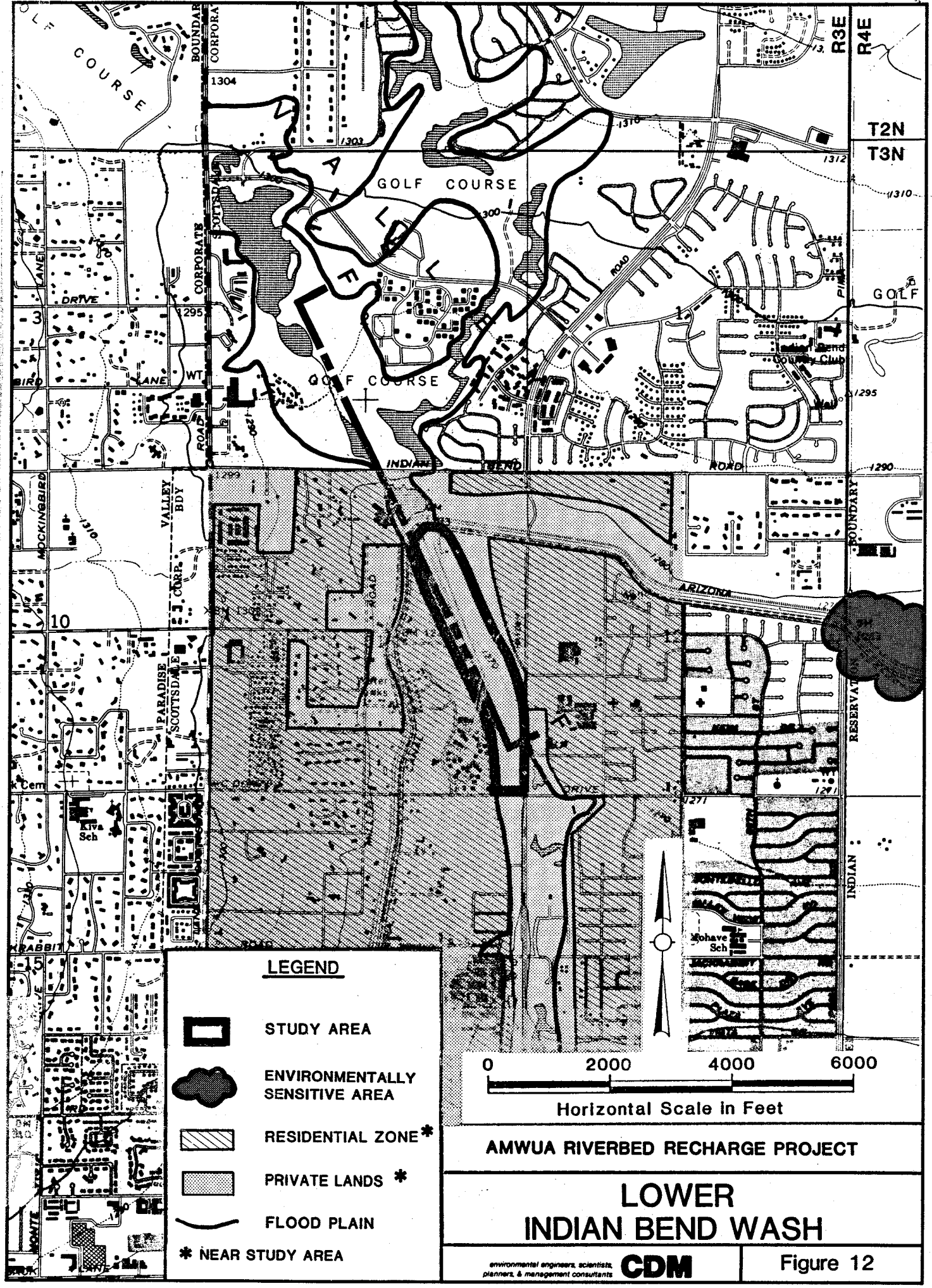
0 2000 4000 6000

Horizontal Scale in Feet

AMWUA RIVERBED RECHARGE PROJECT

SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION H-H'

Figure 11



AMWUA RIVERBED RECHARGE PROJECT

LOWER INDIAN BEND WASH

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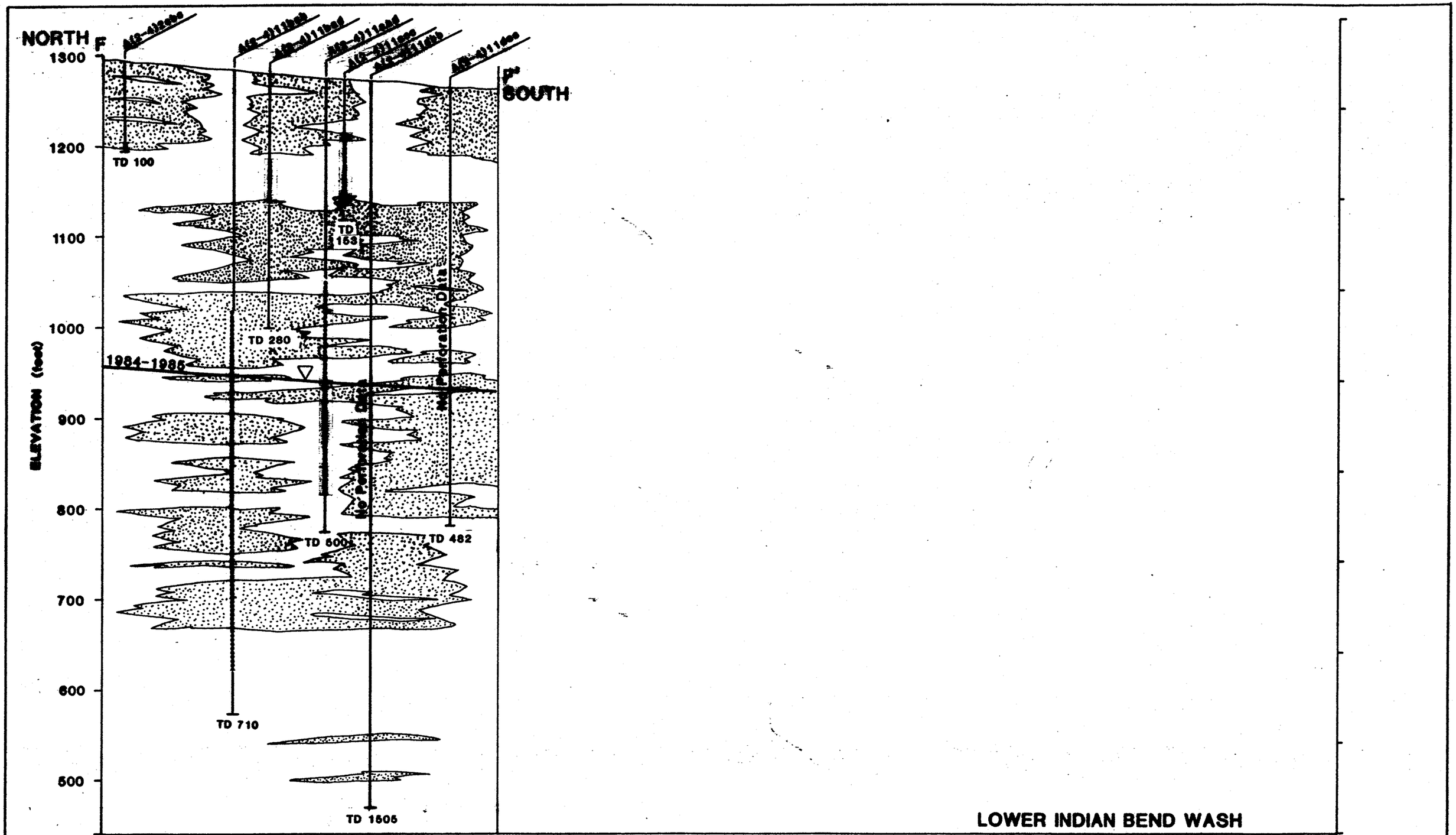
Figure 12



LEGEND

Aquitard (Mostly Fine-grained Sediments)

Water Level

Water Well, Dotted Where Perforated, Showing Total Depth (TD) in Feet Below Ground Surface

TD 759

0 2000 4000 6000

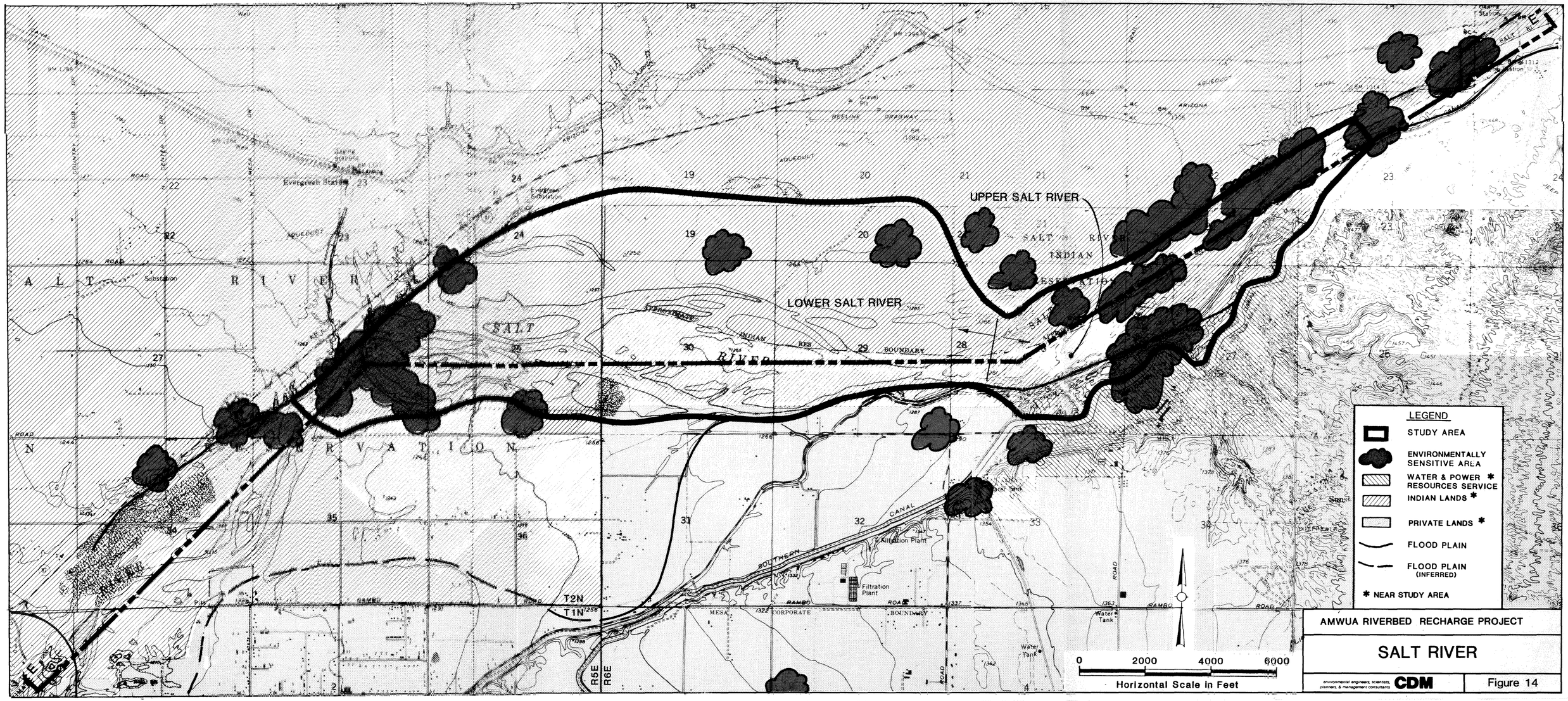
Horizontal Scale in Feet

AMWUA RIVERBED RECHARGE PROJECT

SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION F-F'

CDM

Figure 13



AMWUA RIVERBED RECHARGE PROJECT

SALT RIVER

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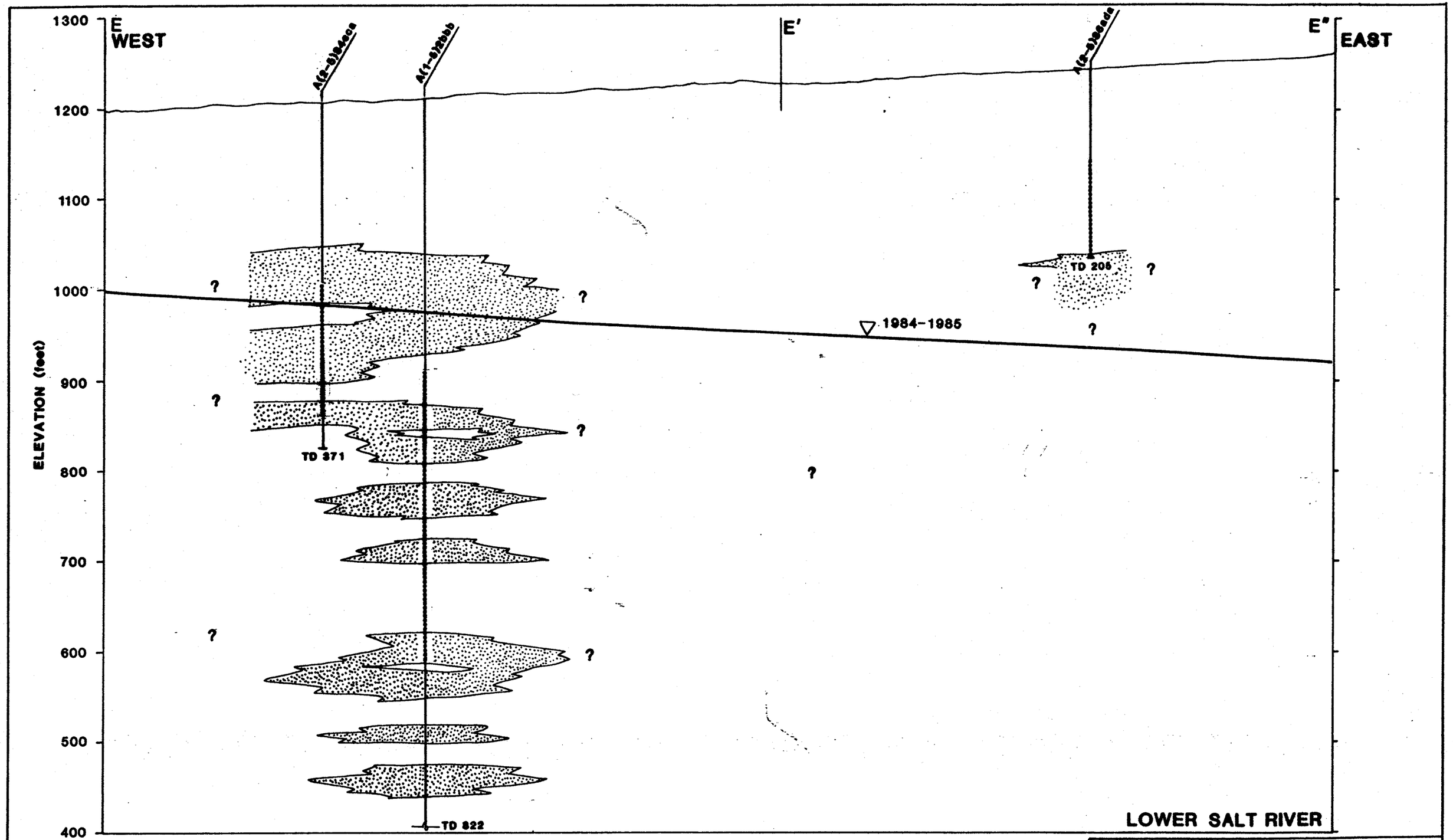
Figure 14

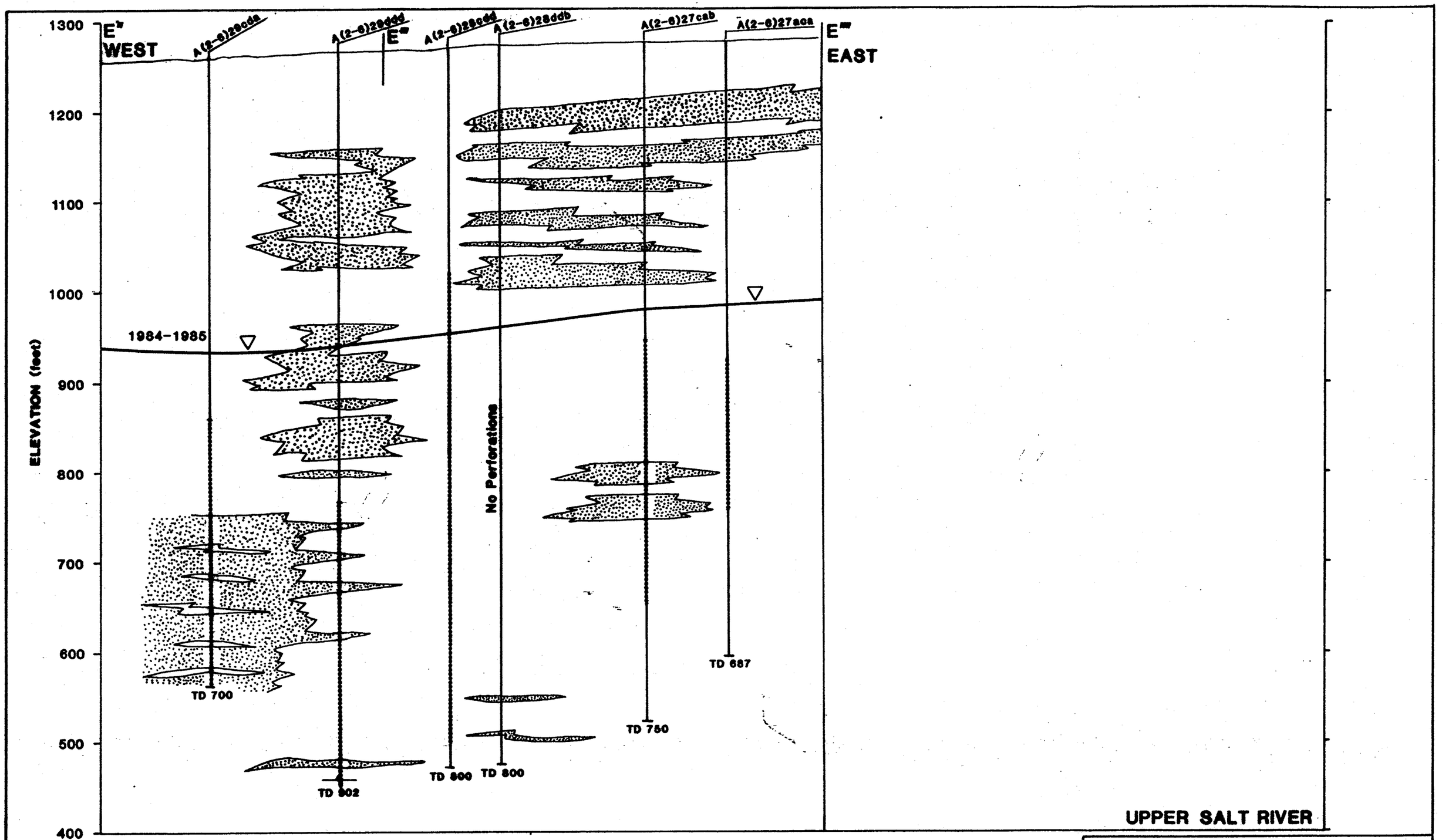


AMWUA RIVERBED RECHARGE PROJECT

SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION E-E"

CDM

Figure 15



LEGEND

Aquitard (Mostly Fine-grained Sediments)

Water Level

Water Well, Dotted Where Perforated, Showing Total Depth (TD) in Feet Below Ground Surface

TD 759

0 2000 4000 6000

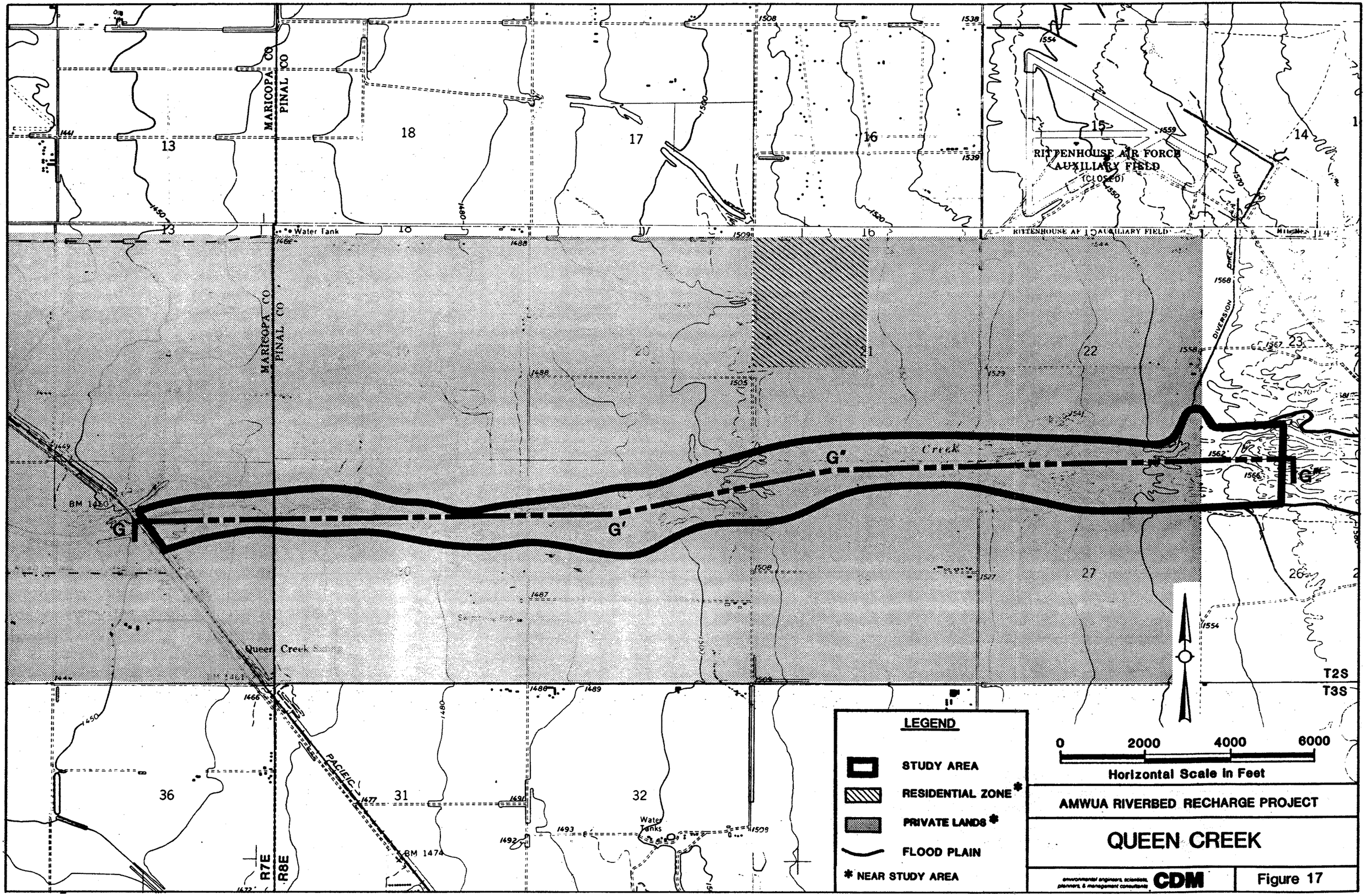
Horizontal Scale in Feet

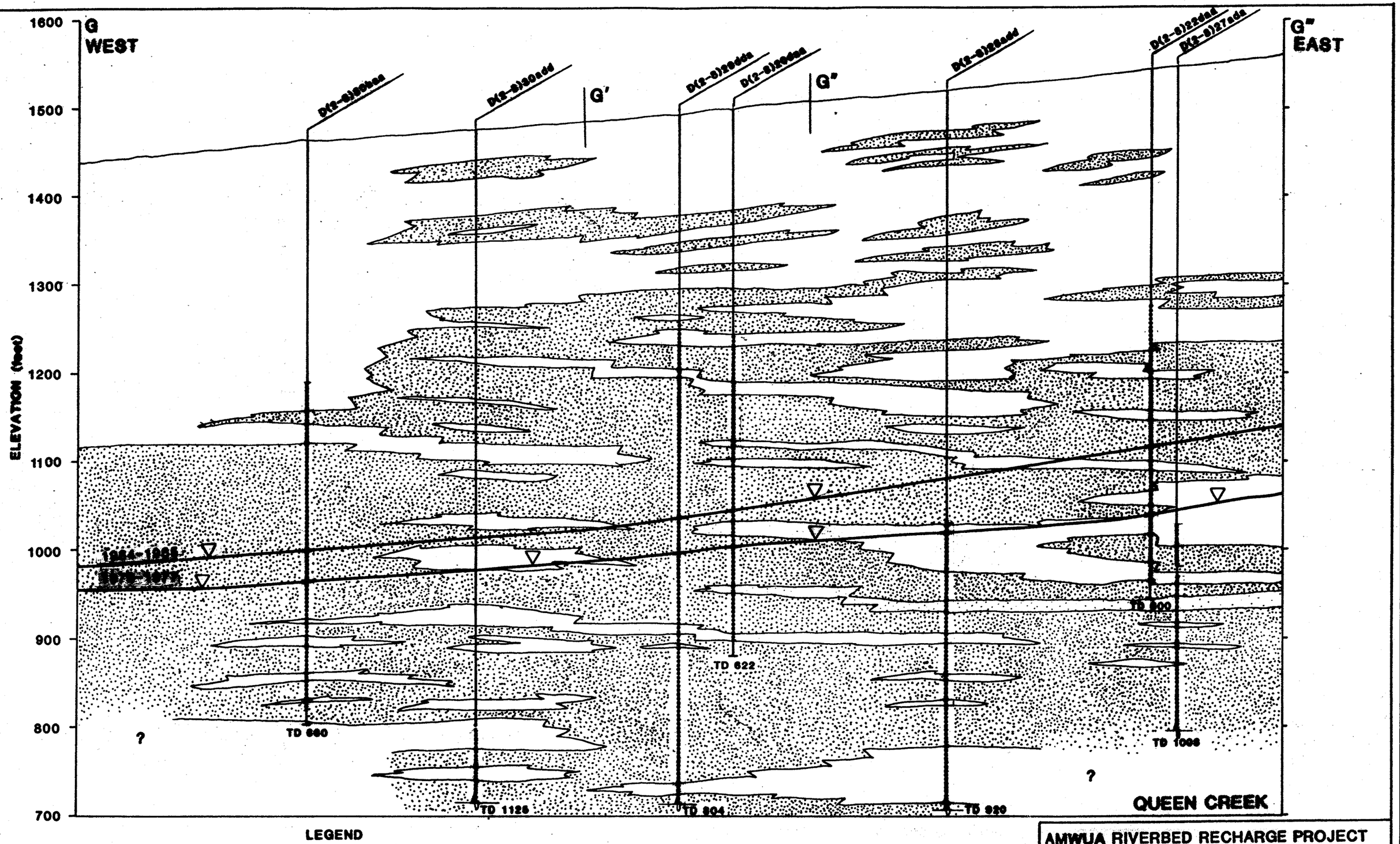
AMWUA RIVERBED RECHARGE PROJECT

SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION E"-E'''

CDM

Figure 16


MARICOPA CO
PINAL CO
RITTENHOUSE AIR FORCE AUXILIARY FIELD
(CLOSED)
Water Tank
Queen Creek
PACIFIC
BM 1474
Water Tanks
DIVERSION DIKE
G
G'
R7E
R8E
T2S
T3S
LEGEND
STUDY AREA
RESIDENTIAL ZONE *
PRIVATE LANDS *
FLOOD PLAIN
* NEAR STUDY AREA
0
2000
4000
6000
Horizontal Scale in Feet
AMWUA RIVERBED RECHARGE PROJECT
QUEEN CREEK
environmental engineers, scientists, planners, & management consultants
CDM
Figure 17



AMWUA RIVERBED RECHARGE PROJECT

SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION G-G"

CDM

Figure 18

ECONOMIC CONSIDERATIONS 4.0

4.1 INTRODUCTION

In the prior section of this report, each of the sites was evaluated according to technical considerations. The cost of constructing, as well as operating and maintaining the proposed recharge facility must also be evaluated and considered as part of the final ranking process. The objective of this preliminary economic evaluation is to (1) identify the major cost components of the recharge program, and (2) identify any significant difference in costs among the various potential recharge sites.

In this portion of the report, the annualized capital and annual operation and maintenance costs are developed for the sites. To accomplish this, engineering criteria are developed, any required conveyance facilities are identified, and the conceptual designs for each of the facilities are presented for each site.

4.2 ENGINEERING CRITERIA

Based on the technical considerations for large-scale recharge programs in the Phoenix area and because of the need to implement a recharge program quickly with facilities capable of recharging large quantities of water in a short period of time, the choice of recharge methods has been narrowed to include river-bed "T"-levees and shallow off-channel basins. Because it was available within the site area, an existing deep pit was integrated in the New River spreading facilities. The following paragraphs outline and discuss the engineering criteria used to formulate the conceptual designs for both the riverbed "T"-levee basins and the shallow off-channel basins. In addition, the general conveyance requirements are discussed for each of the recharge facilities.

4.2.1 RIVERBED "T"-LEVEE BASINS

As indicated earlier, these facilities are constructed within the active areas of the river channel by dozing "T"-configured levees. The spacing between "T"-levees is a function of the slope of the river channel and the desired depth of water on the upstream face of the "T"-levee. For this study, the depth of water upstream of the levee was assumed to be five feet, with the spacing adjusted in each river channel so that the entire area between the consecutive "T"-levees would be wetted. The height of the levees was assumed to be six feet.

4.2.2 OFF-CHANNEL SHALLOW BASINS

Spreading facilities located outside the active channel of the river are also designed as a function of the slope of the ground surface in the area. The spacing between the levees which are situated parallel to the natural contours of the area, is adjusted to develop a depth of water at the downstream levee which ranges between 8 and 10 feet, and 1 or 2 feet at the upstream portion of the basin. The basins are further designed to achieve a balance of earthwork.

The off-channel spreading facilities are provided with a means of controlling water level and flow between basins. Adjustable sharp-crested weirs offer the most control over the water level because flash boards can be added or removed to raise or lower the water level and the flow between basins. In addition, gated culverts are placed at each basin to allow for rapid drainage when the basin is scheduled for drying, cleaning, and maintenance.

4.2.3 CONVEYANCE FACILITIES

In general, the candidate recharge sites were selected on the basis of their proximity to the CAP aqueduct or other major water conveyance facility which can receive water from the CAP. Consequently, water conveyance facilities are generally not required. In all cases, it was originally envisioned that recharge water would be discharged from the major water conveyance facility into the natural drainage course that is

tributary to the recharge site. However, in some cases, landfills and dumps have been located within the flood plain of the river channel, upstream of the candidate recharge facility, as is the case for Skunk Creek and Cave Creek. In these areas, it may be necessary to construct a lined conveyance facility parallel to the river, between the CAP to the recharge basins. The facility would ensure that the recharge water would not penetrate the landfill material through surface flow or via groundwaters rising from stream bed recharge in the immediate vicinity of the landfill.

The location of the permanent turnout structures constructed along the CAP aqueduct have been identified. These structures might be used to discharge the CAP water to the proposed recharge sites along Agua Fria River, New River, Cave Creek, Salt River, and Queen Creek. For the remaining recharge sites along Skunk Creek and Indian Bend Wash, diversion facilities will be required. For ease of implementation, it was assumed that temporary low head pumping facilities would be installed at all locations requiring a turnout facility. The temporary pumping plants could be replaced by a more permanent gravity turnout facility, if the long-term viability of recharge is determined for a site. For the existing turnouts and the temporary pumping plants, water flow rate measurement devices would have to be installed.

4.3 CONCEPTUAL DESIGNS

Utilizing the criteria briefly described above, a conceptual layout of recharge facilities was prepared for each of the 10 recharge sites. At sites where substantial amounts of public lands appear to be available, the conceptual layout was configured to maximize the use of public lands. In these instances, the area of the recharge facility utilized in the conceptual design is less than the areal extent of the original study area, as indicated on Table 11. Also, at each site, the most appropriate recharge method, i.e., riverbed "T"-levees, off-channel shallow basins or deep basins, was selected. The following is a brief description of the conceptual recharge plan at each of the sites.

4.3.1 AGUA FRIA RIVER

Although this recharge site (formerly referred to as the Middle Agua Fria) appears to be relatively undeveloped and of large river channel width, private land ownership encroachment in the river channel area affects the design of the facility. For the most part, public lands were utilized for this spreading facility.

In the northwestern portion, as shown on Figure 19, the spreading facility consists of a 3-mile long riverbed "T"-levee, comprising about 610 acres. In the southeastern portion of the recharge facility, where public lands were also available immediately adjacent to the floodplain of the river, a more permanent off-channel shallow basin system was laid out. The surface area of these basins is about 515 acres.

Water for the Agua Fria Recharge Facilities would be diverted through the existing CAP turnout into the Beardsley Canal. The water would then be discharged from the Beardsley Canal near the upper reaches of the recharge facilities. For the "T"-levee system, the diversion capacity from the Beardsley Canal would be about 310 cubic feet per second (cfs). The diversion capacity for the off-channel facilities would be about 260 cfs. If insufficient capacity is available in the Beardsley Canal for the recharge program, then water could be diverted from the CAP directly into the Agua Fria River. If this is done, however, some water will infiltrate and be trapped in the Upper Agua Fria River groundwater subbasin.

4.3.2 NEW RIVER

The most appropriate spreading facility for this recharge site was determined to be riverbed "T"-levees, as shown on Figure 20. However, in the lower portion of the recharge area, existing sand and gravel pits were incorporated into the recharge layout. The areal extent of the "T"-levee system, including deep basins, is approximately 515 acres. Nearly all of the lands required for the conceptualized spreading facility are privately owned.

Water would be diverted from the CAP through a turnout structure into the New River channel and travel 15,000 feet into the "T"-levee system. Some water will infiltrate into the Upper New River subbasin and be trapped. Total capacity of the diversion would be 310 cfs.

4.3.3 SKUNK CREEK

The recharge system for Skunk Creek is located behind Skunk Creek flood control dam. The type of spreading facility deemed the most appropriate for this site is shallow off-channel basins, as shown on Figure 21. About 520 acres of shallow basins were laid out in the form of fifteen 30- to 40-acre basins. An existing sand excavation is used as an initial desilting basin. The facility layout is situated on both publicly and privately owned lands.

Because an existing CAP turnout is not available at Skunk Creek, a diversion system will have to be constructed. The diversion would require a capacity of up to 60 cfs. A landfill is located between the CAP and the spreading basins, and therefore, a bypass channel will need to be constructed parallel to the river channel. The 19,000 foot long channel would have a capacity of 60 cfs.

4.3.4 CAVE CREEK

Conceptual layouts were prepared for both the Upper and Lower Cave Creek recharge sites. A river channel "T"-levee system was conceived to run continuously through both project sites, as shown on Figure 22. Shallow basins were laid out on adjacent undeveloped lands. The total area of in-channel facilities for the Upper and Lower Cave Creek facilities is about 190 acres. The off-channel facilities comprise about 190 and 305 acres for the upper and lower recharge sites, respectively. The recharge systems are located primarily on private lands.

A permanent turnout structure has been located on the CAP aqueduct at Cave Creek. However, because a landfill is present just upstream of the

spreading facilities, a 10,000-foot-long channel will need to be constructed from the CAP turnout. The capacity of the channel required to supply the Upper Cave Creek facilities is about 20 cfs for the in-channel system and about 80 cfs for the off-channel system. The capacity of the channel required to supply the Lower Cave Creek facilities is about 55 cfs for the in-channel system and about 190 cfs for the off-channel system. The final capacity of the channel would be dependent on which of the recharge facilities is constructed along Cave Creek.

4.3.5 UPPER INDIAN BEND WASH

This facility is located immediately adjacent to the CAP, but does not lie within the flood plain of the river. As a result, the most appropriate recharge facility for this site is the shallow off-channel basins (Figure 23). About forty 30- to 40-acre shallow basins were laid out within the boundary of this site. The total area of the spreading facilities is 1,430 acres. Nearly all of the land within the boundary of this proposed recharge site is privately owned. Because an existing turnout is not available at this site, a low head pumping system with a capacity of about 145 cfs will be required to divert CAP water into the Upper Indian Bend Wash spreading facilities.

4.3.6 LOWER INDIAN BEND WASH

Riverbed "T"-levees were laid out on this 90-acre site, as shown on Figure 24. All of the lands within the proposed recharge site are privately owned. If capacity is available, the only way to convey CAP water to the site is via the Arizona Canal, which siphons beneath Indian Bend Wash at the upstream end of the spreading basins. The water would be diverted into the spreading basins with a pumping station having a capacity of about 10 cfs.

4.3.7 UPPER SALT RIVER

For this site, riverbed "T"-levees were deemed the most appropriate recharge facilities because of Indian land ownership and topographic

constraints. A layout of these facilities was prepared for that portion of the study area which is located entirely on public lands (Figure 25). The area of this recharge facility is approximately 295 acres. CAP water would be diverted through a proposed CAP/SRP Interconnection Facility near Granite Reef Dam and allowed to flow in the Salt River to the spreading facilities. The discharge rate through the turnout required to serve these facilities would be about 150 cfs.

4.3.8 LOWER SALT RIVER

Like the Upper Salt River conceptual design, a layout was prepared for this facility that utilized only public lands within the flood plain of the river. The conceptual recharge facility incorporates both the riverbed "T"-levee basins and off-channel shallow basins, as shown on Figure 25. The "T"-levee basins have an area of about 565 acres and the off-channel basins have an area of about 310 acres.

CAP water can enter the Lower Salt River spreading facilities in two ways. The first is through the proposed Interconnection Facility near Granite Reef Dam. This water would flow to the spreading basins via the Salt River and Upper Salt River spreading facilities. If capacity is available, CAP water could also be delivered to the lower facilities via the Southern Canal, which runs along the south side of the Salt River. The water would have to be diverted from the Southern Canal into the spreading facilities. For the in-stream facilities, the diversion would have a capacity of about 285 cfs. For the off-channel facilities, the diversion would have a capacity of about 160 cfs.

4.3.9 QUEEN CREEK

This proposed recharge facility is composed almost entirely of privately held lands. For this reason, the most appropriate recharge system for this area is riverbed "T"-levees constructed, as shown on Figure 26. The layout for this facility utilizes about 755 acres of land. An existing CAP turnout is available for Queen Creek. CAP water would be discharged from the

aqueduct directly into the spreading facilities. Approximately 530 cfs of the turnout capacity would be required to supply water to the spreading basins.

4.4 RECHARGE CAPABILITIES

Using the areas devoted to in-stream and off-stream recharge facilities and the estimated average sustained infiltration rates from Table 12, a revised annual recharge rate for each site was calculated. The results of the determination are shown in Table 15 for each site. The total conceptual design recharge area is about 6,300 acres and has a total recharge capability of about 1.9 million ac-ft/year.

4.5 CAPITAL AND ANNUAL O&M COST

This portion of the report deals with determining the cost of developing, as well as operating and maintaining (O&M) the recharge facilities. Capital costs, exclusive of private land acquisition costs, were developed for the spreading facilities and any required turnout and conveyance facilities. These costs were annualized on a dollars per acre-foot basis to facilitate cost comparisons of the candidate recharge facilities. Annual O&M costs were based on the cost to operate and maintain similar facilities elsewhere.

4.5.1 CAPITAL COST

Using the conceptual layouts for each facility, as previously described, and cost information for earthwork and hydraulic structures, the costs for constructing riverbed "T"-levee systems and off-channel shallow basin facilities were developed. The capital cost information for each site is summarized in Table 16. As can be seen from the table, the cost to construct recharge facilities varies between $120,000 for Lower Indian Bend Wash to about $6,800,000 for Skunk Creek. In general, facilities with off-channel basins cost more to construct than those without those facilities because of the earthwork required. These costs do not include land acquisition costs.

TABLE 15

CONCEPTUAL DESIGN RECHARGE CAPABILITIES FOR
ALTERNATIVE RECHARGE SITES

Feasibility Study Report -- AMWUA Riverbed Recharge Project

Recharge Site	Design Recharge Area (ac.)	Estimated Average Sustained Infiltration Rate [a] (ft/day)	Design Annual Recharge Rate (kaf/yr)
Agua Fria River			
In-stream	610	1.0[b]	225
Off-stream	515		190
New River			
In-stream	515	1.2	225
Skunk Creek			
Off-stream	520	0.2	40
Upper Cave Creek			
In-stream	50	0.9	15
Off-stream	190		60
Lower Cave Creek			
In-stream	90	1.2	40
Off-stream	305		135
Upper Indian Bend			
Off-stream	1,430	0.2	105
Lower Indian Bend			
In-stream	90	0.1	5
Upper Salt River			
In-stream	295	1.0	110
Lower Salt River			
In-stream	565	1.0[b]	205
Off-stream	310		115
Queen Creek			
In-stream	755	1.4	385
Totals	6,260		1,855

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(a) Based upon a 30-day wet-dry application cycle
(b) Recharge rate is limited by rise in groundwater recharge mound

TABLE 16
CONCEPTUAL DESIGN CAPITAL COST ESTIMATED FOR AMWUA RECHARGE SITES
Feasibility Study Report — AMWUA Riverbed Recharge Project

RECHARGE SITE	DESIGN AREA (ac)	RECHARGE RATE (1) (kaf/yr)	CAPITAL COSTS ($ x 1000) CANAL TURNOUT (2)	CONVEYANCE FACILITIES	EARTHWORK (3)	INTER-BASIN FACILITIES	CONTINGENCY FACTOR (35%)	TOTAL COSTS (4)
AGUA FRIA RIVER								
In-Stream Facilities	610	225	125	0	290	NA	145	561
Off-Stream Facilities	515	190	109	0	830	390	465	1,795
NEW RIVER								
In-Stream Facilities	515	225	125	3,260	260	NA	1,276	4,921 *
SKUNK CREEK								
Off-Stream Facilities	520	40	43	4,200	530	250	1,758	6,781 *
UPPER CAVE CREEK								
In-Stream Facilities	50	15	32	450	80	NA	197	758 *
Off-Stream Facilities	190	60	52	1,570	200	95	671	2,588 *
LOWER CAVE CREEK								
In-Stream Facilities	90	40	43	500	115	NA	230	888 *
Off-Stream Facilities	305	135	85	1,680	285	135	765	2,950 *
UPPER INDIAN BEND WASH								
Off-Stream Facilities	1,430	105	72	0	1,460	690	778	2,999 *
LOWER INDIAN BEND WASH								
In-Stream Facilities	90	5	27	0	60	NA	31	118 *
UPPER SALT RIVER								
In-Stream Facilities	295	110	74	0	180	NA	89	343
LOWER SALT RIVER								
In-Stream Facilities	565	205	116	0	225	NA	119	461
Off-Stream Facilities	310	115	76	0	455	215	261	1,008
QUEEN CREEK								
In-Stream Facilities	755	385	196	0	475	NA	235	906

NOTES:
1. Recharge rates assume 30-day wet-dry cycle.
2. Turnouts include flow measurement devices.
3. Earthwork is initial cost of construction at $1.80 per cu. yd.
4. Costs are exclusive of private land acquisition costs. Significant additional costs can probably be expected if plan is fully implemented for those sites marked with an "*".

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As indicated earlier, many of the proposed recharge sites require the use of privately owned lands. It is not clear at this point whether a temporary easement, leasing arrangement, or acquisition of these lands would be appropriate or required. Further, the use of private lands will probably complicate and lengthen the implementation schedule of any recharge project requiring private lands. However, AMWUA staff provided estimated values for lands included within the conceptual recharge areas. The land values varied from $1,000 to $30,000 per acre, as follows:

Recharge Site	Cost/ac.
Agua Fria River	$10,000
New River	10,000
Skunk Creek	10,000
Cave Creek	20,000
Indian Bend Wash	30,000
Salt River	10,000
Queen Creek	1,000

However, at any particular site, the value of different parcels can vary significantly, depending on adjacent land use and development. Since little or no publically owned lands are available within the New River, Cave Creek and Indian Bend conceptual recharge areas, substantial additional costs to those shown in Table 16 would be incurred to develop these recharge facilities. Public lands are also not available along Queen Creek, but as indicated, land values appear to be relatively low in comparison to the other recharge locations. Consequently, additional costs for land purchase would not be as great in the Queen Creek area as with the other areas.

The Skunk Creek conceptual recharge facility, unlike the previously mentioned recharge areas, utilizes a mixture of publicly and privately owned land. However, per acre costs for private land are about $10,000, and a substantial additional cost would be expected if the conceptual plan were fully implemented.

The conceptual plans for the Salt and Agua Fria Rivers utilized very little privately owned lands. Further, sufficient publicly owned lands appear to be available to develop a relatively large recharge facility. Therefore, additional land costs to implement the conceptual plans for these sites are considered minimal.

Because groundwater recharge by surface spreading is land intensive, it is advisable for preliminary and final designs to configure recharge facilities so as to avoid the potential significant additional costs for acquiring privately owned lands.

4.5.2 OPERATION AND MAINTENANCE COSTS

The annual operation and maintenance (O&M) costs are estimated based on the experience with similar facilities by the Los Angeles Department of Public Works and Orange County Water District. These agencies operate large groundwater spreading facilities composed of a mixture of both riverbed "T"-levees and off-channel facilities. These agencies report annual O&M costs ranging between $4 and $6 per acre-foot of water recharged. It should be noted that these O&M costs include costs to periodically reconstruct portions of the riverbed "T"-levees that are destroyed by flood flows. It should also be noted that these costs are in addition to the cost of purchasing CAP water for recharge. In the near term, CAP recharge water is expected to cost $30 to $40 per acre-foot.

A precise evaluation of the frequency of "T"-levee washout and extent of "T"-levee destruction in the Phoenix area due to flooding is difficult. Unimpaired recurrence intervals for various magnitude flood flows for each drainage course that flows through the recharge sites were obtained (Table 17). These unimpaired flood frequency data indicated that the riverbed "T"-levee system would endure frequent washouts similar to the washout occurrence in Southern California. However, unlike Southern California, an extensive network of water supply reservoirs has been constructed upstream of the recharge facilities. The water supply reservoirs tend to capture and hold most flood flows, thus, substantially reducing the downstream occurrence of flood flow that would damage the

TABLE 17

FLOOD FREQUENCY DATA FOR SELECTED STREAMFLOW GAGING STATIONS IN AMWUA STUDY AREA

LOCATION INTERVAL	PERIOD OF RECORD	DRAINAGE AREA (mi^2)	FLOOD MAGNITUDE (CFS) FOR INDICATED RECURRENCE INTER					
			2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Agua Fria at El Mirage A(3,1) 18bb	Insufficient Data							
New River at Bell Road A(3,1) 3aa	1963 1965-75	187.0	1,470	5,110	9,650	18,800	28,800	42,100
Skunk Creek near Phoenix A(5,2) 35d	1960-75	64.6	1,200	4,750	9,600	20,100	32,100	48,900
Indian Bend Wash near Scottsdale A(2,4) 11ab	1961-75	142.0	288	2,450	7,340	23,200	48,300	92,800
Salt River at Granite Reef Dam	———	———	———	40,000	———	145,000	175,000	240,000

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Sources: USGS - WRI Paper 79-5, 1979; US Corp. of Engineers, 1980 Flood report on Salt River

riverbed "T"-levees. As a result, it is concluded that the annual operation and maintenance cost for recharge facilities in the Phoenix area would be somewhat less than those in Southern California. As a conservative estimate of the cost for facilities in the Phoenix area however, a $4 per acre-foot annual operation and maintenance cost is assumed.

4.5.3 ANNUALIZED COST

So that costs of implementing recharge programs at candidate sites can be compared on the basis of the amount of water recharged, the capital cost for each facility was annualized. The capital cost for each site (exclusive of land) shown on Table 16 is annualized based on a 25-year repayment period and an interest rate of 8 percent.

The annualized cost for each facility is expressed in dollars per acre-foot of water recharged on Table 18. [The cost of private land, if required, has not been included, but is shown on the table as a possible additional cost]. The annualized capital cost was divided by the amount of water which could be recharged per year at each facility. This figure, added to the O&M cost of $4.00 per acre-foot of water recharged, is the annual cost per acre-foot to recharge water at the various facilities.

As indicated on the table, the O&M costs are usually much greater than the annualized capital costs. Also, off-stream facilities are generally more expensive to develop than in-stream facilities. The least expensive facilities to develop on a per acre-foot basis are Queen Creek, Salt River, and Agua Fria, with costs ranging from $4.20 to $4.30 per acre-foot. However, the Queen Creek site will probably cost somewhat more than indicated because of land acquisition costs. The most expensive facility is Skunk Creek at nearly $20 per acre-foot.

Excluding Skunk Creek, the annualized cost difference (in dollars per acre-foot of water recharged) between the least and most expensive facilities is about $4.50 per acre-foot, which is small when compared to the cost of purchasing the water from CAP. Consequently, re-ranking of the

TABLE 18

ANNUALIZED CAPITAL AND O&M COSTS FOR CONCEPTUAL DESIGNS

Feasibility Study Report — AMWUA Riverbed Recharge Project

RECHARGE SITE	RECHARGE RATE (kaf/yr)	CAPITAL COST ($ x 1000)		ANNUAL COST ($/AF)		
		TOTAL	ANNUALIZED	CAPITAL	O & M	TOTAL
AGUA FRIA RIVER						
In-Stream Facilities	225	561	53	0.23	4.00	4.23
Off-Stream Facilities	190	1,795	168	0.89	4.00	4.89
NEW RIVER						
In-Stream Facilities	225	4,921	461	2.05	4.00	6.05
SKUNK CREEK						
Off-Stream Facilities	40	6,781	635	15.88	4.00	19.88
UPPER CAVE CREEK						
In-Stream Facilities	15	758	71	4.73	4.00	8.73
Off-Stream Facilities	60	2,588	242	4.04	4.00	8.04
LOWER CAVE CREEK						
In-Stream Facilities	40	888	83	2.08	4.00	6.08
Off-Stream Facilities	135	2,950	276	2.05	4.00	6.05
UPPER INDIAN BEND WASH						
Off-Stream Facilities	105	2,999	281	2.68	4.00	6.68
LOWER INDIAN BEND WASH						
In-Stream Facilities	5	118	11	2.21	4.00	6.21
UPPER SALT RIVER						
In-Stream Facilities	110	343	32	0.29	4.00	4.29
LOWER SALT RIVER						
In-Stream Facilities	205	461	43	0.21	4.00	4.21
Off-Stream Facilities	115	1,008	94	0.82	4.00	4.82
QUEEN CREEK						
In-Stream Facilities	385	906	85	0.22	4.00	4.22

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NOTES:
1. Capital costs are exclusive of land acquisition costs.
2. Capital costs ammortized at 8% over 25 years.
3. The O&M costs are exclusive of the purchase of CAP water.

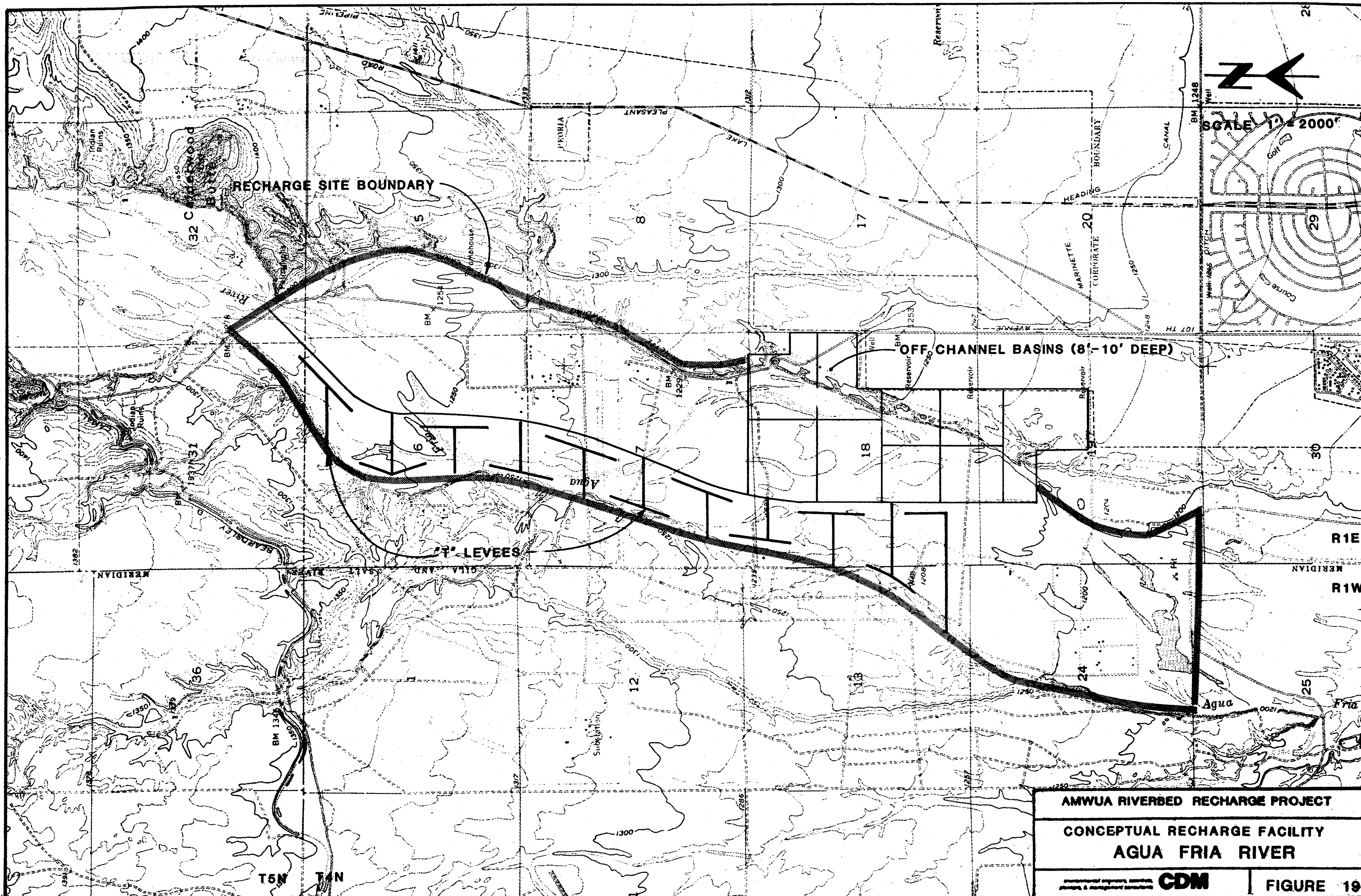
recharge sites, as indicated on Table 15, is unnecessary based on the costs developed in this section, with the exception that Skunk Creek should be moved into the least feasible category.

4.6 FINAL SITE SELECTION

All ten sites evaluated during the screening process can be used to recharge CAP water. None of the sites has a technical "fatal flaw." The difference in cost for constructing, operating, and maintaining the candidate sites was not sufficient justification to eliminate sites. Even though it is feasible to develop each of the sites evaluated, some sites are better than others, considering that one of the primary objectives of the program is to get large quantities of water recharged in a short period of time in the near future. This criterion suggests that in-channel facilities would be best for rapid development, provided that the sites are located on public land and that conveyance facilities are not required. The sites which meet this criterion are the Agua Fria and the Upper and Lower Salt River. Because they are contiguous, the in-channel facilities in the Upper and Lower Salt River can be combined into one facility. Together, the recharge facilities on the Agua Fria and Salt Rivers have a maximum potential recharge capacity of 540,000 acre-feet per year, which probably exceeds the amount of surplus water available from the CAP.

Based on the evaluation and screening presented in this report, and in consultation with AMWUA staff, the project team prepared preliminary designs for in-channel facilities on the Agua Fria and Salt Rivers.

As mentioned above, all sites evaluated are suitable for recharging water. However, if any of the excluded seven sites are considered for development as recharge sites in the future, serious data deficiencies should be considered prior to completing preliminary and final designs. A list of these data deficiencies and associated corrective actionsfor these seven sites are listed on the table provided in Appendix A.

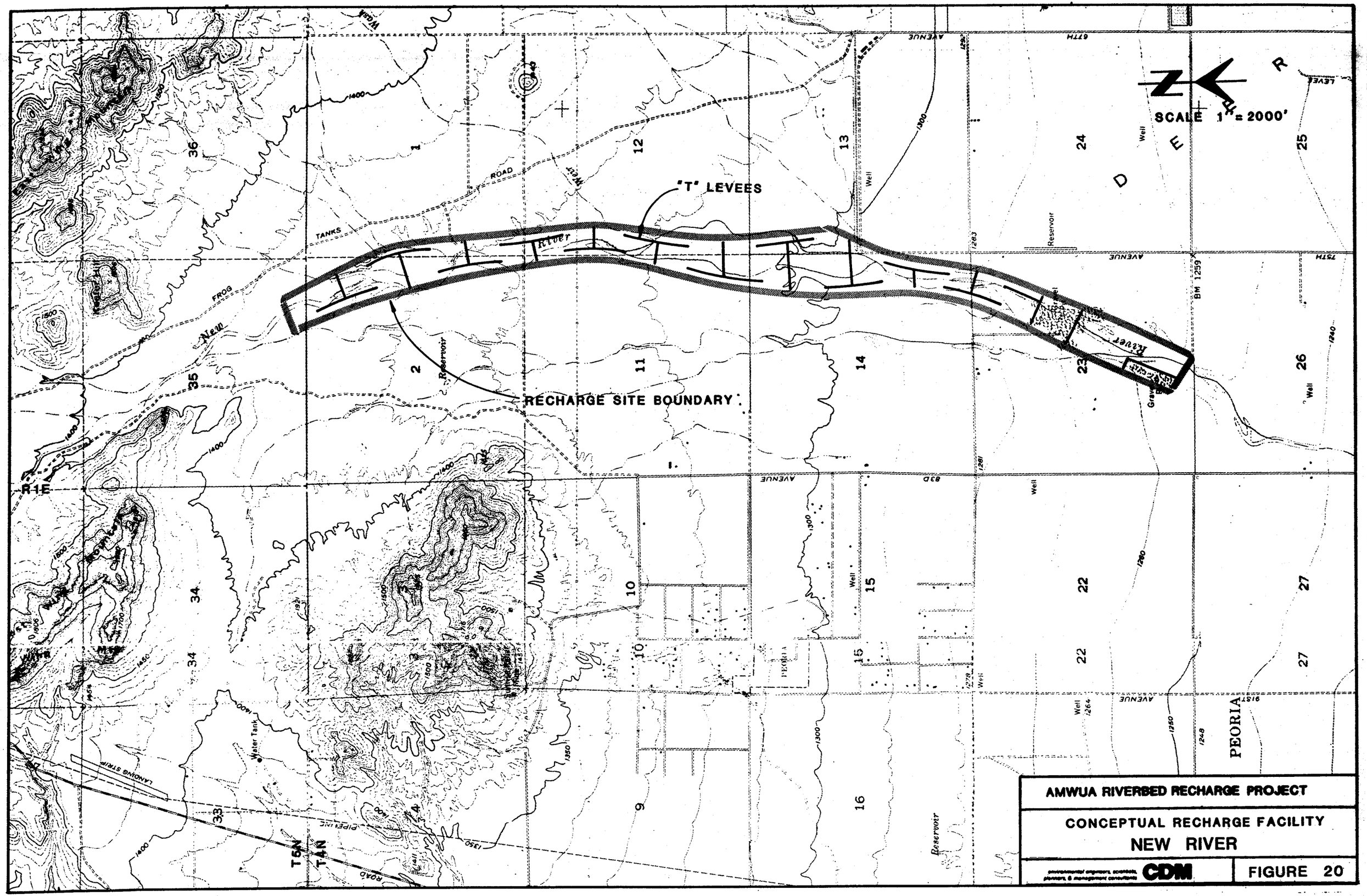


AMWUA RIVERBED RECHARGE PROJECT

CONCEPTUAL RECHARGE FACILITY
AGUA FRIA RIVER

CDM

FIGURE 19



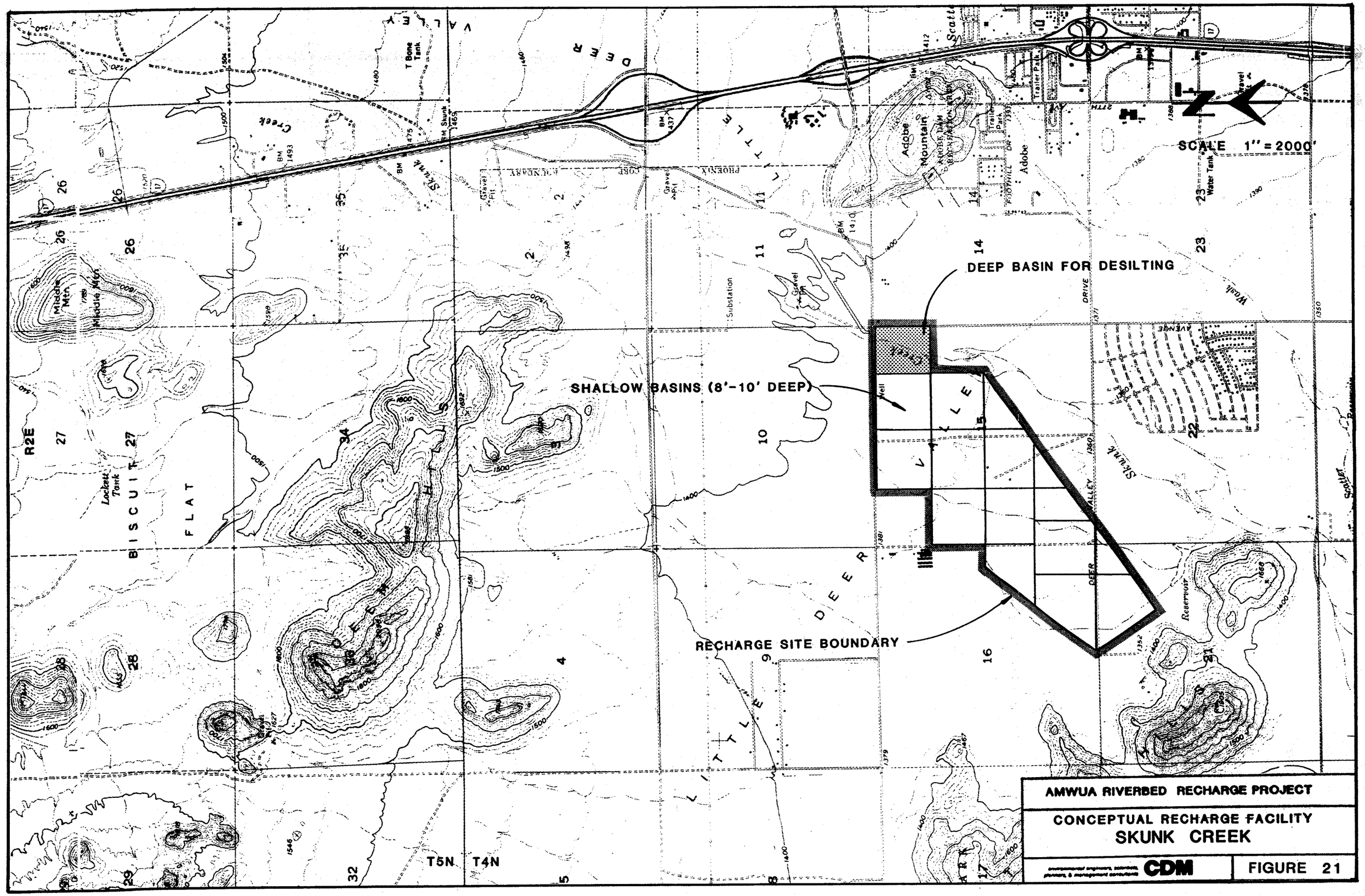
AMWUA RIVERBED RECHARGE PROJECT

CONCEPTUAL RECHARGE FACILITY

NEW RIVER

CDM

FIGURE 20

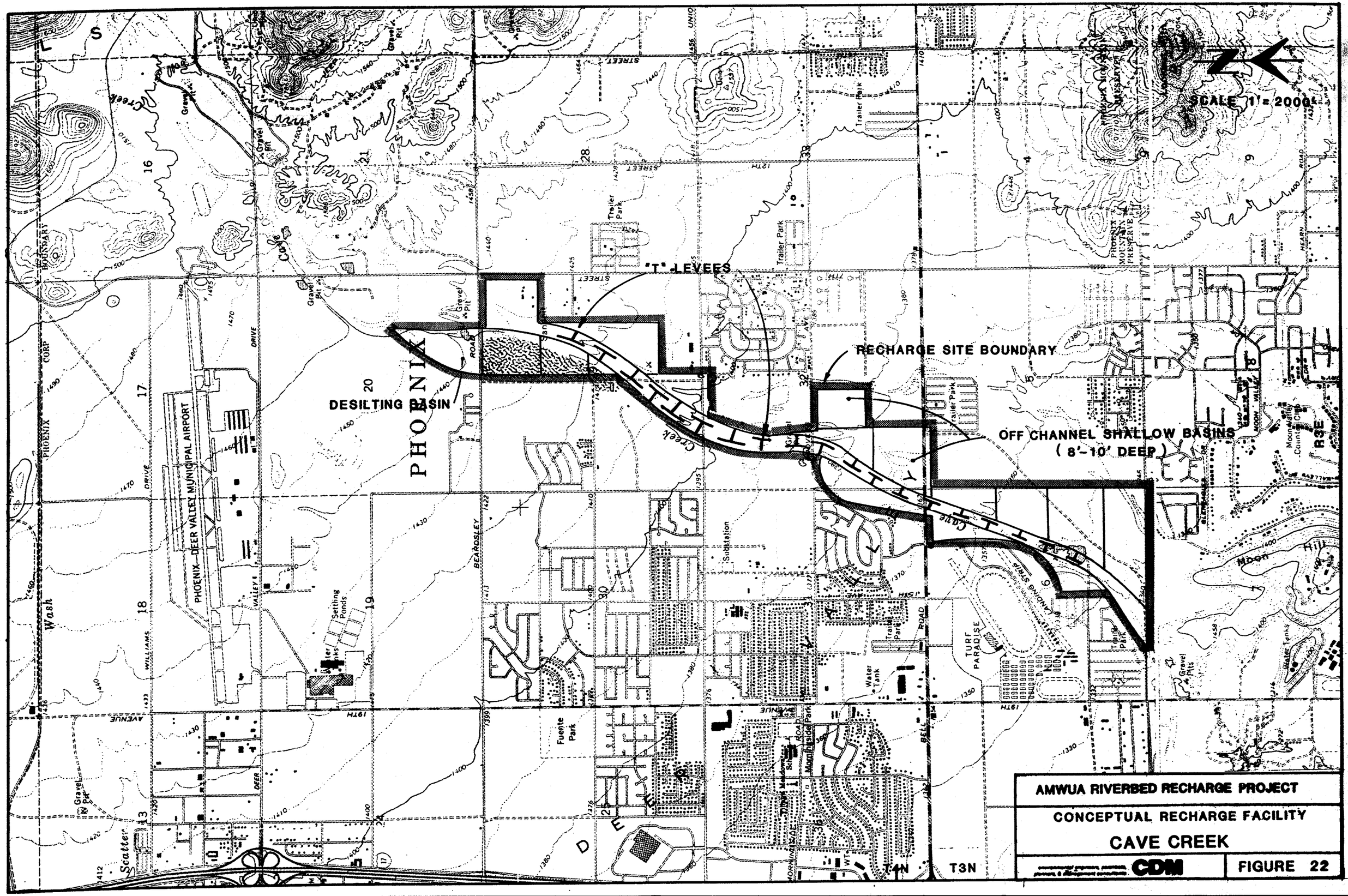


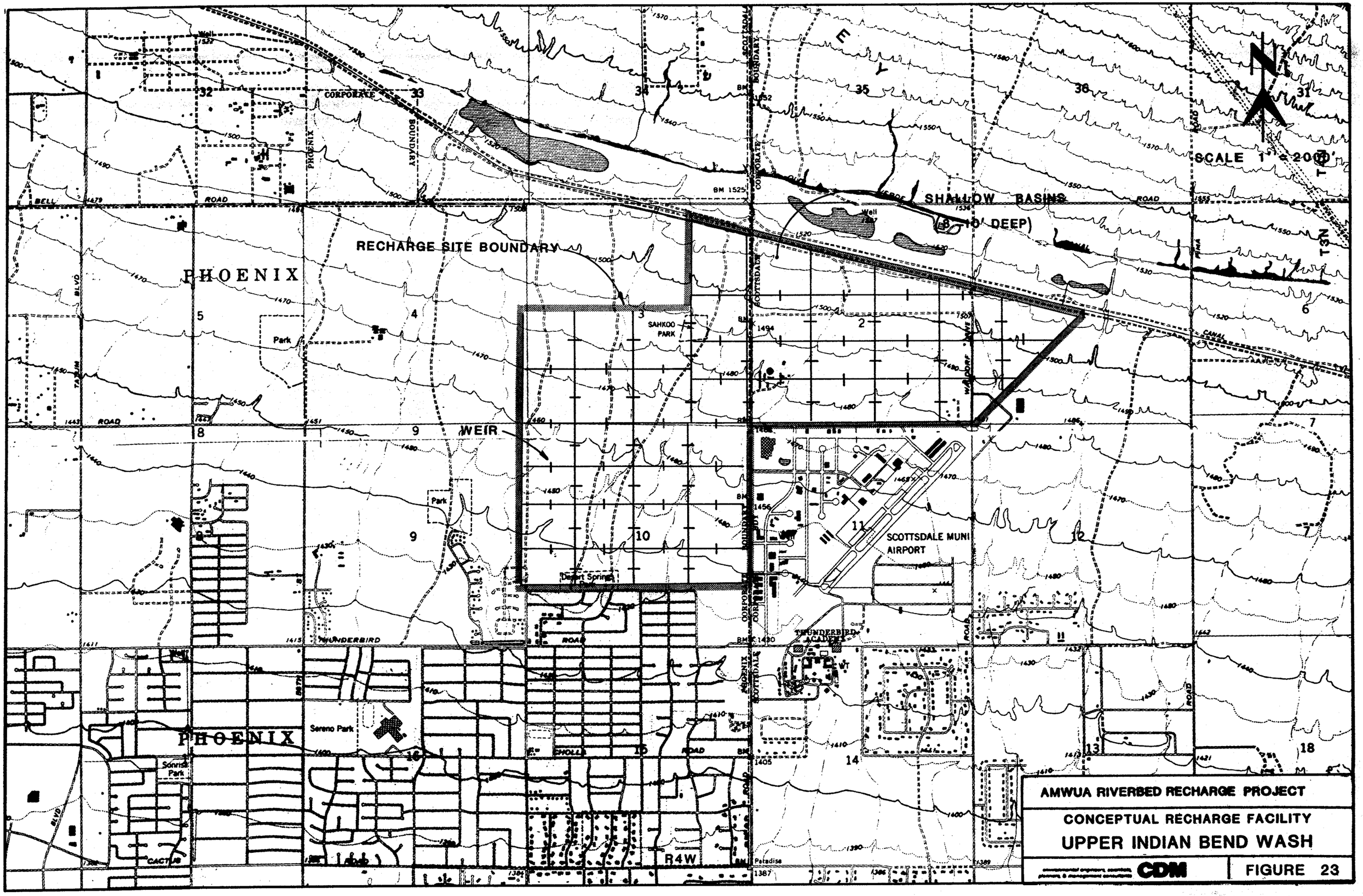
AMWUA RIVERBED RECHARGE PROJECT

CONCEPTUAL RECHARGE FACILITY
SKUNK CREEK

CDM

FIGURE 21


SCALE 1" = 2000'
"T" LEVEES
RECHARGE SITE BOUNDARY
DESILTING BASIN
OFF CHANNEL SHALLOW BASINS
(8'-10' DEEP)
PHOENIX
PHOENIX—DEER VALLEY MUNICIPAL AIRPORT
Cave Creek
Scatter Wash
Trailer Park
Gravel Pit
Sewing Ponds
Water Tanks
Substation
Fuente Park
TURF PARADISE
Moon Hill
Moon Valley
Moonwatch Country Club
PHOENIX MOUNTAINS PRESERVE
T4N
T3N
R3E
AMWUA RIVERBED RECHARGE PROJECT
CONCEPTUAL RECHARGE FACILITY
CAVE CREEK
CDM
FIGURE 22



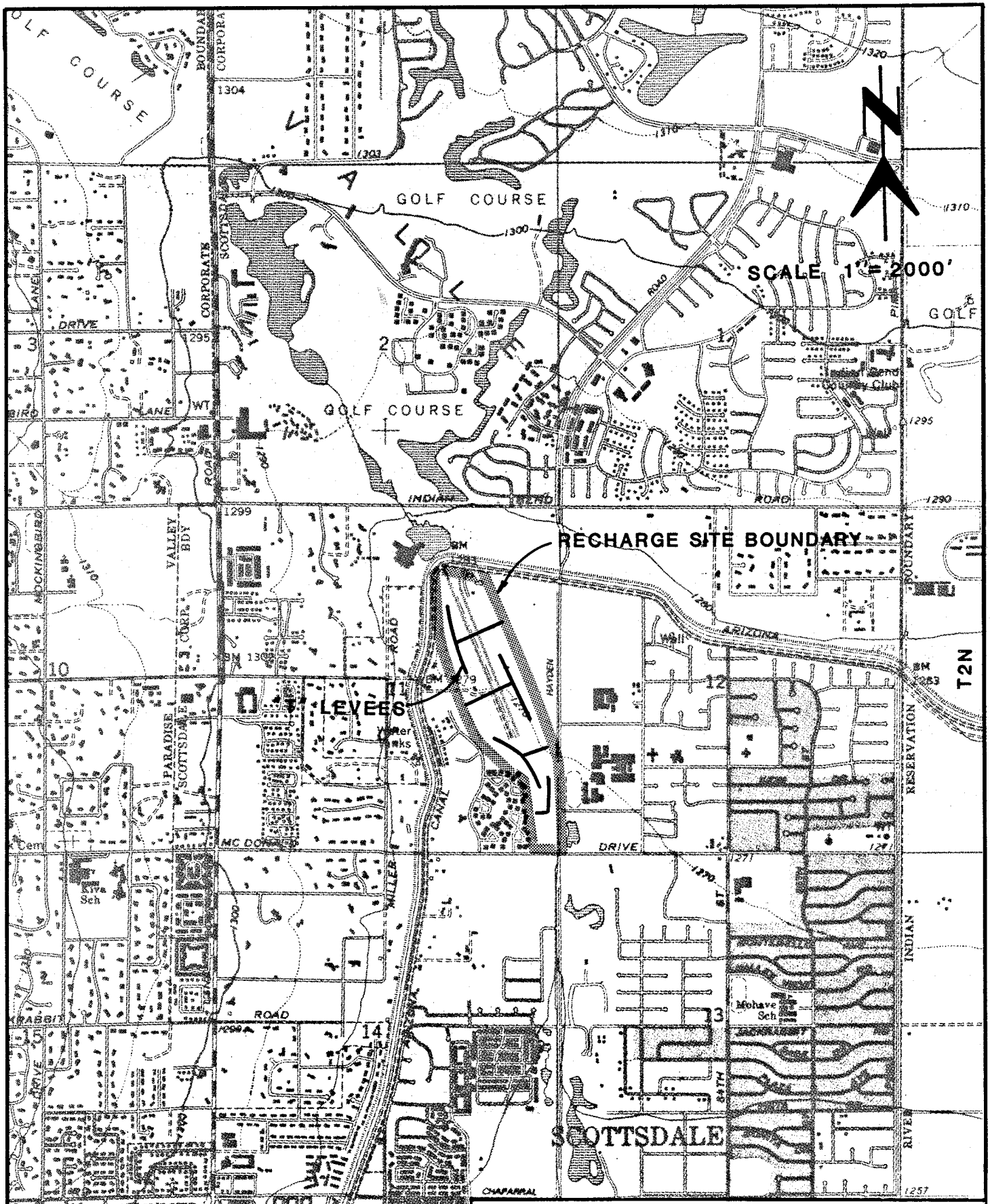
AMWUA RIVERBED RECHARGE PROJECT

CONCEPTUAL RECHARGE FACILITY

UPPER INDIAN BEND WASH

CDM

FIGURE 23

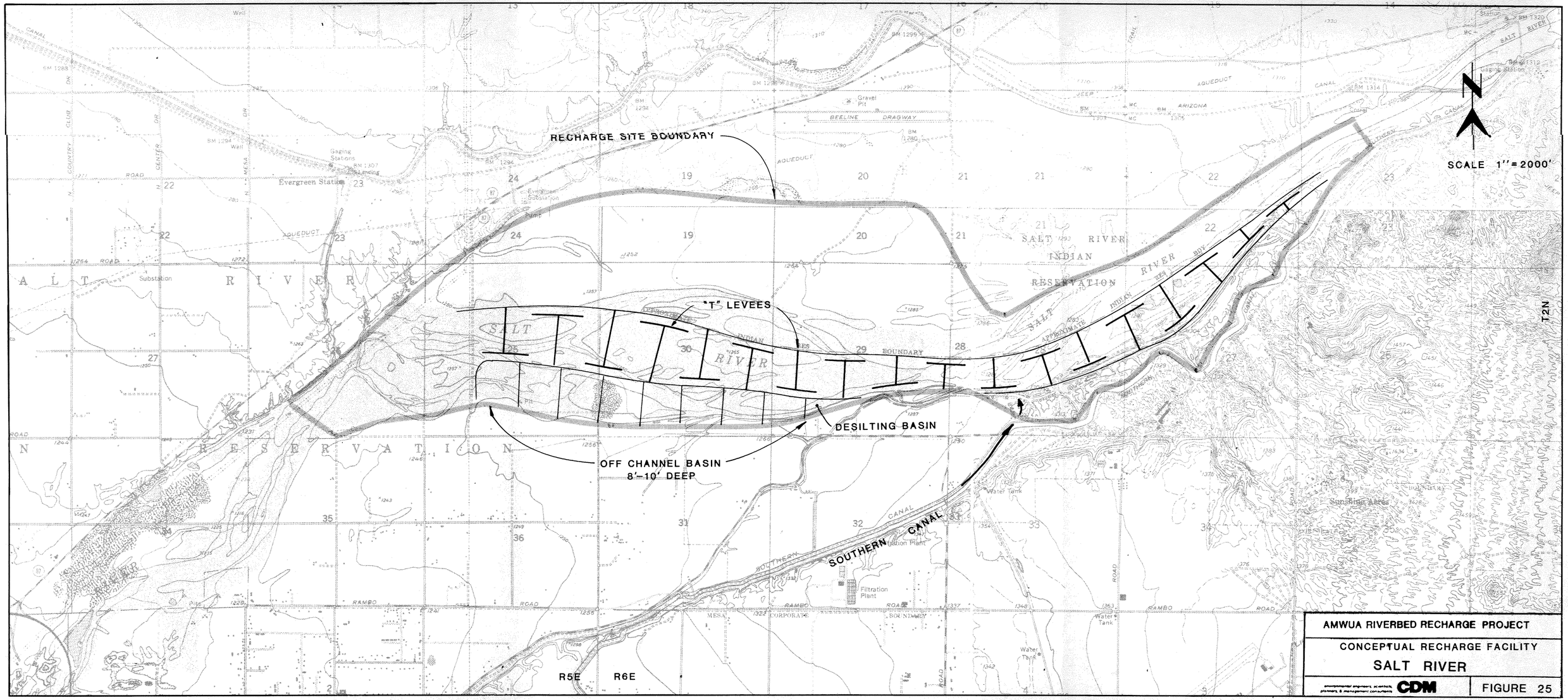


AMWUA RIVERBED RECHARGE PROJECT

CONCEPTUAL RECHARGE FACILITY
LOWER INDIAN BEND WASH

CDM

FIGURE 24



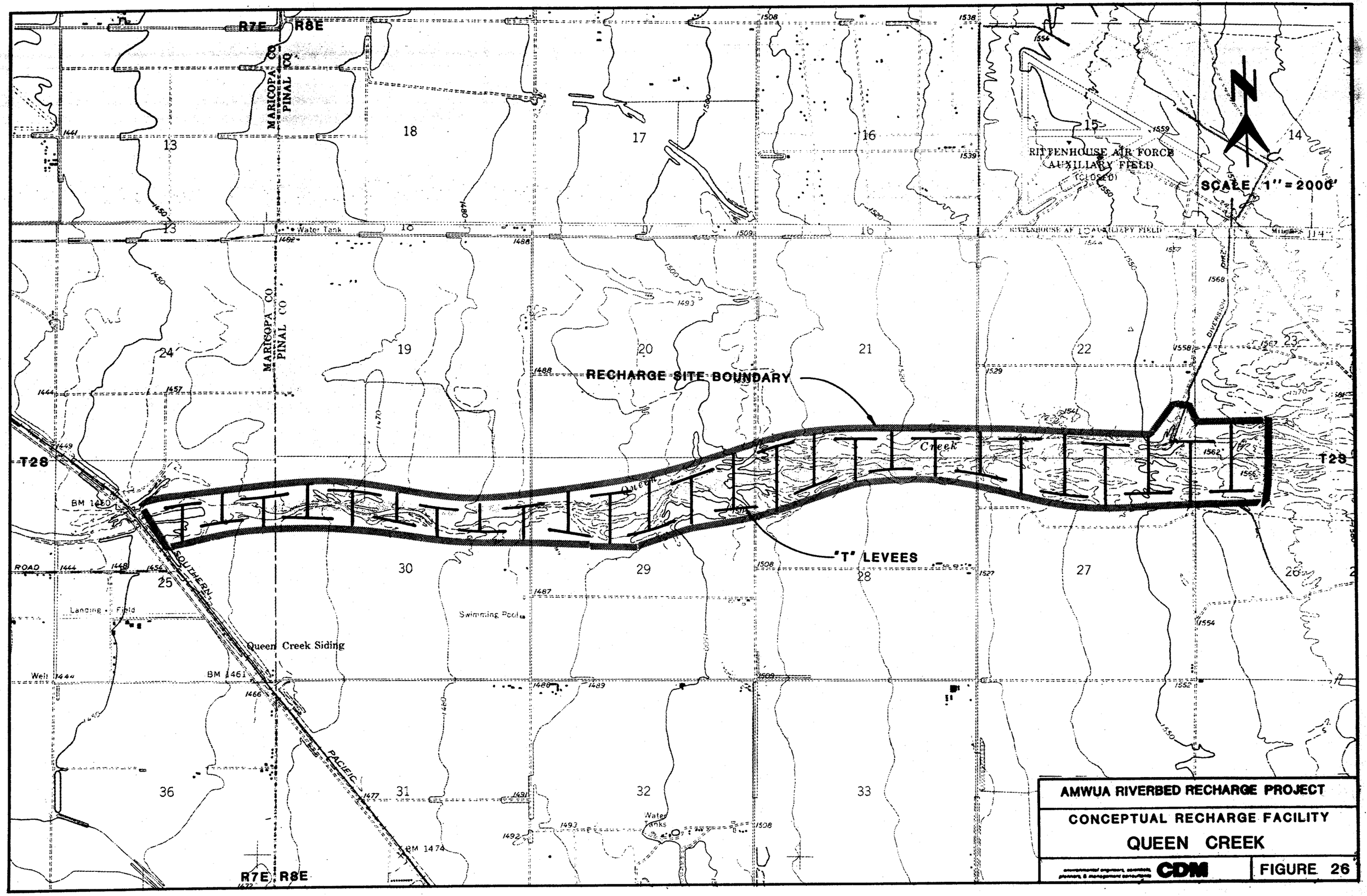
AMWUA RIVERBED RECHARGE PROJECT

CONCEPTUAL RECHARGE FACILITY

SALT RIVER

CDM

FIGURE 25



AMWUA RIVERBED RECHARGE PROJECT

CONCEPTUAL RECHARGE FACILITY

QUEEN CREEK

CDM

FIGURE 26

5.1 INTRODUCTION

This section of the report describes the preliminary designs and the criteria used to prepare them for the Agua Fria River and Salt River recharge facilities. The designs are shown on Plates 6 through 10. Also described are groundwater monitoring systems for each recharge facility. The monitoring networks are shown on Figures 27 and 28. Finally, detailed cost estimates are presented for these recharge systems.

As the project progressed from the conceptual design phase to the preliminary design phase, the focus of the evaluation changed from a general overview to a more detailed consideration of the selected sites. Conceptual designs for ten recharge systems were formulated and described in Section 4.0 of this report. The conceptual recharge systems were configured to make reasonable use of available vacant lands within each study area. Land ownership did not constrain the layout. The recharge area of each system was, in general, limited to vacant lands within the flood plain, except in the case of the Agua Fria and Salt Rivers, where the conceptual designs were limited to about 1,000 acres on the basis that similar facilities in southern California are about this size. In some cases, conceptual designs were also prepared for off-channel shallow basins, even though this type of recharge facility would cost more than in-channel recharge facilities. The off-channel systems provide a concept for a more permanent recharge facility that might be used in the future to artificially recharge local storm waters as well as imported waters.

Once the Agua Fria and Salt River areas were screened and selected, a more in-depth investigation of these sites was warranted for the development of the preliminary designs. To assist in the preliminary design, the recharge facilities on the Agua Fria and Salt Rivers were visited by the project team on July 11, 1986. The preliminary design activity focuses the engineering design process at a scale that allows the engineer to consider and deal with topographic, cultural and other constraints. Although preliminary designs cannot be used for construction, they do provide

valuable information on constraining characteristics of the land, data deficiencies, and reasonably accurate construction cost estimates.

5.2 GENERAL DESIGN CRITERIA

Prior to initiating the preliminary design process, the project team and AMWUA staff considered and decided on several issues that greatly affected the preliminary designs, including the design annual recharge rate, the size and type of facility, and use of privately versus publicly owned land. These issues are discussed in the following paragraphs.

5.2.1 ANNUAL RECHARGE RATE

AMWUA staff estimated that the available maximum surplus CAP water will be about 400,000 ac-ft/yr in the near future. However, as demands for CAP water increase in the future, the quantity of surplus water that might be available for recharge in the long term will probably be significantly less than the 400,000 ac-ft/yr figure. Consequently, it was decided that the recharge area for the preliminary designs would be sufficient to recharge about 200,000 ac-ft/yr at each site.

The sustained infiltration rates shown in Table 12 for each site represent one-half of the estimated infiltration rate because of the assumption of a 30-day alternating wet-dry cycle operational mode. Thus, on an annual basis, the percolation basins are wet only for about 180 days and the average infiltration rate for the year is one-half of the estimated rate.

It is noted that CAP water may not be available during the summer peak demand period for groundwater recharge. Since the annual recharge calculation includes dry periods totaling 180 days, the summer non-availability of CAP water should not affect the annual quantity of recharge. Further, experience in Southern California indicates that recharge rates using Colorado River Water are much higher than those obtained when storm waters are recharged. Therefore, actual percolation rates may be higher than the estimates derived in this study.

The actual infiltration rate is estimated to be 2 ft/day. With a 30-day wet-dry cycle, the effective infiltration rate over the entire site area is 1 ft/day (Table 12). Therefore, the corresponding area needed to recharge 200,000 ac-ft/yr is about 550 acres for each site, assuming water is available 365 days per year. As shown by the following calculation, the area required for recharge is: 200,000 AF/yr / 2 Ft/day x 180 days = 550 acres. However, infiltration rates have not been verified in either the Agua Fria or Salt River areas. Fortunately, sufficient area is available at both facilities to allow for expansion or contraction of the facility to accommodate the actual recharge rates and available water.

5.2.2 SALT RIVER FACILITIES

The Upper and Lower Salt River conceptual designs contained nearly 1,200 acres, which is substantially more than the required 550 acres. Since the recharge characteristics of the two facilities are similar, it was decided to layout the Salt River facility without regard to the former division (upper and lower) and instead begin the recharge facility at a location convenient to a future turnout location on the Southern Canal. Potential turnout locations were investigated during a field trip. The most favorable location, based on existing drainage channel size and distance to the Salt River was identified. The 550-acre Salt River recharge facility was then laid out downstream of this tributary drainage channel. However, this does not preclude moving the proposed interconnection to deliver recharge water directly to the riverbed and allowing it to flow into the recharge facility.

5.2.3 PUBLICLY OWNED LANDS

As previously indicated, the use of publicly owned lands should expedite the final design because land purchases and/or easements for private lands would not be required. Further, the recharge facilities could be constructed more cheaply by avoiding the cost of purchase and/or lease of privately owned lands.

Land ownership, as indicated on the individual site maps, was reviewed to determine if sufficient publicly owned lands within the conceptualized recharge plan areas were sufficient to develop the 550-acre recharge facility. For the Agua Fria, it was determined that the amount of publicly owned lands was sufficient. Therefore, it was decided to configure the preliminary design to exclude privately owned lands. The available information on the Salt River indicated that the Salt River floodplain was divided between the Indian Reservation to the north, and public lands to the south. In keeping with the concept of developing recharge facilities only on public lands, the preliminary design was laid out south of the reservation boundary. During the Draft Report review process, it was discovered that the Reservation includes nearly all of the Salt River channel. (All affected plates and figures were subsequently modified to reflect this new information) . Consequently, the Salt River preliminary design overlies reservation lands. Conditional use permits, or their equivalent, will need to be obtained from the Indian community prior to initiating the implementation process.

5.2.4 IN-CHANNEL RECHARGE FACILITIES

Because of the adequate availability of publicly owned lands within each recharge area, and because of the need to rapidly implement the recharge system, it was concluded that preliminary designs would be prepared only for in-channel "T" levee spreading facilities. As indicated previously, this type of recharge facility is easily and cheaply constructed. The system should provide the desired recharge capability at the earliest time and at the lowest cost.

5.3 "T" LEVEE RECHARGE BASIN DESIGN

As indicated in Section 4.2.1 of this report, "T" levee basins are constructed within the active areas of the river channel by dozing "T" configured levees. The spacing between "T" levees is a function of the slope of the river channel and the desired depth of water on the upstream face of the "T" levee. In the following paragraphs, the components of the "T" levee system are described in more detail.

5.3.1 LEVEE DESIGN

For the preliminary design, the depth of water upstream of the levee was set at five feet, with the spacing adjusted in each river channel so that the entire area between the consecutive "T" levees would be wetted. The height of the levees was set at six feet. It was assumed that the "dozed" levees would stand at a natural angle of repose of 3 horizontal to 1 vertical (3:1). No data were available to define the slope characteristics, but the 3:1 slope ratio is considered a worst case judging from prior experience in Orange County and the field investigation. If lower levee side slope ratios, such as 2.5:1 or 2:1, are attainable, then the amount of earthwork required to form the "T" levees could be reduced.

5.3.2 "T" BASIN SPACING

The spacing between the "T" levees, or length (measured along the river flow line) of each "T" basins, is a function of channel slope and the five-foot downstream depth. The average slope of the Agua Fria and Salt River systems was 0.3 and 0.2 percent, respectively. Consequently, the average length of the "T" basins is 1,300 and 1,500 feet, respectively. The total lengths of both the Agua Fria and Salt River recharge facilities were configured at about 16,000 feet.

The topographic control available for the preliminary design was poor. For the Agua Fria River, the only topographic data available had 10-foot contour intervals. For the Salt River, 4-foot contour interval data were available and obtained. Normal accuracy standards are such that the topographic information interpreted from the survey is accurate to one-half of the contour interval. Thus, the channel elevations along the Agua Fria are accurate to plus or minus 5 feet. In both cases, the available topographic information is deficient to base a final design. Also, the level of accuracy precludes the development of a responsive preliminary design. Therefore, the "T" levees were placed at average spacings rather than at spacings that would vary along specific reaches, thus taking advantage of the existing terrain and minimizing the movement of channel bottom.

5.3.3 DESIGN FLOW RATE

The overall recharge rate was previously established at 200,000 ac-ft/yr. or about 275 cfs of continuous flow. However, because of annual canal maintenance shut-downs, seasonal capacity limitations, and possible non-availability of surplus water during peak demand periods, the annual rate cannot be used as a design rate. For purposes of the preliminary design, a flow rate of 400 cfs was assumed for designing conveyance systems.

5.3.4 INTERBASIN CONVEYANCE CHANNELS

The horizontal portion of the "T", together with the constraining levee or natural channel bank, form the opposing banks of the interbasin conveyance channel. The width of the channel must be sufficient to reduce flow velocities to below eroding velocities. The interbasin channels were configured to pass the design flow at less than 5 feet per second, thus minimizing levee or bank erosion.

It should be noted that the interbasin flow rate will decrease from the upstream to the downstream portions of the recharge facility because of the percolation of recharge water.

5.4 TURNOUT AND CONVEYANCE SYSTEM

The Agua Fria and Salt River recharge facilities have been designed to receive CAP water from local irrigation canals. Turnout structures and appurtenances will need to be constructed at each canal. In the following paragraphs, the modification to existing irrigation canals that will be required to serve the recharge facilities are described.

5.4.1 AGUA FRIA RIVER

CAP water for the Agua Fria River recharge facility is proposed to be discharged into the Beardsley Canal via the Maricopa Water District (MWD) CAP turnout. The capacity of the CAP turnout to the Beardsley Canal was

determined to be sufficient to handle both the needs of the Agua Fria recharge facilities and the Maricopa Water District (MWD). The CAP water would be conveyed approximately 3 miles in the Beardsley Canal to a proposed turnout at a large dry wash that is immediately tributary to the Agua Fria River. The turnout location is shown on Plate 6.

The MWD was contacted to determine the capacity of the Beardsley Canal and availability of unused capacity. Based on these discussions, it appears that the canal could be utilized to convey about 180,000 ac-ft/yr. The canal capacity is estimated to be limited to about 300 cfs, but could be increased by raising and strengthening several levee segments. A preliminary cost estimate was prepared for increasing the canal capacity so as to allow the simultaneous conveyance of CAP water and Beardsley water. This cost is included in the cost to construct the recharge facility.

5.4.2 SALT RIVER

CAP water can be conveyed to the Salt River recharge facility either by discharging it directly into the river from the proposed CAP/SRP Interconnection Facility at the Granite Reef Dam or via the SRP's Southern Canal to a proposed turnout structure to be constructed closer to the recharge facilities. As indicated earlier, a large dry wash adjacent to the Southern Canal was selected for the turnout location, as shown on Plate 8.

The actual unused capacity available in the Southern Canal is presently under review by SRP. However, because the capacity of the Southern Canal is relatively large in comparison to the proposed recharge flow rate of 400 cfs, it was assumed that adequate capacity exists within the Southern Canal to convey the recharge water. It should also be recognized that use of the Southern Canal and the construction of the new turnout system may not be neccessary if the proposed CAP/SRP Interconnection Facility at the Granite Reef Dam is constructed with a turnout capability for discharging directly into the Salt River below the Granite Reef Dam.

5.4.3 TURNOUT SYSTEM

For purposes of the preliminary design, a "drop" turnout structure, including conduits with energy dissipaters, was assumed for cost estimation. Design criteria for each of these structures would be obtained from the canal operators prior to final design. Detailed elevation, location and canal as-built data would also be necessary.

Flow measurement would be accomplished by constructing a Parshall flume equipped with a strip chart recorder at each turnout.

5.5 MONITORING PROGRAM

An intergral part of a groundwater recharge project is a groundwater monitoring system. The system should be capable of detecting changes in water quality that may be directly or indirectly attributable to the recharge operation. Consequently, the monitoring network should be installed prior to the initiation of recharge. The monitoring system should also provide information necessary to establish rates and directions of movement of the recharged water.

A preliminary groundwater monitoring network was developed for both the Agua Fria and Salt River recharge facilities. Possible well locations for the Agua Fria and Salt River areas are shown on Figures 27 and 28, respectively. Twelve monitoring wells form the Agua Fria well network. The average depth of these wells is approximately 380 feet. The Salt River groundwater monitoring network consists of 14 wells, having an average depth of about 415 feet. Typical well construction details are shown on Plate 10.

5.6 ESTIMATES OF RECOVERABLE RECHARGE WATER

5.6.1 INTRODUCTION

Nonrecoverable losses of recharge water occur through free surface evapora-

tion, evapotranspiration and satisfaction of soil moisture deficit in the unsaturated zone. Estimates of water loss for the Agua Fria and Salt River recharge facilities were formulated based on the preliminary design recharge areas and estimated sustained infiltration rates.

5.6.2 FREE SURFACE EVAPORATION

Free surface evaporation occurs as the water is standing in the recharge basins. It is estimated using lake evaporation data, which was based on pan evaporation data and its associated adjustment coefficient for the State of Arizona (U.S. Department of Commerce, 1968). Table 19 shows the expected surface evaporation for the recharge sites. The amounts were computed by assuming that the entire recharge area (550 acres at each site) would be wetted continuously. Thus, the computed values represent the maximum possible evaporation loss of the recharge water. The computed values amount to less than 4,000 ac-ft/yr, which is only about 2 percent of the 200,000 ac-ft/yr of water recharged for each of the facilities.

5.6.3 EVAPOTRANSPIRATION

Evapotranspiration is the loss of water caused by plant consumption. It is assumed to be zero for both sites because: (1) general maintenance activities at the sites should prevent establishment of phreatophytes in and adjacent to the recharge areas; and (2) any evapotranspiration from phreatophytes that might become established at the site would not increase the loss to the atmosphere because surface evaporation rates exceed evapotranspiration rates.

5.6.4 SOIL MOISTURE DEFICIENCY

It is unlikely that a significant soil moisture deficiency exists at either site. Frequent and long-duration releases from upstream dams have been made during the last several years on the Salt River. Extensive flood flows also occurred in 1981 on both rivers. A portion of these flows infiltrated the Agua Fria recharge site and replenished the soil moisture

TABLE 19

ESTIMATE OF RECOVERABLE WATER FOR THE AGUA FRIA AND SALT RIVER RECHARGE SITES

Feasibility Study Report — AMWUA Riverbed Recharge Project

Recharge Site	Design Recharge Area (ac)	Estimated Average Sustained Infiltration Rate (ft/day)	Annual Recharge Rate (kaf/yr)	Surface Evaporation[a] (kaf/yr)	Evapotrans-piration (kaf/yr)	Soil Moisture Deficiency[b] (af)	Recoverable Recharge Water[c] (kaf/yr)
Agua Fria River	550	1.0	200	3.5	0	0.8	196.5
Salt River	550	1.0	200	3.4	0	0.8	196.4

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a Lake evaporation; based on pan evaporation data. Source: U.S. Department of Commerce, 1968, Climatic Atlas of the United States, Iso-Contour Maps for Evaporation, State of Arizona.

b Based on data for a fine sandy loam, where total available water between field capacity and 15 bars is 18 inches for upper 10 feet of vadose zone. Source: Donahue, et al. (1977).

c Difference between annual recharge rate and sum of surface evaporation, evapotranspiration, and soil moisture deficiency - a one-time investment and is negligible over a 25-year period.

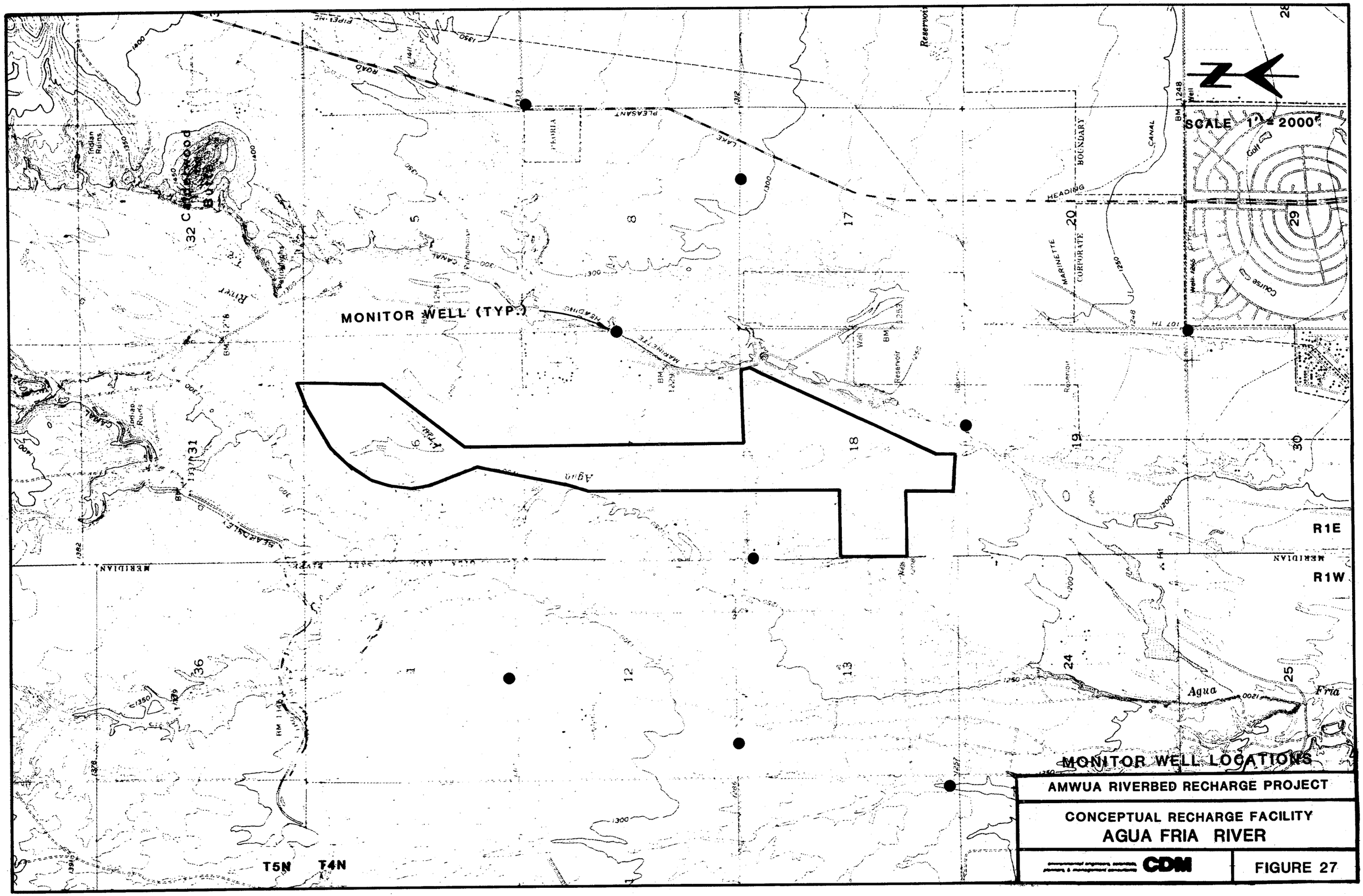
previously lost to evaporation. In addition, groundwater level profiles, as shown on the geologic cross section for the area (Figure 2), indicate a significant water level rise between 1972 and 1984-85. The water level rise supports the theory that infiltration through the unsaturated zone must have occurred during the period 1972-1985.

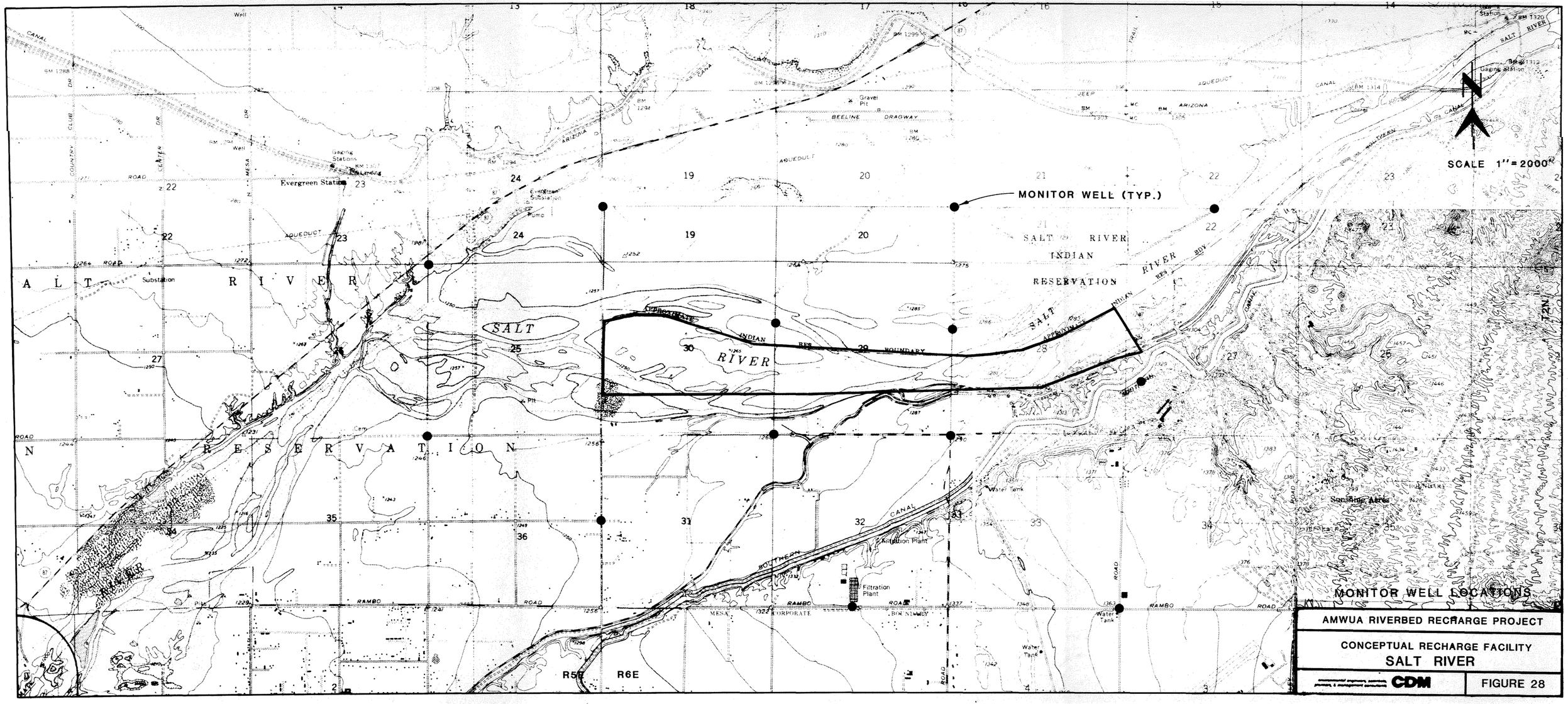
However, some soil moisture deficiency may have occurred in the upper-most portion of the soil horizon since the time of the flooding and controlled releases. Consequently, soil moisture deficiency was assumed to be present in the upper ten feet of the vadose zone.

Soil moisture deficiency is the amount of water necessary to bring the ten feet of vadose zone up to .33 bars pressure, or to field capacity, which is the point at which drainage ceases to occur after a sustained time period. Field capacity is analogous to specific retention in the saturated zone. A fine sandy loam is most typical of the soils in the site areas. Based on a fine sandy loam, the total deficiency between wilting point (15 bars pressure) and field capacity is 18 inches per foot (Donahue, et al., 1977). Thus, the amount of water required to satisfy the initial soil moisture deficiency at the recharge sites is estimated at less than 1,000 ac-ft per site, or less than 0.5 percent of the amount of water recharged the first year. After the first season, soil moisture deficiencies would drop to zero.

5.6.5 RECOVERABLE WATER

Since the soil moisture deficiency and evapotranspiration can be neglected, the only significant loss over the long period is from surface evaporation. Consequently, about 98 percent of the recharged water is recoverable.


MONITOR WELL (TYP.)
SCALE 1" = 2000'
R1E
R1W
T5N
T4N
Agua
Fria
MONITOR WELL LOCATIONS
AMWUA RIVERBED RECHARGE PROJECT
CONCEPTUAL RECHARGE FACILITY
AGUA FRIA RIVER
CDM
FIGURE 27


MONITOR WELL (TYP.)
SCALE 1" = 2000'
SALT RIVER INDIAN RESERVATION
SALT RIVER
SALT RIVER INDIAN RESERVATION
Evergreen Station
Substation
Gravel Pit
BEELINE DRAGWAY
ARIZONA
AQUEDUCT
CANAL
SOUTHERN
Filtration Plant
Water Tank
Sunshine Acres
RAMBO ROAD
MESA CORPORATE BOUNDARY
R5E
R6E
MONITOR WELL LOCATIONS
AMWUA RIVERBED RECHARGE PROJECT
CONCEPTUAL RECHARGE FACILITY
SALT RIVER
CDM
FIGURE 28

PERMITTING REQUIREMENTS AND DATA DEFICIENCIES 6.0

6.1 INTRODUCTION

Implementation of CAP recharge programs at the Agua Fria and Salt River sites will require several major preliminary activities. First, all the necessary permitting with various local, state and federal agencies would have to be performed prior to recharge commencement. Secondly, data deficiencies would need to be addressed including the implementation of a monitoring program to develop baseline information. Finally, development of final designs for the recharge sites would occur once the necessary data deficiencies are satisfied.

The following sections describe these activities in detail and provide information to enable the smooth and timely implementation and construction of recharge sites on the Agua Fria and Salt Rivers.

6.2 PERMITTING NEEDS

Several permits would have to be obtained before implementation of a recharge program on the Agua Fria and Salt Rivers. Approximately six permits would be necessary from local, state and federal agencies to commence recharge activities. Table 20 lists the permits that may be required, the agencies involved, and the time schedule necessary to obtain the permits.

One federal permit, a 404 permit from the U.S. Army Corps of Engineers, would need to be obtained. This permit is required based on Section 404 of the Clean Water Act, which stipulates a permit is necessary for dredged or fill material within a river system in the United States. The application would require a general environmental assessment and would take at least 60 days to obtain after submittal of an application.

TABLE 20

PERMITS AND SCHEDULES REQUIRED TO IMPLEMENT GROUNDWATER RECHARGE PROGRAM

Feasibility Study Report — AMWUA Riverbed Recharge Project

Necessary Permit	Agencies Involved	Time Required to Process Permit
404 Permit	U.S. Army Corps of Engineers	60 days
Recharge Permit	Arizona Department of Water Resources	90 days
Groundwater Discharge Permit	Arizona Department of Health Services	7 to 9 months
Possible NPDES Permit	Arizona Department of Health Services and U.S. Environmental Protection Agency	60 days
Floodplain Use Permit	Maricopa Flood Plain Management Agency and city flood plain management agencies within Salt River Basin. (Phoenix, Scottsdale, Tempe, etc.)	30 days
Possible Zoning Variance	Maricopa and Pinal Counties, and cities within recharge areas	30 days

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Two to three permits would be required from Arizona state agencies. As a result of the passage of Arizona House Bill 2209, a groundwater recharge permit would have to be obtained from the Arizona Department of Water Resources (ADWR). The permit would include a report describing the "Area of Hydrologic Impact" and mounding considerations. In addition, a hydrogeologic report would be necessary, but could be similar to the Arizona Department of Health Services' (ADHS) groundwater discharge permit discussed as follows.

The ADHS permit is a groundwater quality discharge permit necessary for any surface impoundment discharging to groundwater. A notice of disposal (NOD) would initially be submitted which describes the type and volume of discharge. Then, a formal permit application would proceed with a hydrogeologic and groundwater quality report, and a complete discharge and potential mitigation plan. Generally, a formalized permit is granted six to eight months after permit application.

A National Pollutant Discharge Elimination System (NPDES) permit may be necessary. A letter to ADHS, followed by review by EPA with ADHS would determine if an NPDES permit is necessary. The process would probably take at least 60 days.

One or two local permits may be required. Maricopa Flood Plain Management Agency, and possibly other municipal flood plain agencies, will probably require a flood plain use permits. This permit can generally be granted within one month of application. Finally, a zoning variance may be required if the zoning of areas within the recharge sites is incompatible with groundwater recharge use.

6.3 DATA DEFICIENCIES

Both the Agua Fria and Salt River recharge sites have numerous data deficiencies which need to be addressed prior to final design and construction. Table 21 lists these deficiencies and recommends programs to satisfy them. The estimated cost associated with each deficiency correction program is also indicated in the table.

Lack of detailed hydrogeologic information is the major area of data deficiencies for the recharge site areas proposed for the Agua Fria and Salt Rivers. The additional information required would be used to (1) finalize recharge site designs, (2) establish baseline hydrogeologic conditions, and (3) procure the required permits from the appropriate regulatory agencies. Hydrogeologic information needed includes groundwater quality, groundwater levels, depth to water, aquifer hydraulic characteristics, vadose zone characteristics, infiltration characteristics, and subsurface geology. Some of this information was obtained during the initial site screening process using available well logs. However, in the vicinity of the recharge sites, few wells are present to provide the level of detail required to implement the recharge program. For this reason, the preliminary design calls for the construction of 12 to 14 new exploratory wells for each site. These wells will also serve as long-term monitoring points. The location of these wells for the Agua Fria and Salt Rivers is shown on Figures 27 and 28, respectively. Their schematic design is shown on Plate 10.

Surficial soil and vadose zone characteristics should also be obtained prior to final design and commencement of recharge operations. Field infiltration rates should be determined, particularly for the Agua Fria River since no field measurements have been made at this site. Infiltration rates can be obtained within the proposed sites by dual-ring infiltrometer tests or by measuring a controlled discharge into a specially constructed recharge basin. Neutron logging in shallow piezometers prior to and after recharge should yield information on soil moisture deficiency and moisture content beneath the two sites to determine accurate estimate of storage capacity and amount of recoverable water. These estimates will probably be required for a state recharge permit.

Land ownership and accurate estimates of topography will be necessary for the preparation of final designs and construction. A land plat search will help identify the specific public agencies which have jurisdiction over the land within the proposed recharge sites so that conditional use permits can be obtained. Detailed site topographic surveys would also be necessary for each site pror to preparing final designs. Ideally, topographic contours

to the nearest two feet should be established to accurately and efficiently design and construct the sites.

6.4 FINAL DESIGNS AND MONITORING PROGRAM

Final designs should provide specific grading plans and profiles, and specific siting, neutron access tubes, and monitor wells. A specific monitoring program for obtaining water quality, water level, and soil moisture data, as well as aquifer hydraulic characteristics, should be developed for pre- and post-construction, and operational monitoring. Frequency of testing and sampling should be established. The number and type of constituents for the groundwater quality testing should also be established. And, sampling procedures and quality assurance/quality control programs should be developed.

6.5 SCHEDULE FOR PROJECT IMPLEMENTATION

One of the most important objectives of the AMWUA Riverbed Recharge Project is to initiate recharge activities as soon as possible. To get to the point that CAP water is actually being recharged, several intermediate steps need to be completed, including: 1) conducting a detailed hydrogeologic investigation at each site to support preparation of final designs and to meet all permit requirements; 2) preparing final designs, plans, and specifications for construction of recharge facilities; and 3) preparation and submittal of all permit applications, as indicated on Table 20.

A schedule of these activities is summarized in Table 21. The hydrogeologic investigation will consist of: 1) construction, testing, and sampling of monitoring wells in, and around, each recharge site; 2) conducting infiltration tests at each site; 3) preparing a long-term monitoring program for each site using the existing wells and new monitoring wells; and 4) preparing detailed topographic maps of the site area. As indicated on Table 21, the hydrogeologic investigations will require up to ten months to complete. Drilling activities require the

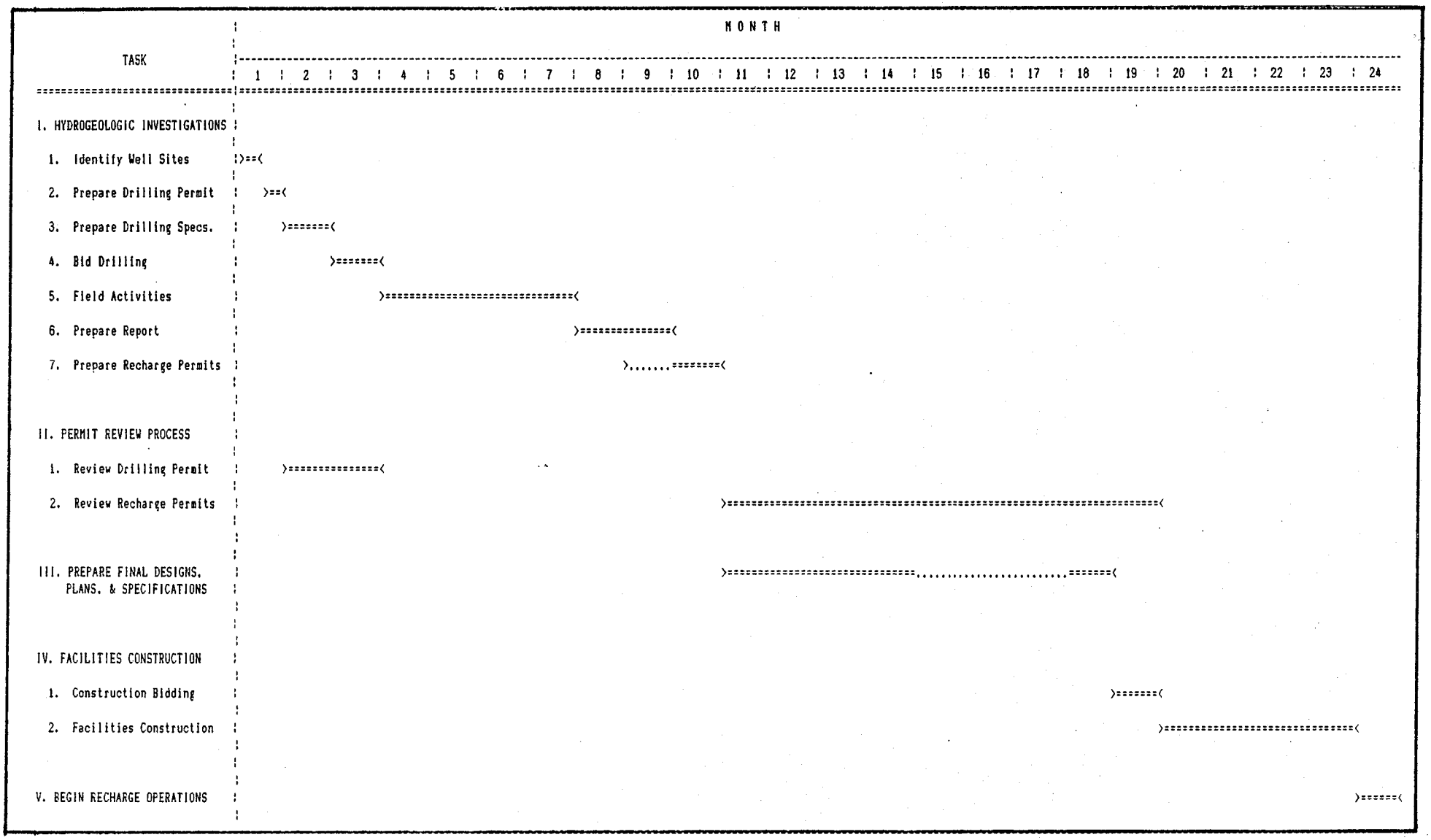
greatest amount of time to complete. The duration of the field activities can be shortened if more drill rigs can be mobilized to the sites and the bidding process can be fast-tracked.

Preparation of the final designs, plans, and specifications will be completed concurrently with the preparation and review of permit applications. Final design activities will require about four months to complete. The permit review process could take as much as nine months to complete, unless the reviewing agencies can conduct their reviews on a fast-track basis.

TABLE 21

SCHEDULE FOR PROJECT IMPLEMENTATION

Feasibility Study Report — AMWUA Riverbed Recharge Project



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7.0 INTRODUCTION

In this Section, the estimated costs are summarized for obtaining permits, finalizing designs, and constructing, operating and maintaining recharge facilities on the Agua Fria and Salt Rivers. The costs associated with each of these phases of project implementation are discussed in the following paragraphs.

7.1 MITIGATING DATA DEFICIENCIES AND OBTAINING PERMITS

In Section 6, the data deficiencies were identified which will require mitigation to complete both the permit process and the final designs of the Agua Fria and Salt River Recharge Facilities. Table 22 summarizes, for each river system, the data deficiencies, the recommended mitigations, and their associated costs. The estimated costs for mitigating data deficiencies for the Agua Fria and Salt River Systems is $95,000 and $90,000, respectively. This costs excludes the design and construction of monitoring wells, which are addressed as part of facilities construction. Filing permits may have an incidental cost.

7.2 COST OF RECHARGE FACILITIES

Quantities of materials were scaled or computed from information derived from the preliminary design drawings. Unit cost information, based on current price levels (ENR 4330) were determined and used to compute total costs.

The costs associated with constructing the Agua Fria and Salt River recharge facilities and monitoring systems are about $1.3 and $1.6 million, respectively, as shown on Table 23.

As indicated earlier, the topographic information available for the preliminary design is considered poor. Since the earthwork construction constitutes the majority of each recharge project's cost, considerable variation from earthwork computations done during this phase of work may

TABLE 22

DATA DEFICIENCIES FOR AGUA FRIA AND SALT RIVER RECHARGE SITES

Feasibility Study Report — AMWUA Riverbed Recharge Project

Site	Deficiency	Recommendation	Estimated Cost
Agua Fria	Water Quality: Few well water quality data in vicinity of recharge site.	Do survey of domestic and public wells and sample wells near site. Drill monitor wells (included in facilities cost).	$ 10,000
	Water Levels: Scanty data in northwest portion of study area.	Well survey and measure water levels with water quality.	Incorporated into w.q.
	Aquifer Properties: Lack of data in the northern portion of study area.	Aquifer tests on existing wells	$ 20,000
	Infiltration: Accurate estimates of sustained infiltration rates.	Percolation tests.	$ 20,000
	Storage Capacity: Better estimates of vadose zone moisture content.	Neutron logging of drill holes.	$ 10,000
	Subsurface Geology: Lack of data in middle portion of proposed recharge area.	Cuttings analyses of new monitor wells or boreholes.	$ 5,000
	Land Ownership: No identification of specific public landowners at recharge site.	Land plat search.	$ 10,000
	Topography: 10-foot contours not accurate enough for final design.	Survey site to nearest 2-foot contours	$ 20,000
Salt River	Water Quality: Lack of data within proposed portion of recharge area.	Well survey and sampling program. Drill monitor wells (included in facilities cost)	$ 15,000
	Water Levels: Lack of data within recharge area.	Well survey and measurements.	Incorporated into w.q.
	Aquifer Properties: Lack of data in south-western & northeastern portion of recharge area.	Aquifer tests on existing wells	$ 15,000
	Infiltration: Accurate measurements of sustained infiltration rates.	Percolation tests.	$ 20,000
	Storage Capacity: Measurements of vadose zone soil moisture content.	Neutron logging of boreholes.	$ 10,000
	Subsurface Geology: Lack of data in proposed recharge area.	Cuttings analyses of new monitor wells or boreholes.	$ 5,000
	Land Ownership: No identification of specific public landowners of recharge site.	Land plat search.	$ 5,000
	Topography: 4-foot contours not accurate enough for final design.	Survey site to nearest 2-foot contours	$ 20,000

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TABLE 23

PRELIMINARY DESIGN RECHARGE FACILITY CONSTRUCTION COSTS

Feasibility Study Report—AMWUA Riverbed Recharge Project

Agua Fria River Recharge Facility

Item	Quantity	Unit	Unit Cost	Total Cost
Earthwork	300,000	CY	$ 1.80	$ 540,000
Beardsley Canal Improvements	1	EA	90,000	90,000
Turnout Structure	1	EA	40,000	40,000
Parshall Flume	1	EA	15,000	15,000
Monitoring Wells	12	EA	25,000	300,000
Contingency, Legal, Engineering and Administration (35%)				345,000
Total				$1,330,000

Salt River Recharge Facility

Item	Quantity	Unit	Unit Cost	Total Cost
Earthwork	420,000	CY	$ 1.80	$ 750,000
Turnout Structure	1	EA	40,000	40,000
Parshall Flume	1	EA	15,000	15,000
Monitoring Wells	14	EA	25,000	350,000
Contingency, Legal, Engineering and Administration (35%)				405,000
Total				$1,560,000

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occur when more precise topographic data become available. Also mentioned earlier, the angle of repose of the "T" levees may vary from that assumed in these calculations. If steeper than 3:1 slopes can be used, then the volume of earthwork (and associated costs) will be reduced correspondingly.

A direct comparison between the preliminary costs displayed in Table 23 and the costs for conceptual design costs shown on Table 16 is not possible because of the differences in recharge areas associated with the preliminary and conceptual designs. The preliminary design costs, on a per acre basis, are slightly greater than those of the conceptual designs

because of the requirement that the "T" levee spacing be reduced and the "T" levee lengths be increased, which resulted in greater earthwork quantities. These increases can be attributed to the more focused preliminary design process.

7.3 OPERATION AND MAINTENANCE COSTS

As discussed in Section 4.5, the costs associated with operating and maintaining riverbed recharge facilities are about $4 per acre foot of water recharged. This is a conservative estimate based on the operation and maintenance of similar facilities in Southern California.

In addition to the operation and maintenance costs of $4 per acre foot, the current cost to purchase surplus Colorado River water will probably range between $30 and $40 per acre foot.

7.4 SUMMARY OF PRELIMINARY PROJECT COSTS

The total estimated costs to implement the recharge projects on the Agua Fria and Salt Rivers are summarized in Tables 24 and 25. In general, the total unit cost for recharge of 200,000 acre-feet at either of the proposed facilities is $40/ac-ft of water recharged, which includes capital and O&M for the recharge facility and raw water (untreated) costs. By comparison, similar recharge facilities developed on the Santa Ana River in Southern California, currently operates at an annual cost of $163 per acre foot.

The total annual budget for a $200,000 ac-ft/yr recharge facility is estimated at approximately $8,000,000 for either the Agua Fria or Salt River site.

TABLE 24

SUMMARY OF COSTS -- 200,000 AC-FT/YR AGUA FRIA RECHARGE FACILITY

Feasibility Study Report -- AMWUA Riverbed Recharge Project

Item	Construction Cost (x1000)	Annual Cost (x1000)	Annual Unit Cost ($/AF)
RECHARGE FACILITY			
Earthwork	540		
Beardsley Canal	90		
Turn Out Structure	40		
Parshall Flume	15		
Monitoring Wells	300		
Contingency, etc.	345		
Subtotal	1,330		
DATA DEFICIENCIES & PERMITTING	95		
Total	1,425	130(b)	1(c)
OPERATION & MAINTENANCE (a)	---	800	4
WATER PURCHASE (a)	---	7,000	35(d)
Total	1,425	7,930	40

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(a) Based on purchase of 200,000 AF/YR.
(b) Annualization based on 8% interest over a period of 25 years.
(c) Rounded.
(d) Estimated at $35/ac-ft

TABLE 25

SUMMARY OF COSTS -- 200,000 AC-FT/YR SALT RIVER RECHARGE FACILITY

Feasibility Study Report -- AMWUA Riverbed Recharge Project

Item	Construction Cost (x1000)	Annual Cost (x1000)	Annual Unit Cost ($/AF)
RECHARGE FACILITY			
Earthwork	750		
Turn Out Structure	40		
Parshall Flume	15		
Monitoring Wells	350		
Contingency, etc.	405		
Subtotal	1,560		
DATA DEFICIENCIES & PERMITTING	90		
Total	1,650	150(b)	1(c)
OPERATION & MAINTENANCE (a)	—	800	4
WATER PURCHASE (a)	—	7,000	35(d)
Total	1,650	7,950	40

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(a) Based on purchase of 200,000 AF/YR.
(b) Annualization based on 8% interest over a period of 25 years.
(c) Rounded.
(d) Estimated at $35/ac-ft.

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TABLE A-1

DATA DEFICIENCIES FOR NEW RIVER AND SKUNK CREEK RECHARGE SITES

Feasibility Study Report — AMWUA Riverbed Recharge Project

Site	Deficiency	Recommendation	Estimated Cost
New River			
	Water Quality: Lack of data within proposed portion of recharge area.	Well survey and sampling program. Drill monitor wells (included in facilities cost).	$ 10,000
	Water Levels: Lack of data within recharge area.	Well survey and measurements.	Incorporated into w.q.
	Aquifer Properties: Lack of data in south-western & northeastern portion of recharge area.	Aquifer tests on existing wells.	$ 20,000
	Infiltration: Accurate measurements of sustained infiltration rates.	Percolation tests.	$ 20,000
	Storage Capacity: Measurements of vadose zone soil moisture content.	Neutron logging of boreholes.	$ 10,000
	Subsurface Geology: Lack of data in proposed recharge area.	Cuttings analyses of new monitor wells or boreholes.	$ 5,000
	Land Ownership: No identification of specific public landowners of recharge site.	Land plat search.	$ 5,000
	Topography: 4-foot contours not accurate enough for final design.	Survey site to nearest 2-foot contours	$ 20,000
Skunk Creek			
	Water Quality: No data within recharge site boundaries.	Well survey and sampling program. Drill monitor wells (included in facilities cost).	$10,000
	Water Levels: No data within recharge site boundaries.	Well survey.	Incorporated into w.q.
	Aquifer Properties: Lack of data within recharge area.	Aquifer tests on existing wells or new monitor wells.	$10,000
	Infiltration: Accurate measurements of sustained infiltration rates.	Percolation tests.	$20,000
	Storage Capacity: Measurements of vadose zone soil moisture content.	Neutron logging of boreholes.	$10,000
	Subsurface Geology: Lack of data within recharge boundaries.	Cuttings analyses of new monitor wells or boreholes.	$ 5,000
	Land Ownership: No identification of specific landowners on recharge site.	Land plat search.	$ 5,000

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TABLE A-2

DATA DEFICIENCIES FOR UPPER CAVE CREEK AND LOWER INDIAN BEND RECHARGE SITES

Feasibility Study Report — AMWUA Riverbed Recharge Project

Site	Deficiency	Recommendation	Estimated Cost
Upper Cave Creek			
	Water Quality: Few well water quality samples in vicinity of recharge site.	Do survey of domestic and public wells and sample wells near site. Drill monitor wells (included in facilities cost).	$10,000
	Infiltration: Accurate measurements of sustained infiltration rates.	Percolation tests.	$20,000
	Storage Capacity: Measurements of vadose zone soil moisture content.	Neutron logging of boreholes, gravimetric analyses, and other tests.	$10,000
	Subsurface Geology: Lack of data within recharge boundaries.	Cuttings analyses of new monitor wells or boreholes.	$ 5,000
	Land Ownership: No identification of specific landowners on recharge site.	Land plat search.	$ 5,000
Lower Indian Bend			
	Water Quality: Lack of data in vicinity of recharge area.	Well survey and sampling program. and sample wells near site. Drill monitor wells (included in facilities cost).	$10,000
	Water Levels: Lack of data within recharge area.	Well survey and measurements.	Incorporated into w.q.
	Aquifer Properties: Lack of data in northern portion of recharge area.	Aquifer tests on existing wells	$ 5,000
	Infiltration: Accurate measurements of sustained infiltration rates.	Percolation tests.	$10,000
	Storage Capacity: Measurements of vadose zone soil moisture content.	Neutron logging of boreholes.	$10,000
	Subsurface Geology: Lack of data within proposed recharge area.	Cuttings analyses of new monitor wells or boreholes.	$ 5,000
	Land Ownership: No identification of specific landowners at recharge site.	Land plat search.	$ 5,000
	Sensitive Areas: No information available on possible archeological sites in recharge area.	Archeological survey.	$ 5,000

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TABLE A-3

DATA DEFICIENCIES FOR LOWER CAVE CREEK AND UPPER INDIAN BEND RECHARGE SITES

Feasibility Study Report — AMWUA Riverbed Recharge Project

Site	Deficiency	Recommendation	Estimated Cost
Lower Cave Creek			
	Water Quality: Few well water quality samples in vicinity of recharge site.	Well survey and sampling program. Drill monitor wells (included in facilities costs)	$10,000
	Water Levels: Lack of data within boundaries of recharge area.	Well survey and measurements.	Incorporated into w.q.
	Infiltration: Accurate measurements of sustained infiltration rates.	Percolation tests.	$20,000
	Storage Capacity: Measurements of vadose zone soil moisture content.	Neutron logging of boreholes.	$10,000
	Subsurface Geology: Lack of data within boundaries of study area.	Cuttings analyses of new monitor wells or boreholes.	$ 5,000
	Land Ownership: No identification of specific landowners on recharge site.	Land plat search.	$ 5,000
Upper Indian Bend			
	Water Quality: No well water quality samples in center of recharge site.	Do survey of domestic and public wells and sample wells near site. Drill monitor wells (included in facilities costs).	$10,000
	Water Levels: Scanty data in southern portion of study area.	Well survey and measure water levels with water quality.	Incorporated into w.q.
	Aquifer Properties: Lack of data in the central portion of study area.	Aquifer tests on existing wells	$ 5,000
	Infiltration: Accurate estimates of sustained infiltration rates.	Percolation tests.	$20,000
	Storage Capacity: Better estimates of vadose zone moisture content.	Neutron logging of drill holes.	$10,000
	Subsurface Geology: Lack of data in western portion of proposed recharge area.	Cuttings analyses of new monitor wells or boreholes.	$ 5,000
	Land Ownership: No identification of specific landowners at recharge site.	Land plat search.	$ 5,000
	Sensitive Areas: No information available on possible archeological sites in recharge area.	Archeological survey.	$25,000

TABLE A-4

DATA DEFICIENCIES FOR QUEEN CREEK RECHARGE SITE

Feasibility Study Report — AMWUA Riverbed Recharge Project

Site	Deficiency	Recommendation	Estimated Cost
Queen Creek			
Water Quality:	Lack of data within proposed recharge site.	Do survey of domestic and public wells and sample wells near site. Drill monitor wells (included in facilities cost).	$10,000
Water Levels:	Lack of data in western portion of study area.	Well survey and measure water levels with water quality.	Incorporated into w.q.
Infiltration:	Accurate estimates of sustained infiltration rates.	Percolation tests.	$20,000
Storage Capacity:	Better estimates of vadose zone moisture content.	Neutron logging of drill holes.	$10,000
Subsurface Geology:	Lack of data within proposed recharge area.	Cuttings analyses of new monitor wells or boreholes.	$ 5,000
Land Ownership:	No identification of specific landowners at recharge site.	Land plat search.	$10,000
Landfills:	Lack of data.	Review Pinal County recrods.	$ 5,000

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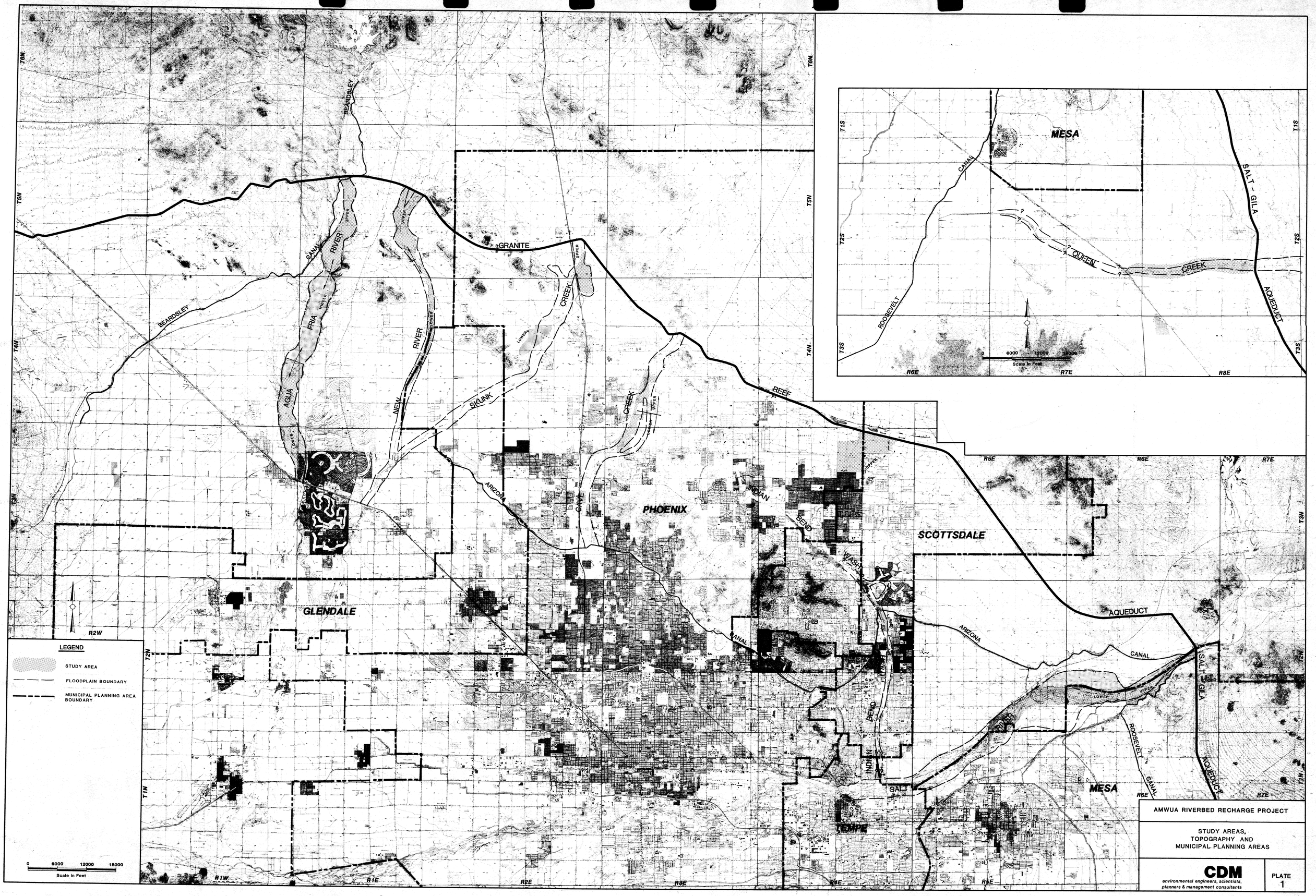
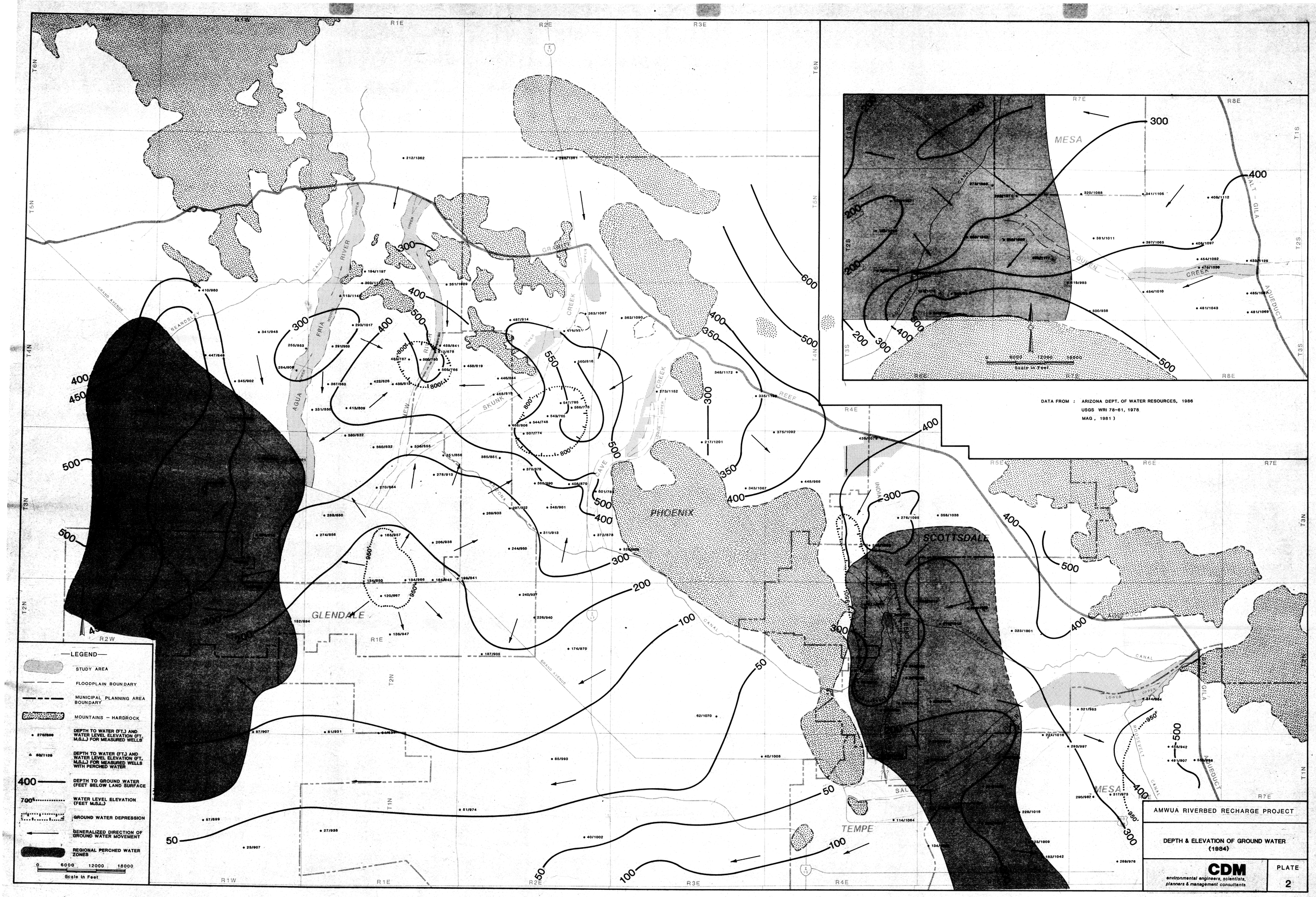


AMWUA RIVERBED RECHARGE PROJECT

STUDY AREAS, TOPOGRAPHY AND MUNICIPAL PLANNING AREAS

CDM
environmental engineers, scientists, planners & management consultants

PLATE 1

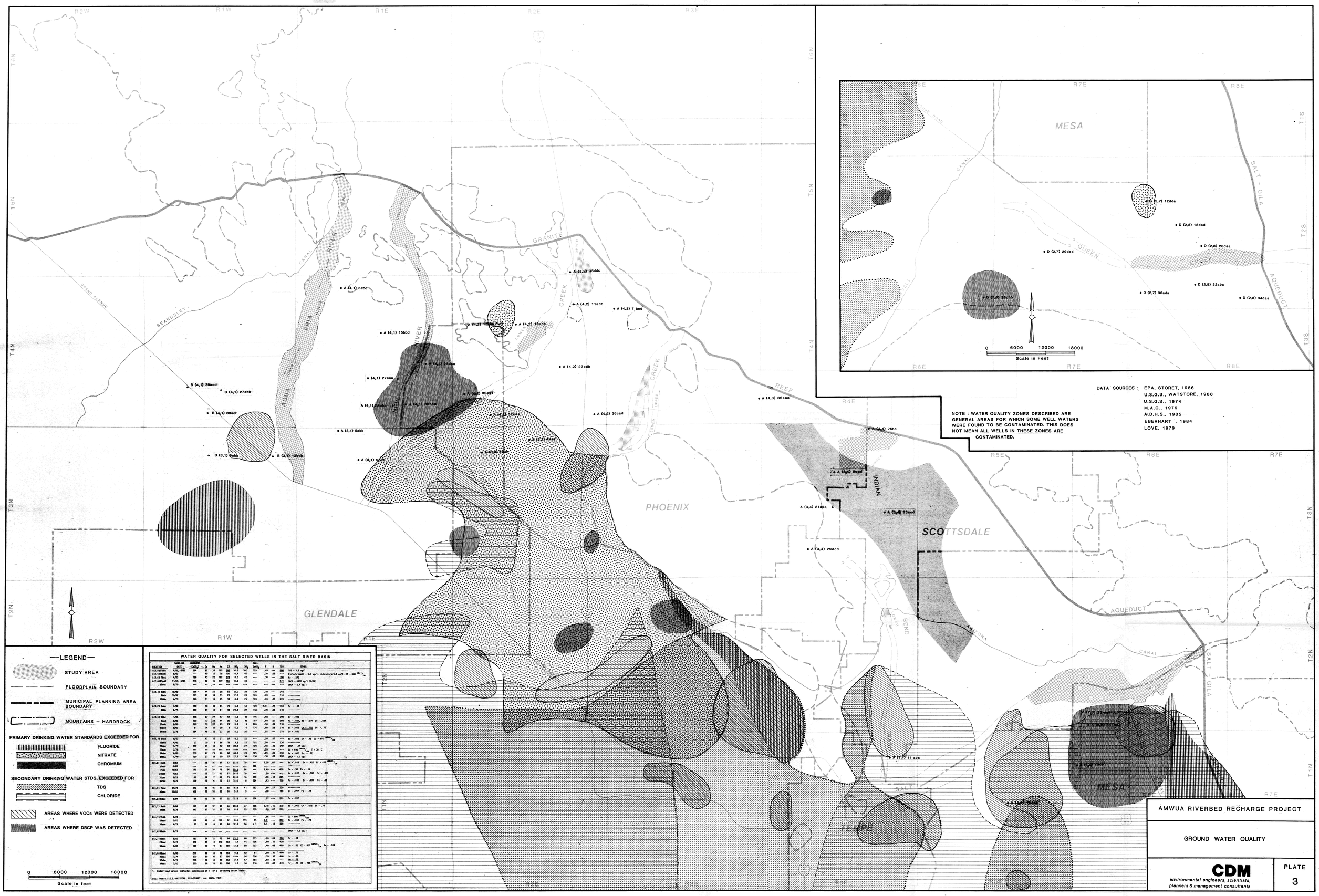


AMWUA RIVERBED RECHARGE PROJECT

DEPTH & ELEVATION OF GROUND WATER (1984)

CDM
environmental engineers, scientists, planners & management consultants

PLATE 2



WATER QUALITY FOR SELECTED WELLS IN THE SALT RIVER BASIN

LOCATION	SAMPLING DATE	SAMPLING ELEMENTS Ca	Mg	Na	Cl	SO_4	NO_3	$CaCO_3$	F	B	TDS	OTHER
A(1,4)15dcc	6/82, 6/84	204	42	31	165	206	34.2	502	1.29	---	800	TCE = 3.8 ug/l
A(1,4)15bdd	6/82	---	60	12	76	120	6.4	46	---	.30	---	Sb(antimonate) = 5.7 ug/l, chloroform=5.5 ug/l, EC = 680 umhos/cm
A(1,4)3 7bcc	5/83	188	42	22	160	225	8.0	42	---	.30	---	700 Fe = .270
A(2,4)27cdd	11/80, 6/84	218	56	179	295	96.0	33	---	---	---	1,1	DBCP = 4400 ug/l (5/84)
30aaa	6/79	---	---	---	---	---	---	---	---	---	---	DBCP = 2.4 ug/l
A(3,1) 5abb	10/82	198	46	21	35	51	12.0	29	1.30	.15	---	300 ----------
9aaa	10/82	183	42	19	35	71	12.0	28	1.20	.20	---	316 ----------
12bbb	6/79	192	31	15	25	18	8.4	25	1.20	.20	.07	220 ----------
A(3,4) 9dbc	6/82	150	30	18	41	14	6.4	18	1.20	1.0	.05	300 Cr = .42
20dbb	6/79	122	24	14	61	46	23.5	22	1.40	.20	.06	330 ----------
A(2,4) 2bcc	1/86	178	27	27	47	42	6.0	10	1.14	.50	---	290 Cr = .010
3bcd	6/82	120	17	122	66	20	6.0	10	1.01	.50	.07	390 As = .011 Se = .014 Cr = .024
17adb	6/80	160	19	27	45	29	5.6	9	0.90	.50	.06	310 ----------
23cad	6/80	83	14	11	20	8	5.1	6	1.14	.40	.08	210 As = .016 Se = .190 Sr = .75
29dcd	3/75	164	45	12	37	20	11.0	26	---	.35	---	276 Cr = .010
A(4,1) 5acd	6/82	---	47	15	31	24	8.0	22	---	.20	.07	--- As = .043 Sr = .45 EC = 475 umhos/cm
15bbd	6/82	37	10	3	60	39	3.5	27	1.02	.30	---	226 ----------
27aaa	6/79	140	34	14	42	34	28.4	27	1.20	.40	.10	292 DBCP = .14 ug/l
27aac	3/75	---	---	---	---	---	---	---	---	.35	---	--- EC = 400 umhos/cm T = 30 C
34aac	6/80	210	47	23	46	60	46.7	49	1.20	.35	.05	360 As = .042 Sr = .12
35aaa	6/79	120	27	13	50	27	27.2	16	1.20	.30	.08	190 DBCP = 1.2 ug/l
A(4,2)11adb	6/82	---	26	16	37	13	22.0	30	---	1.00	.07	--- As = .019 Sr = .420 EC = 415 umhos/cm
18abb	6/80	---	---	---	---	---	---	---	1.60	---	---	164 Fe = .30 Zn = .14
23cdb	11/82	130	21	15	76	64	30.1	36	---	1.40	---	400 As = .012 Se = .060 Sr = .450
27cdb	1/83	---	29	17	63	37	26.8	30	---	.30	---	---
35cac	6/79	85	16	7	63	29	24.0	16	1.30	.20	.10	224 ----------
36cad	2/75	114	22	14	22	11	15.0	6	1.24	.43	---	190 As = .010 Cr = .030 Fe = .33
A(4,3) 7bcd	11/73	120	23	16	57	22	16.6	41	1.63	.30	.27	320 ----------
36aaa	3/80	168	33	18	35	30	6.3	7	---	.30	---	310 Cr = .007 Fe = .13
A(5,2)35dcc	3/84	34	22	10	57	12	12.8	8	1.14	.07	---	214 Cr = .037
A(3,1)5abb	6/80	130	33	12	50	66	26.8	27	1.08	1.10	.10	370 As = .045 Cr = .015 Sr = .78
12bbb	6/79	140	31	15	25	18	8.4	25	1.20	.20	.07	210 ----------
A(4,1)27abb	1/75	---	---	---	---	---	---	---	---	---	---	EC = 400 umhos/cm
29acd	3/82	138	46	4	258	30	8.4	123	1.1	1.0	---	860 As = .040 Fe = .15
33acc	6/79	70	18	6	50	40	12.1	56	< 1	1.4	.14	320 ----------
A(2,4)29dcd	6/79	---	---	---	---	---	---	---	---	---	---	DBCP = 1.5 ug/l
A(2,4)21dda	6/82	180	42	12	72	89	13.2	40	1.23	.20	.09	320 Cr = .18
23aad	1/75	110	35	3	110	155	1.7	44	1.06	.10	.11	420 ----------
26aaa	7/83	160	50	9	87	180	13.3	56	---	.40	.08	450 As = .02 EC = 867 umhos/cm Ba = .039
A(2,4)18dad	1/80	210	67	14	100	140	5.0	81	---	.30	.10	480 Cr = .79
20daa	1/75	230	69	14	63	155	----	84	1.06	.30	.10	460 Cr = .05
32aba	3/75	250	75	14	80	160	2.7	97	1.03	.30	.10	500 Sr = .45
34daa	7/83	220	66	13	69	160	1.7	86	1.10	.20	.08	470 Cr = .11 EC = 788 umhos/cm

1. Underlined values indicate exceedance of 1 or 2 drinking water limits.

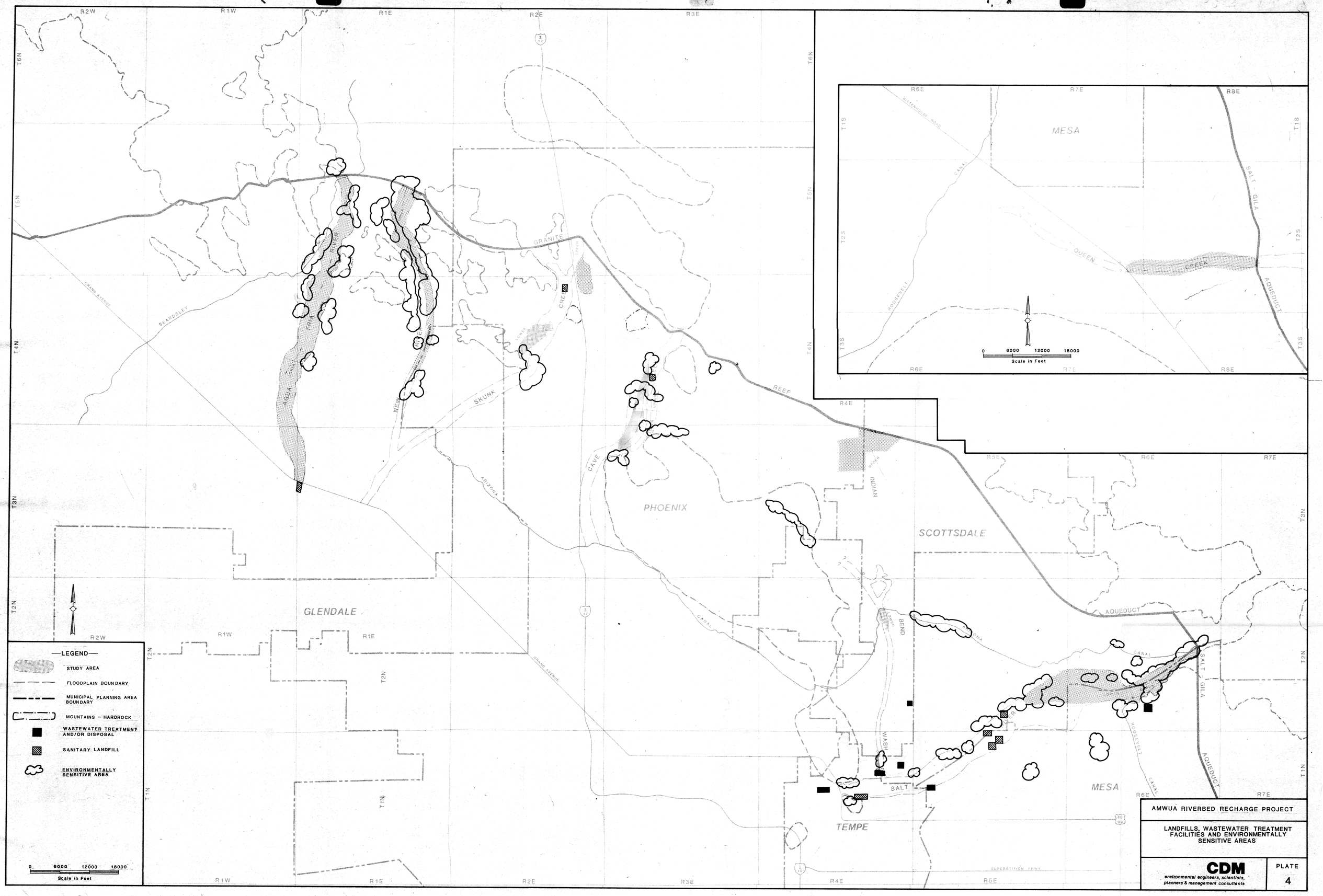
Data from U.S.G.S.-WATSTORE; EPA-STORET; and ADHS, 1979.

AMWUA RIVERBED RECHARGE PROJECT

GROUND WATER QUALITY

CDM
environmental engineers, scientists, planners & management consultants

PLATE 3

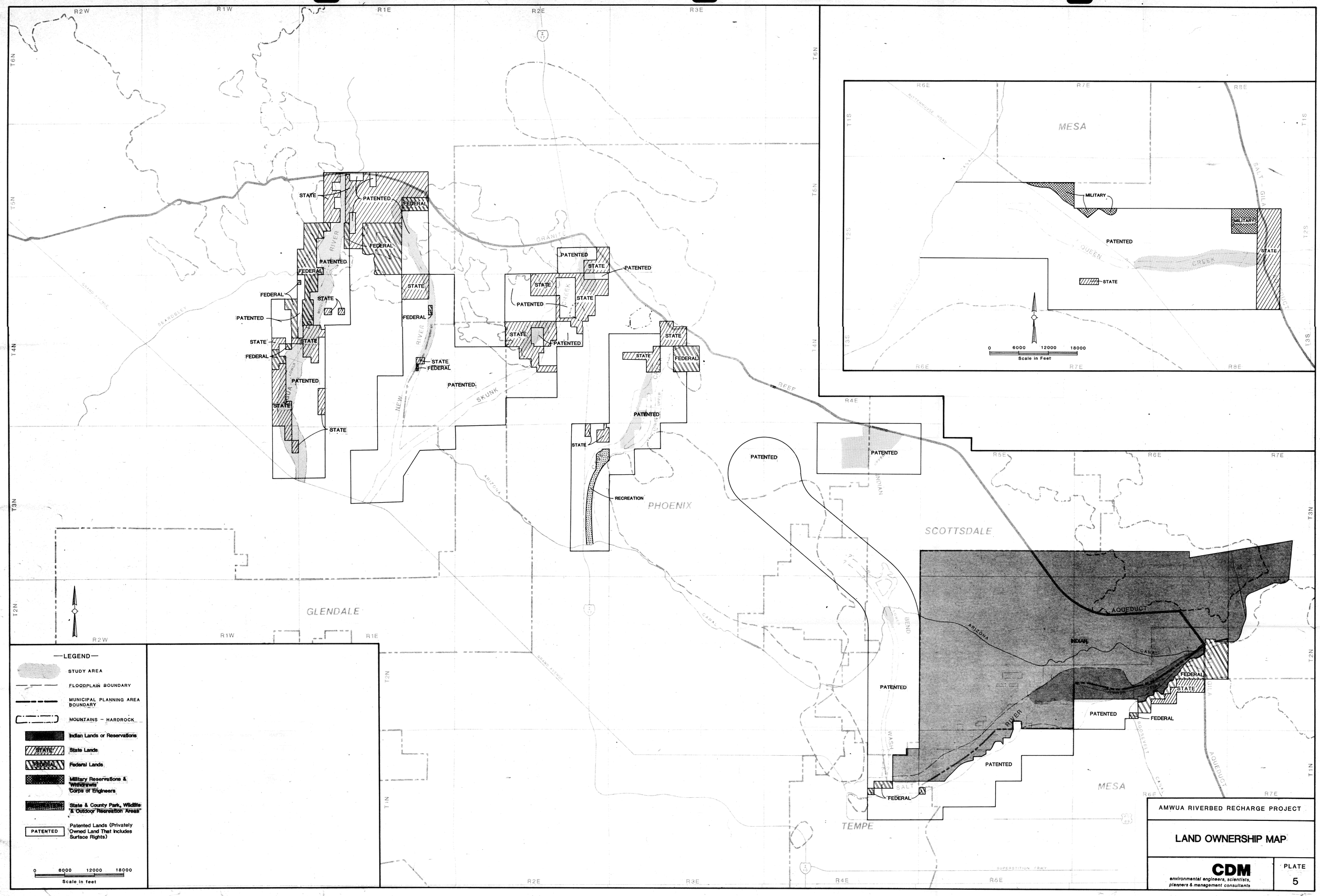


AMWUA RIVERBED RECHARGE PROJECT

LANDFILLS, WASTEWATER TREATMENT FACILITIES AND ENVIRONMENTALLY SENSITIVE AREAS

CDM
environmental engineers, scientists, planners & management consultants

PLATE 4

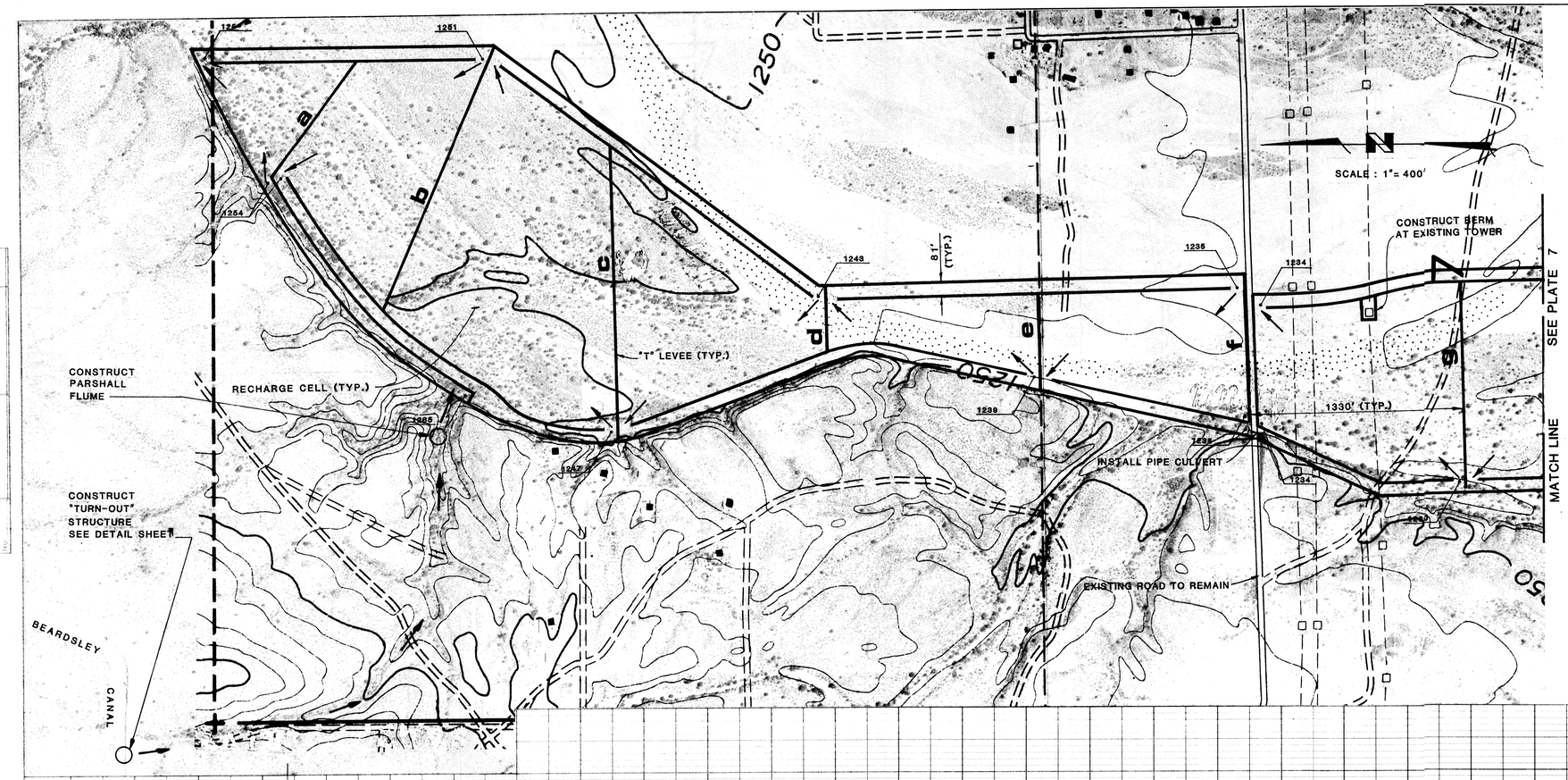


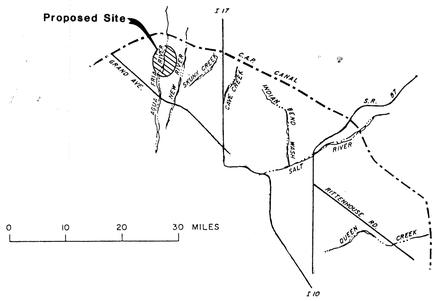
AMWUA RIVERBED RECHARGE PROJECT

LAND OWNERSHIP MAP

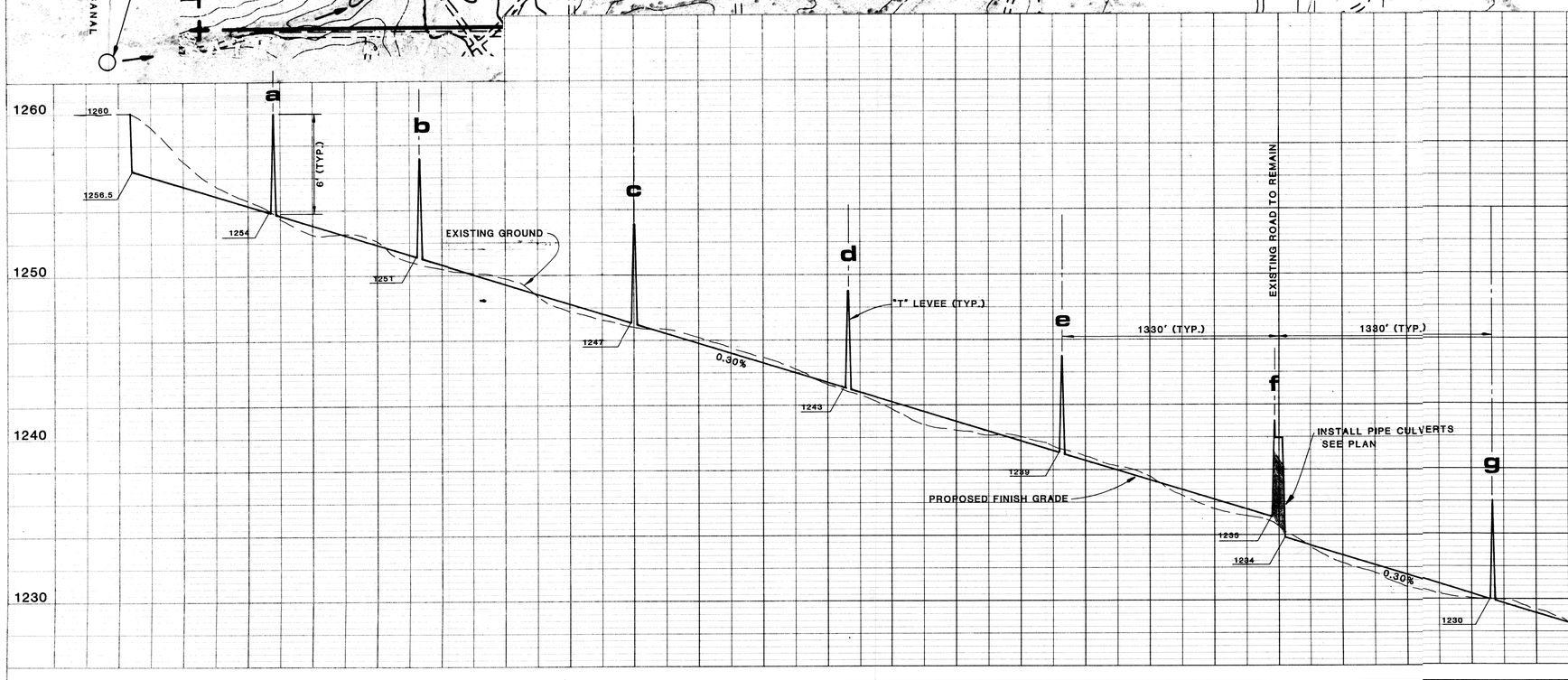
CDM
environmental engineers, scientists, planners & management consultants

PLATE 5





REGIONAL MAP



SCALE 1"=400' HORIZONTAL
1"=4' VERTICAL

AMWUA RIVERBED RECHARGE PROJECT

PRELIMINARY DESIGN
AGUA FRIA RIVER RECHARGE FACILITY

CAMP DRESSER & McKEE INC.

Cambridge Court
2701 North 16th Street
Phoenix, Arizona 85006

CDM
environmental engineers, scientists, planners, & management consultants

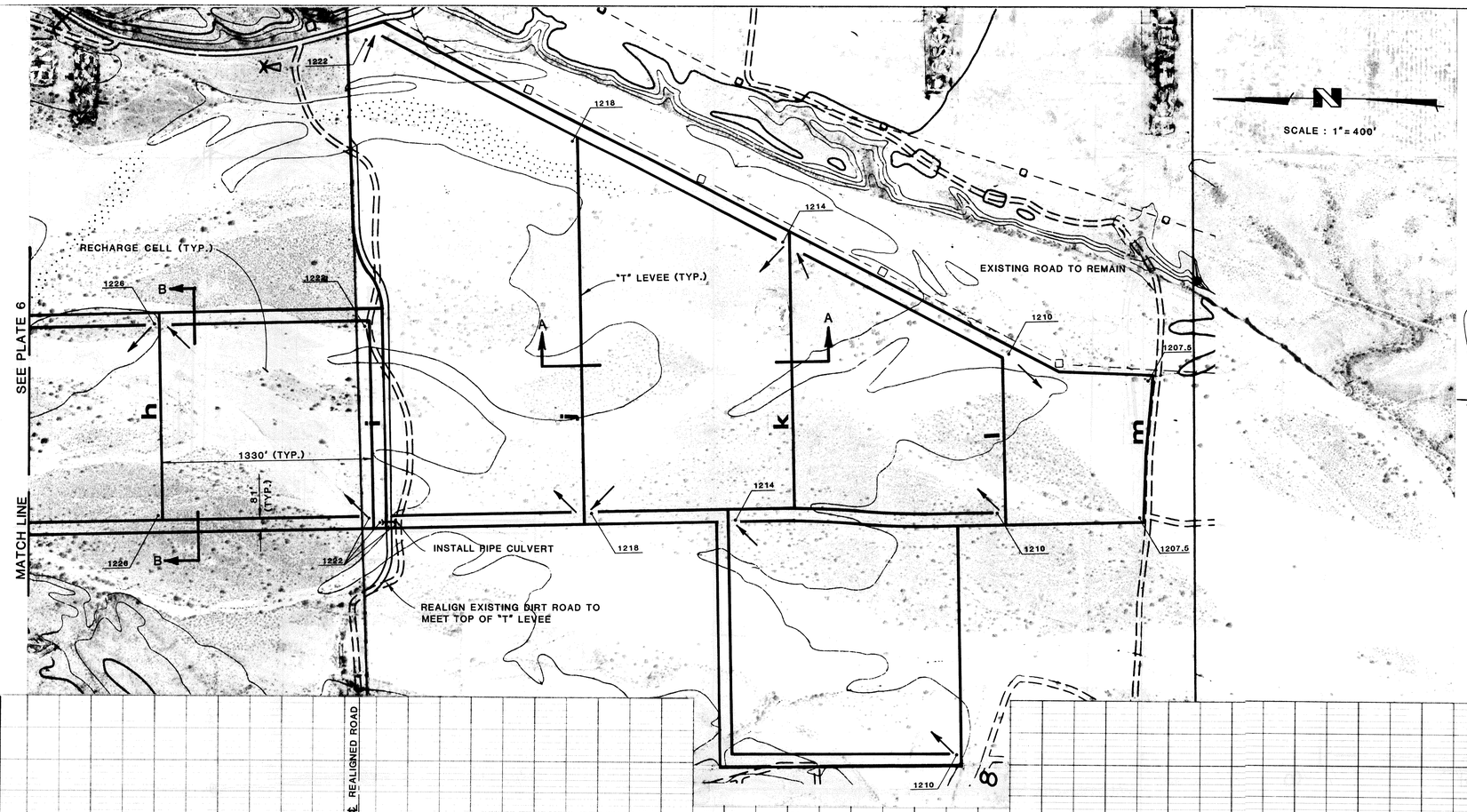
PLATE NO.
6

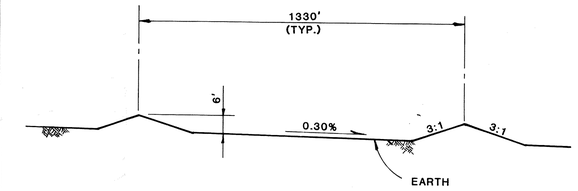
PLAN
SURVEYED
PLOTTED
DRAWN
NOTE BOOK
NO.
SCALE CHECKED
DESIGN CHECKED

PROFILE
SURVEYED
PLOTTED
DRAWN
NOTE BOOK
NO.
SCALE CHECKED
DESIGN CHECKED

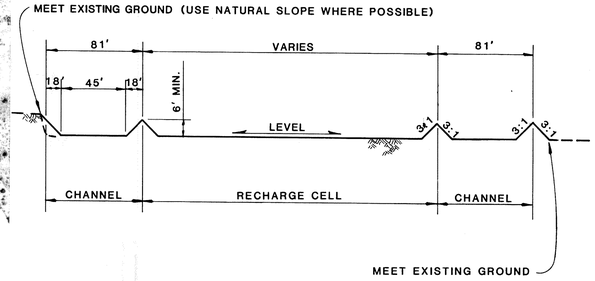
PLATE 1 PLAN PROFILE (D. P. R. & R. E. STANDARD)

DIETZGEN CORPORATION





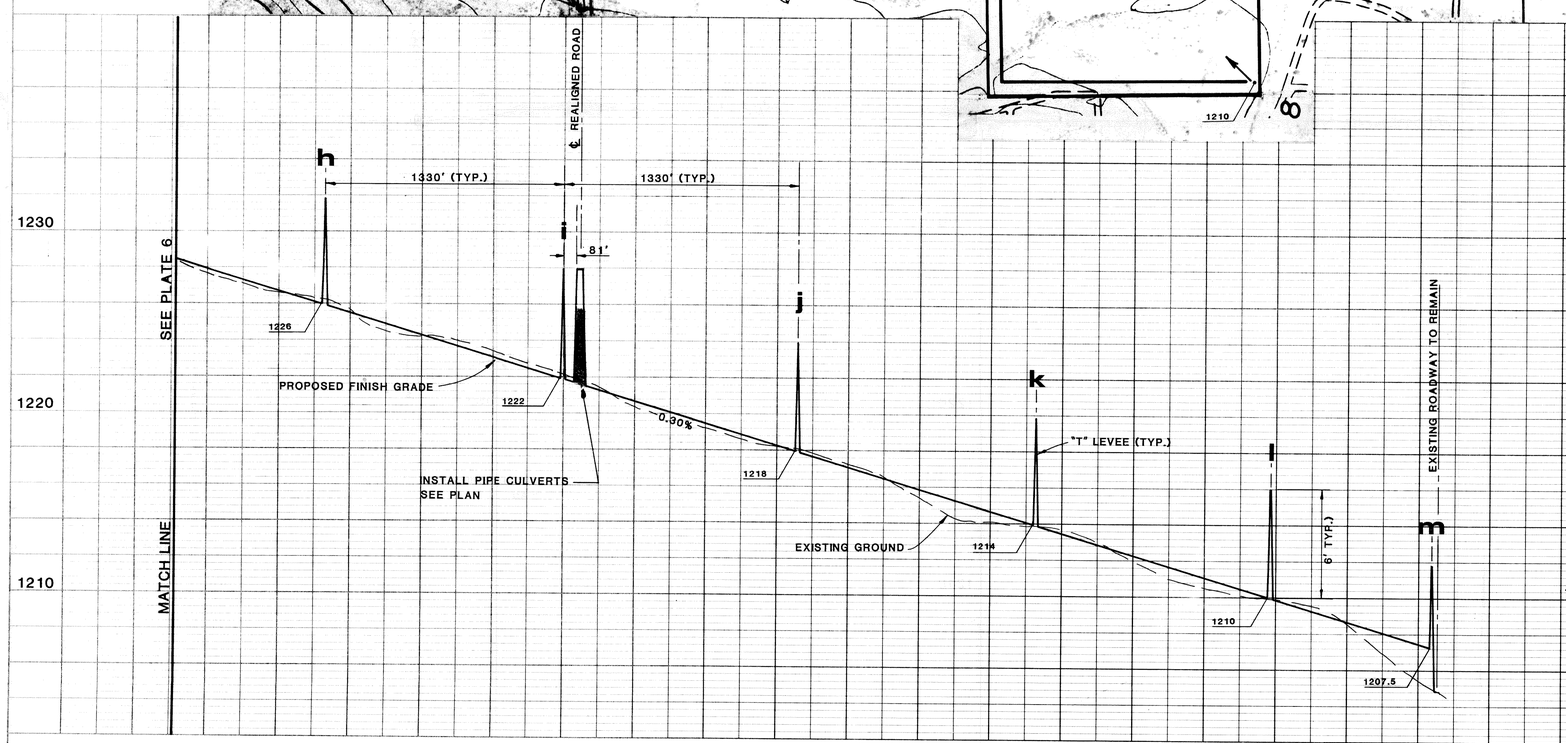
— SECTION 'A-A' —



— SECTION 'B-B' —

— TYPICAL SECTIONS THROUGH RECHARGE CELL —

NOT TO SCALE



SCALE 1" = 400' HORIZONTAL
1" = 4' VERTICAL

AMWUA RIVERBED RECHARGE PROJECT
PRELIMINARY DESIGN
AGUA FRIA RIVER RECHARGE FACILITY

CAMP DRESSER & McKEE INC.
Cambridge Court
2701 North 16th Street
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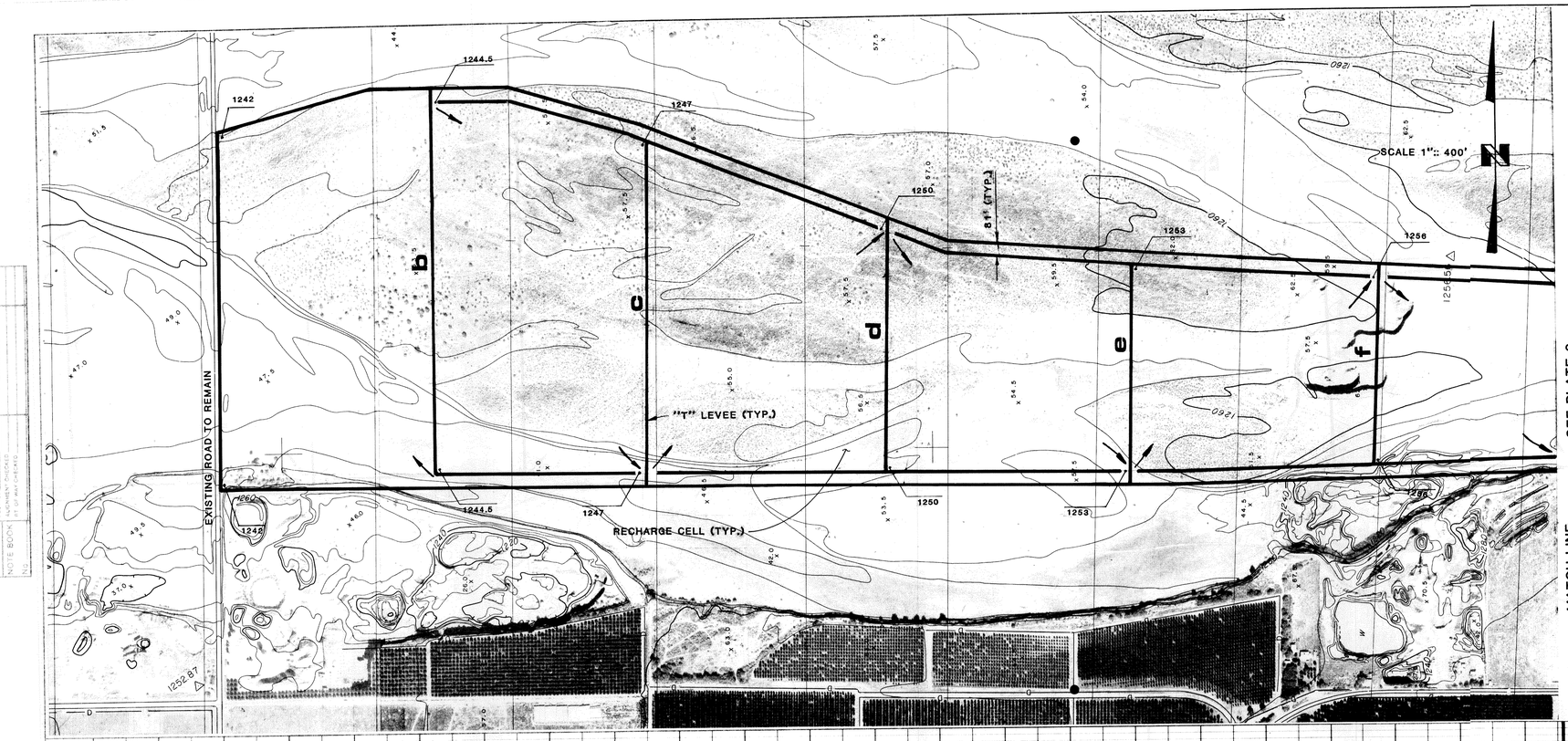
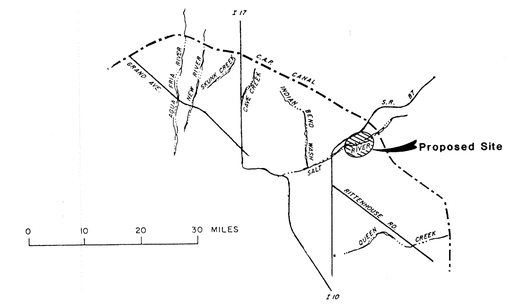
PLATE NO.
7

PLAN
PROFILE

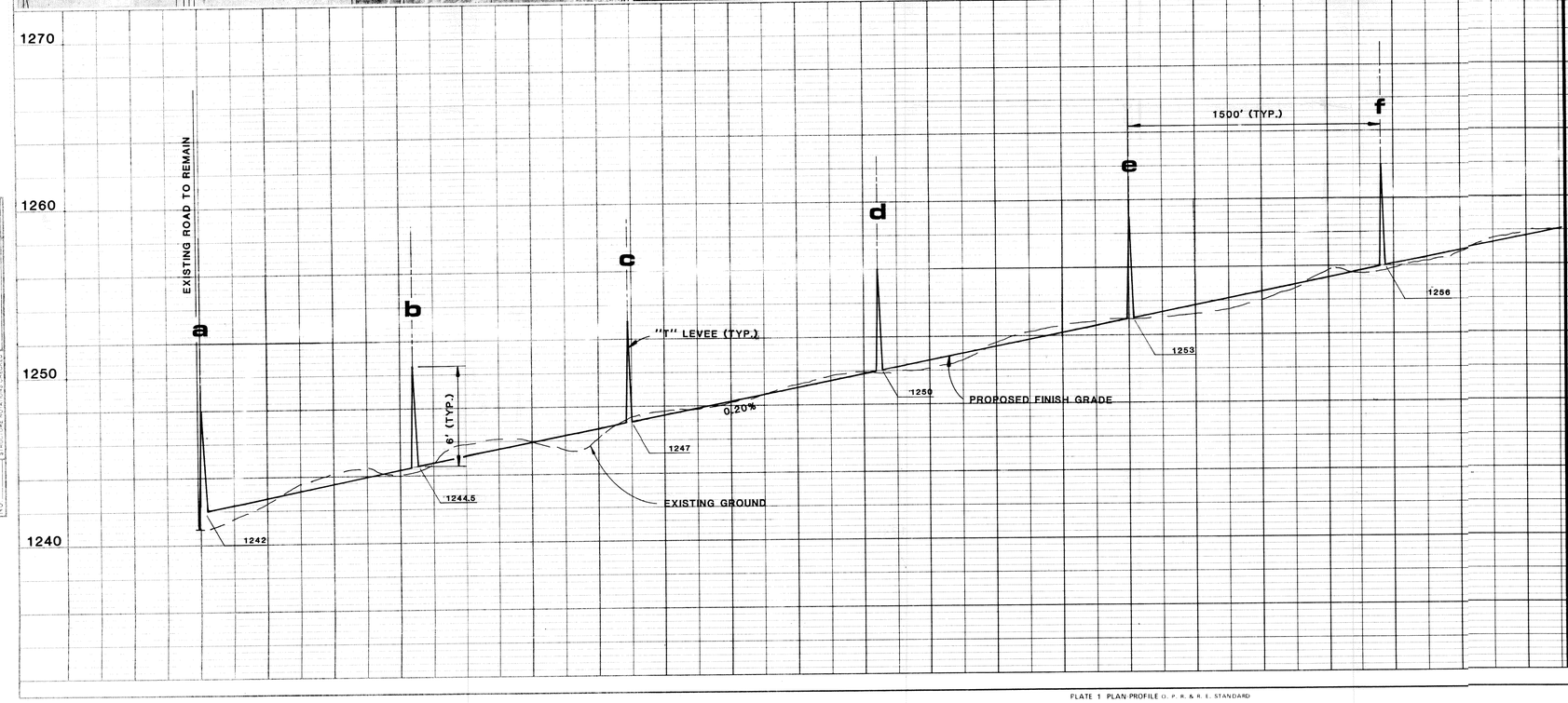
PLATE 1 PLAN PROFILE O. P. R. & R. E. STANDARD

DIETZGEN CORPORATION





REGIONAL MAP

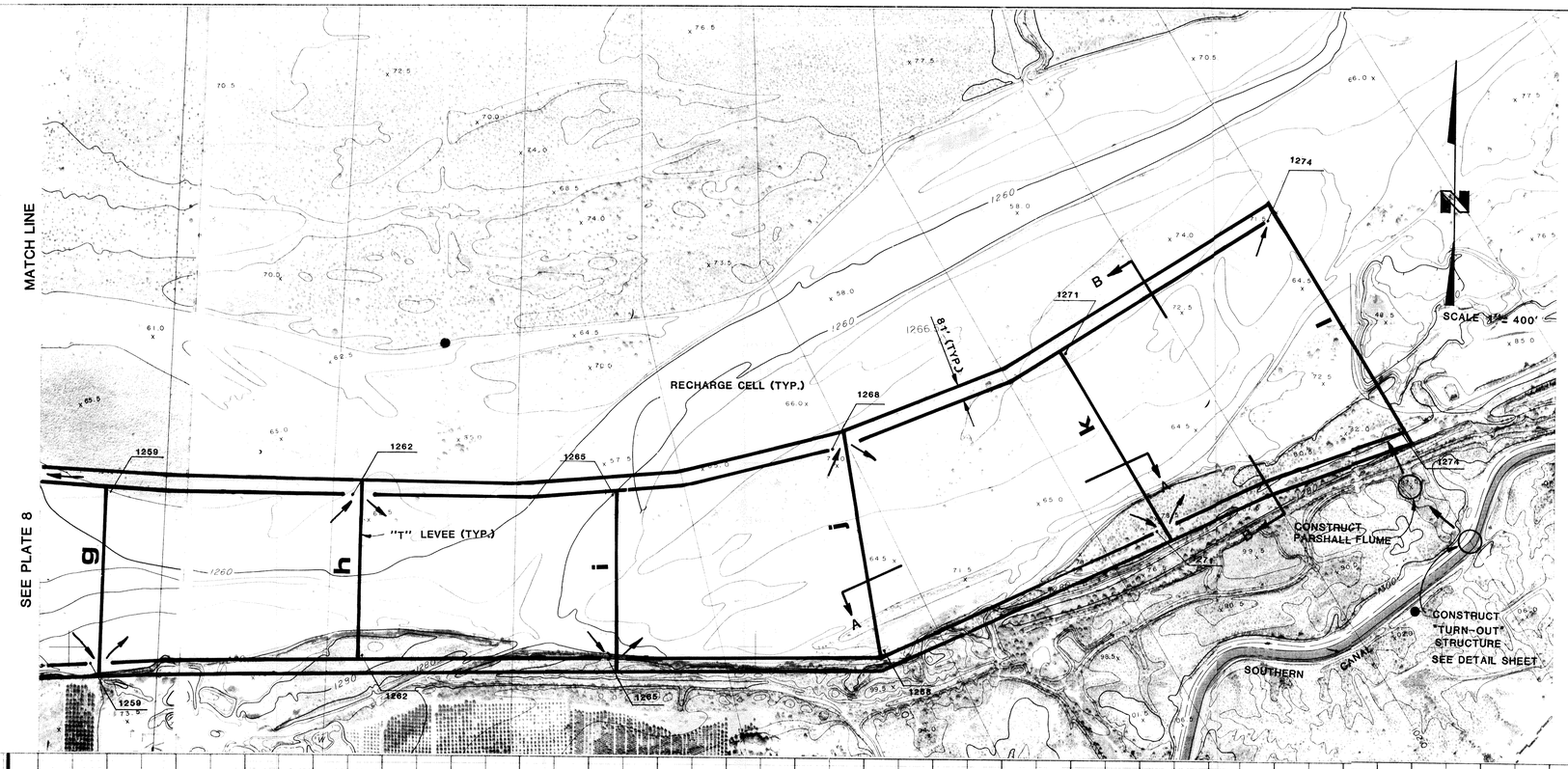


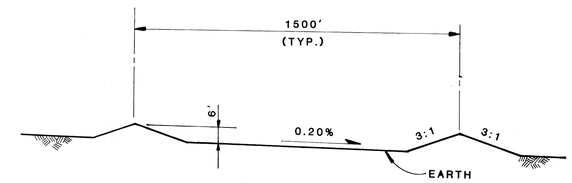
SCALE 1" = 400' HORIZONTAL
1" = 4' VERTICAL

AMWUA RIVERBED RECHARGE PROJECT	
PRELIMINARY DESIGN SALT RIVER RECHARGE FACILITY	
CAMP DRESSER & McKEE INC. Cambridge Court 2701 North 16th Street Phoenix, Arizona 85006 CDM environmental engineers, scientists, planners, & management consultants	PLATE NO. 8

PLAN — SURVEYED, PLOTTED, ALIGNMENT PLOTTED, NOTE BOOK, NO.

PROFILE — SURVEYED, PLOTTED, GRADES CHECKED, B.M. & NOTED, STRUCTURE INVERTS CHECKED, NOTE BOOK, NO.





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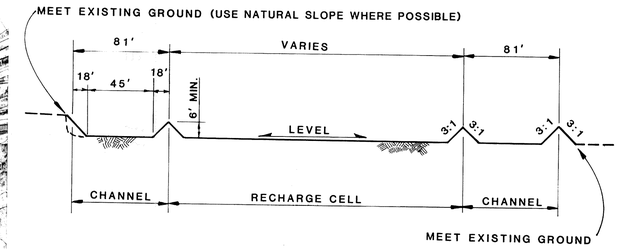
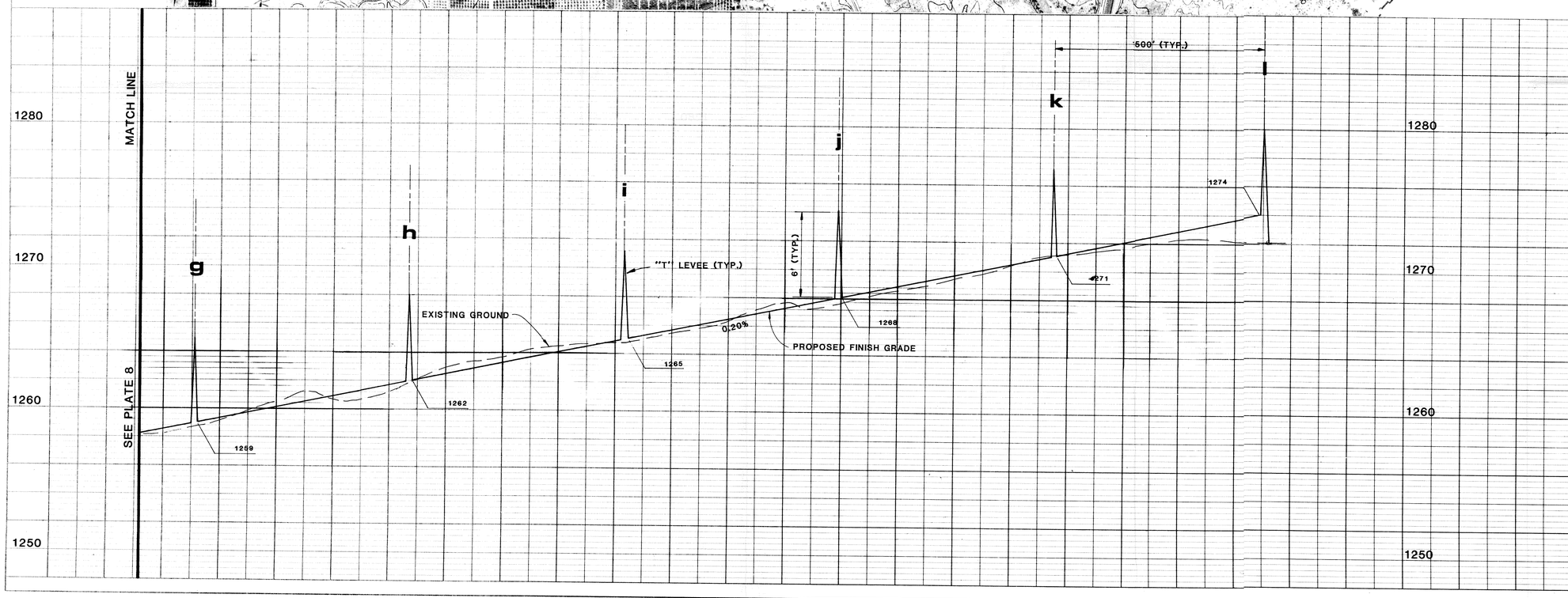


— SECTION 'B-B' —

TYPICAL SECTIONS THROUGH RECHARGE CELL

NOT TO SCALE



SCALE 1" = 400' HORIZONTAL
1" = 4' VERTICAL

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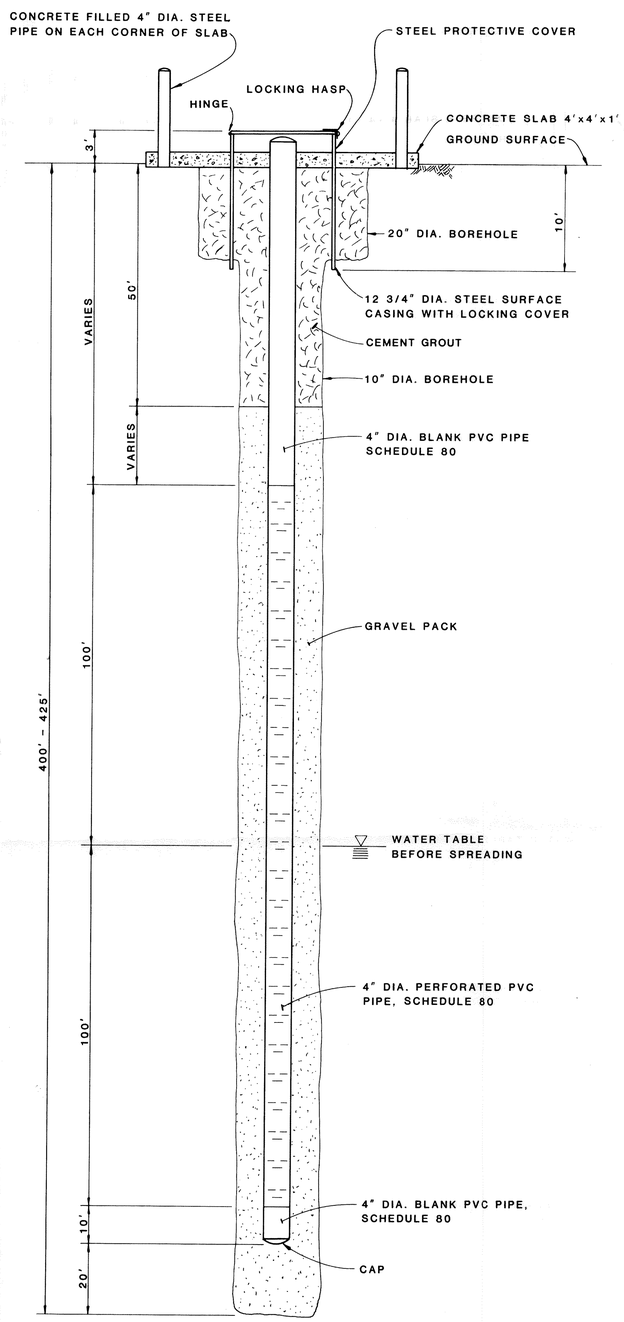
PLATE NO. 9

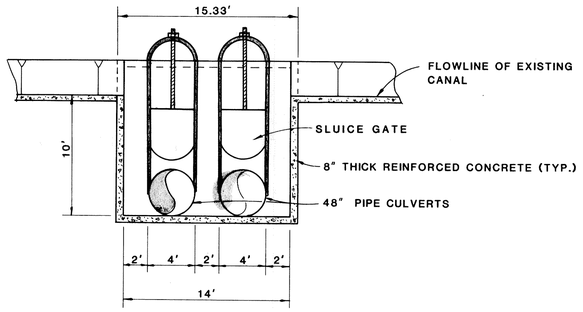
PLAN
SURVEYED
PLOTTED
DRAWN BY/CHECKED
NOTE BOOK
PLAN SHEET SHEET
No.

PROFILE
SURVEYED
PLOTTED
DRAWN BY/CHECKED
NOTE BOOK
B M & NOTED
No.

85872



— TYPICAL MONITORING WELL DETAIL —
NO SCALE



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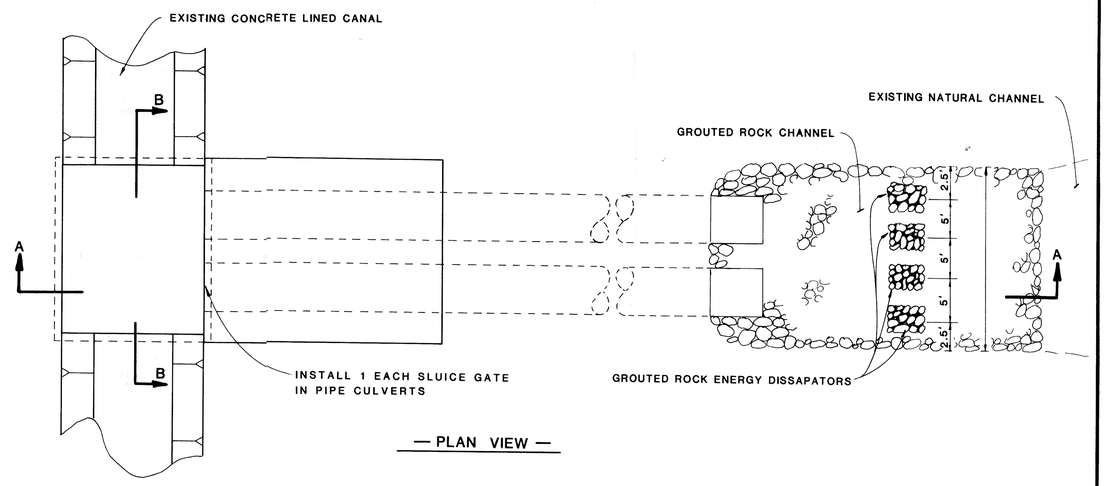
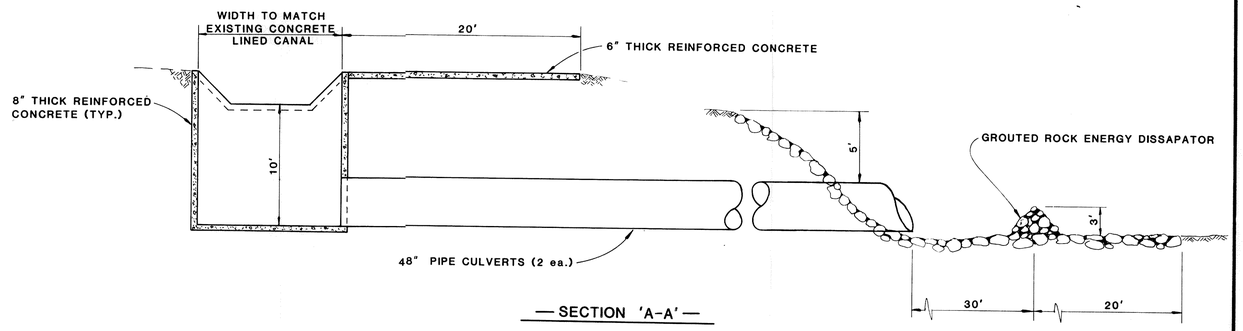


— PLAN VIEW —



— SECTION 'A-A' —

— TYPICAL TURN-OUT STRUCTURE DETAIL —
NO SCALE

ARCHITECTURAL	STRUCTURAL	ELECTRICAL	INSTRUMENTATION	HVAC	PLUMBING	PROJECT ENGINEER	PROJECT MANAGER
Approved by:	Approved by:	Approved by:	Approved by:	Approved by:	Approved by:	Approved by:	Approved by:
Date:	Date:	Date:	Date:	Date:	Date:	Date:	Date:

Date	Ch'k'd.	Revision

Designed by: _____
Drawn by: _____
Checked by: _____
Approved by: _____
Date: _____
Scale: _____

AMWUA RIVERBED RECHARGE PROJECT

PRELIMINARY DESIGN
DETAIL SHEET

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PLATE NO.
10