AMWUA RIVERBED RECHARGE PROJECT

INTERIM TECHNICAL REPORT

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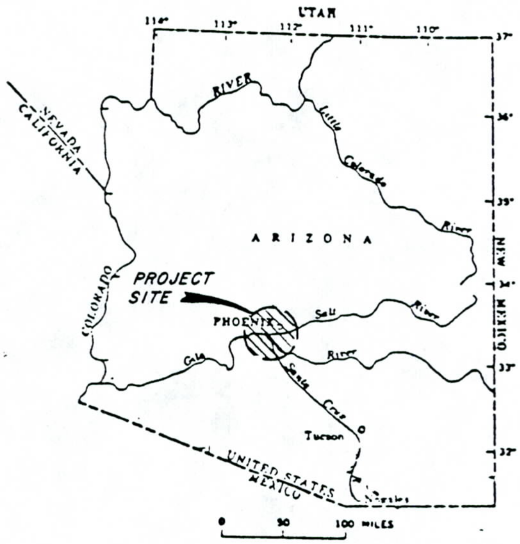
BACKGROUND

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. Because surplus water is available from the CAP, early delivery and storage of water will enhance future conjunctive management of present and future water supplies. 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, and Tempe, which together represent over 80 percent of both the population, and municipal and industrial water use in Maricopa County.

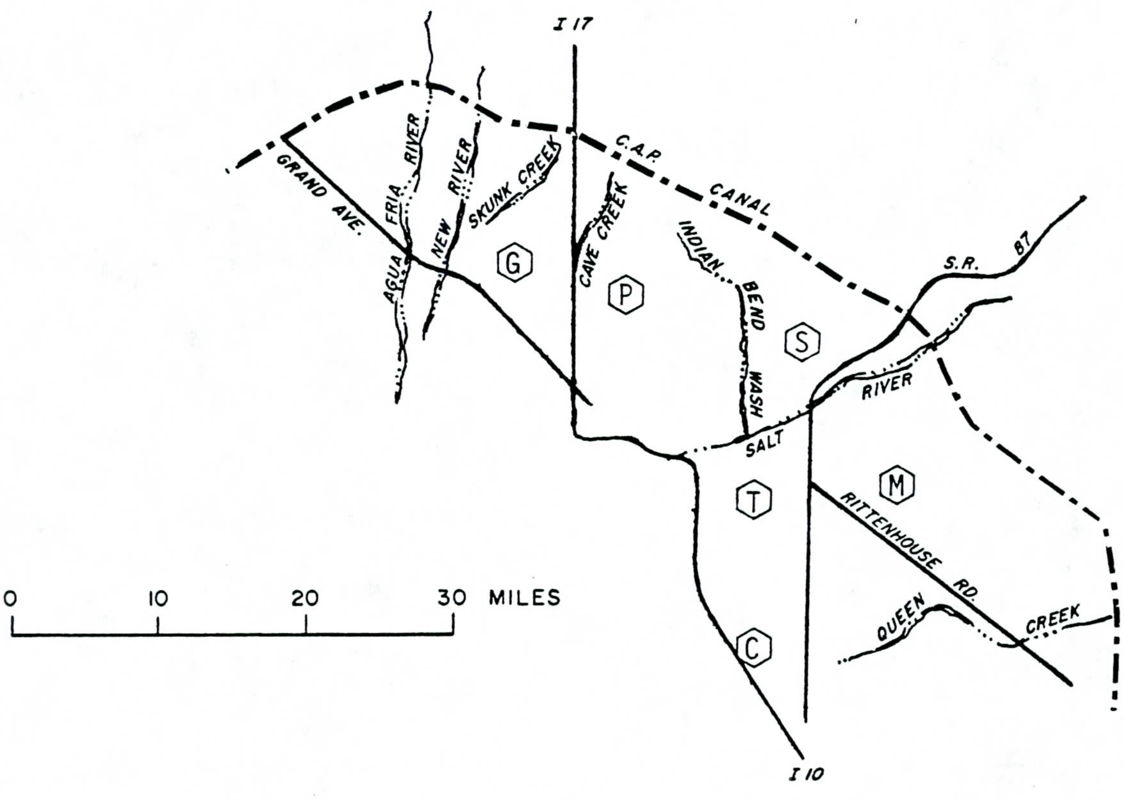
AMWUA retained Camp Dresser & McKee Inc. (CDM) to evaluate the feasibility of recharging and storing surplus CAP water in the Maricopa County area groundwater basins. The location of the study area is shown on Figure 1. The specific areas that were to be considered included the river channel areas down-stream 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.



GENERAL LOCATION MAP

THE AMWUA RIVERBED RECHARGE PROJECT INCLUDES THE FOLLOWING MUNICIPALITIES:

- (P) PHOENIX
- (T) TEMPE
- (S) SCOTTSDALE
- (M) MESA
- (G) GLENDALE
- (C) CHANDLER



PROJECT SITE MAP

FIGURE 1 - LOCATION OF AMWUA RIVERBED RECHARGE PROJECT

The information presented herein discusses the progress of the study through the site screening stage. 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. In the next phase of work, the preliminary design of the two best sites will be developed.

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.

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 to the water table.

Two types of shallow basins are commonly utilized; temporary shallow basins, sometimes referred to as "T" levees, and permanent shallow basins. 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 lands is necessary.

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.

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 down-stream of the Granite Reef and Salt-Gila Aqueduct, including the following: ua Fria Rik, and Indian Bend Wash.

Recent aerte 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.

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 Jomax Road and the CAP. This area overlies a relatively small groundwater body that is not in significant hydraulic continuity with the West Basin. The area of this potential recharge site encompases 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 on the permission of the Maricopa Water District, the canal owner and operator.

The Lower Agua Fria site extends 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. Because the recharge potential of the Lower Agua Fria is much greater than that which could be supplied from CAP facilities, CDM estimated that 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 this upper portion of the lower Agua Fria site area. Should additional capacity be needed, in-stream recharge facilities could easily be extended south.

New River

Two potential recharge sites were located along the New River. The Upper New River recharge site encompases 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 recharged area. As mentioned previously, this smaller groundwater basin is not in substantial hydraulic continuity with the West Basin.

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.

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 encompases 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 direct hydraulic continuity with the West Basin.

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

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 includes about 400 acres.

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, 60-acre site was identified within the flood plain and adjacent to the Arizona Canal. The water for this recharge facility would be conveyed by the Arizona Canal.

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. These nearly 2500 acres of flood plain could be supplied recharge water via the Southern Canal or from the CAP turnout at the Granite Reef Dam.

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.

INITIAL SCREENING PROCESS

Because of a large number of recharge sites that were preliminarily identified and also because of their large recharge area which encompasses several thousand acres, it was decided to subject the 13 sites to an initial screening process that would eliminate the least attractive sites and 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 substanial 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 Basins of the Salt River. 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 direct communication with the main groundwater basin in the area. Thus, it would be difficult for the AMWUA member agencies to obtain any signficant 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.

RECHARGE SITE CONSIDERATIONS

The final selection of a recharge site, as well as the method by which wat rechargedcharge site has been evaluated with regard to the following specific selection criteria:

- o Infiltration rates
- o Mounding potential
- o Available storage capacity
- o Groundwater quality
- o Perched water table conditions
- o Proximity to residential neighborhoods
- o Proximity to landfills and waste disposal sites
- o Environmental factors
- o 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 the following paragraphs. The application of these criteria to individual site screen is presented in Section 3, "Technical Evaluation of Recharge Sites."

Infiltration Rates

The infiltration rate is the rate that water passes through the soil surface and enters the unsaturated zone of the soil. 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 Basin 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. Average infiltration rates of over 2.5 ft/day were examined for a 19-mile reach between Granite Reef Dam and 48th Street in Phoenix. These were instantaneous rates for a four day period. Further down channel four-day rates in gravel pits averaged 1.5 ft/day. More sustained rates declined to 1.1 ft/day after two weeks. Babcock and Cushing (1941) determined a range of infiltration rates on Queen Creek over a 20-mile reach. 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 loaded the channel. Infiltration rates in pools of runoff remaining in the channel averaged 0.91 ft/day. These rates were of short duration, and thus sustained rates were not obtained 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 foot/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 soils maps to estimate infiltration rates over large areas, primarily in the stream channels. From observations of other recharge sites, 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 U. S. Soil Conservation Service soils maps.

These sustained infiltration rates were then estimated for each 640-acre section within the potential recharge area on the basis of a weighted mean, in order to obtain the most representative overall rate for each section.

Each section within the potential recharge sites were then planimetered to obtain the actual acreage of each section within the recharge site. In turn, a final weighted mean for sustained infiltration rate, based on acreage of section within the recharge site, was calculated for each site.

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 distance to water beneath proposed recharge facilities and beneath the existing landfills. Recharge operations should not cause groundwaters to rise to the ground surface, resulting in interference with infiltration. Rising groundwater could also penetrate the base of 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, transmissivity, specific yield, width of the recharge basin, and 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 Corp of Engineers reports (U.S. Army Corps of Engineers, 1981) compared quite favorably. Width and total area of the recharge sites were planimetered. Period of recharge was held constant for thirty days before application of a dry cycle. These important variables are listed and summarized in tables for each site later in the text.

Available Storage Capacity

The importance of the 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.

Groundwater Quality

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).

Zones of groundwater quality exceeding primary or secondary drinking water standards, and areas of DBCP and VOC contamination are delineated on the regional map (Plate 3).

Perched Water Conditions

Recharge in areas above perched water tables or continuous tight geologic material may inhibit recharge operations due to the potential for groundwater mounding up to the ground surface, as discussed earlier. Also, perched water table conditions can direct recharged water away from points of desired use. In general, areas with existing or potential perched water tables are unfavorable for 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) describes regional zones of perched water based on the several reports mentioned, as well as water level data. These reports, 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 (Figures 2 through 9) describe potential areas where perched water conditions could occur if large amounts of water were recharged. Aquitard or fine-grained material is delineated.

Proximity to Residential Neighborhoods

A problem commonly encountered with water spreading operations is the propogation of an insect commonly known as the midge. 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 federal or state 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 describe 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 allows rural conditions with horses and livestock, which already attract nuisance pests.

Proximity to Landfills and Waste Disposal Sites

Landfills and waste disposal sites potentially pose substantial groundwater contamination problems, even in the absence of an artificial recharge project. Of concern is the generation and downward migration of landfill leachates and disposal wastes (often organic solvents) into the underlying groundwater reservoir. Thus, groundwater recharge facilities should not be constructed near these sites because the elevated groundwater table may intercept 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.

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 area are on the endangered species list or other lists that require special protection. In addition, several archaeological sites have been identified in previous reports. If these sensitive areas could not be protected from the recharge operation, the recharge location was eliminated from consideration.

Areas which are considered environmentally sensitive by the Arizona State Parks Department are also shown on Plate 4. These areas are shown on site specific m aps delineating the potential recharge sites (Figures 9 through 16).

Land Ownership

This non-technical suitability criteria is important as a cost consideration and as a potential implementation constraint. Privately held lands may be costly to obtain, while publically owned lands 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 were 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.

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. The evaluation 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.

AGUA FRIA

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

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, as shown by areas 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.

Using the maximum estimated infiltration rate of 3.2 ft/day, the Agua Fria recharge area is one of the three sites which was shown to have a potential mounding problem. Recharge potential is thus reduced because of mounding.

TABLE 1

PHYSICAL CHARACTERISTICS
AGUA FRIA RECHARGE AREA

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	no	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.
ND No data.
NA Not applicable.

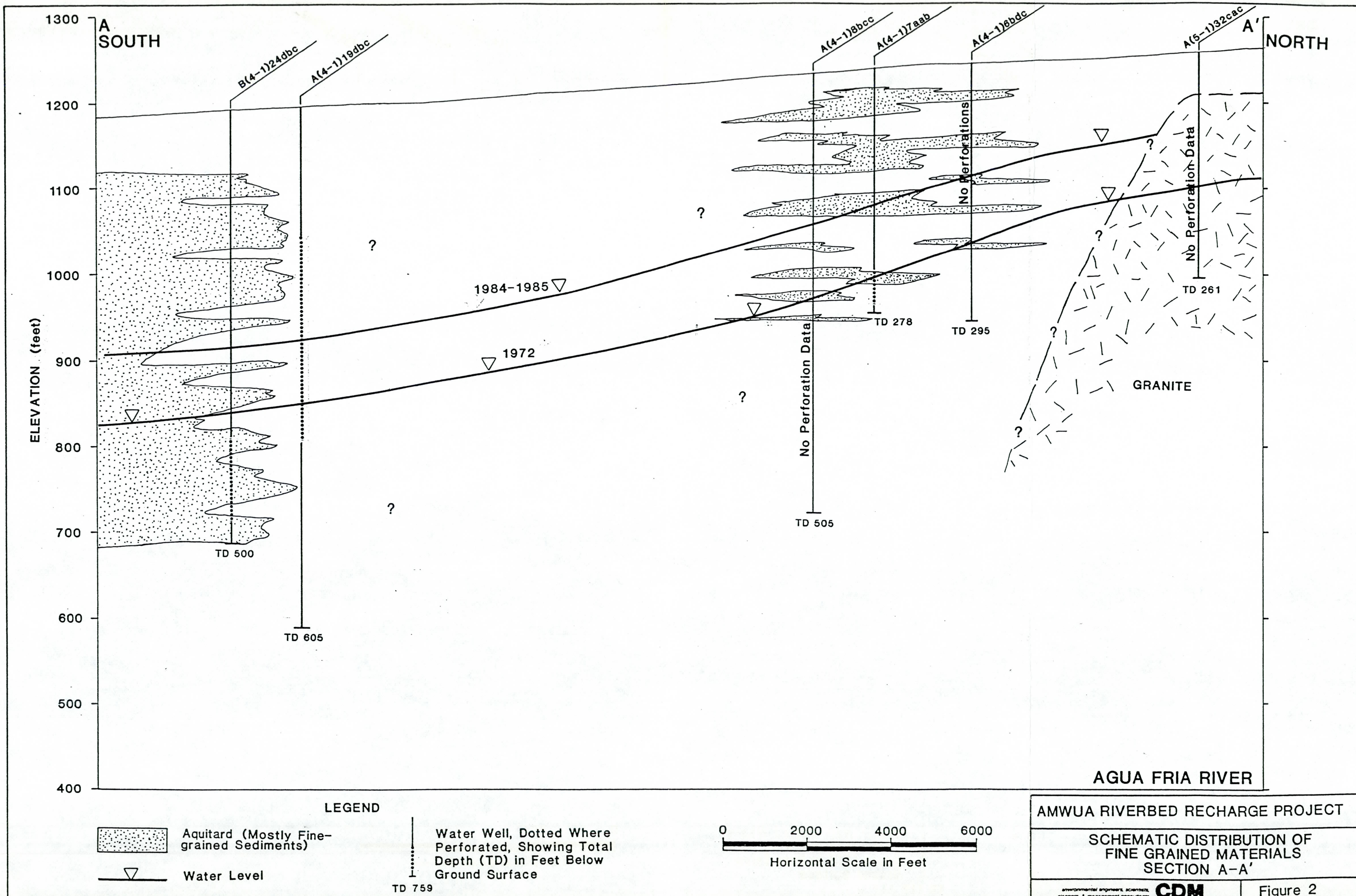
With its high infiltration rates, large width of recharge basin, relatively low transmissivities and specific yields, and a moderate depth to water, the Agua Fria initial mounding calculations resulted in a mound of over twice the depth to water. The estimated basin width is 3,200 feet. Transmissivity ranged 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 ranged from 110 feet below land surface in the very northern 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).

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 potential annual recharge rate at the Agua Fria site is 785,000 acre-feet per year (af/yr; Table 12).

Available storage capacity was calculated to be 54,000 af on the basis of the area weighted depth to water and specific yield, and total area of the recharge site (Table 1). This value represents a storage capacity of 25 af/acre, considered low in comparison to the other recharge sites. But, because of the large area of 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, few water quality data points are available to



A
SOUTH
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ELEVATION (feet)
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900
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700
600
500
400
B(4-1)24dbc
A(4-1)19dbc
A(4-1)8bcc
A(4-1)7aab
A(4-1)6bdc
A(5-1)32cac
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TD 505
TD 278
TD 295
TD 261
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2000
4000
6000
Horizontal Scale in Feet
AMWUA RIVERBED RECHARGE PROJECT
SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION A-A'
environmental engineers, scientists, planners, & management consultants
CDM
Figure 2

describe groundwater quality beneath the Agua Fria recharge site. One groundwater quality sample takes 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). More data are needed within the Agua Fria site to adequately describe water quality at this site.

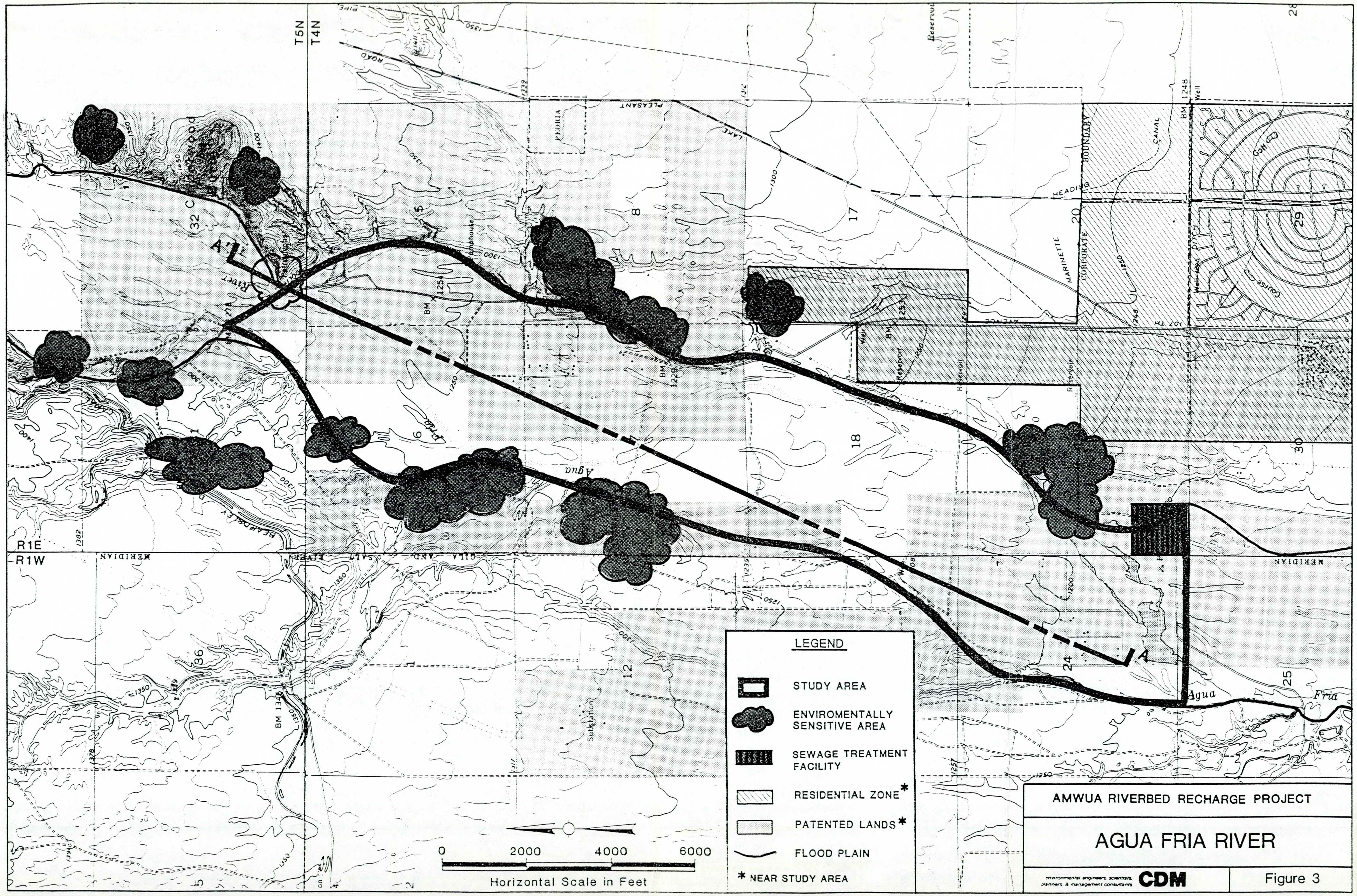
Landfills, wastewater treatment facilities, and farming areas comprise point and non-point potential groundwater pollution sources which could impact the recharge areas. No landfills were identified near the Agua Fria site. The Sun City Wastewater Treatment Facility is located near Deer Valley Road (Figure 3).

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 these sensitive areas.

Some areas within the Agua Fria site are patented lands. 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 accommodate large amounts of CAP water, and it is near a conveyance structure.


LEGEND
STUDY AREA
ENVIROMENTALLY SENSITIVE AREA
SEWAGE TREATMENT FACILITY
RESIDENTIAL ZONE*
PATENTED LANDS*
FLOOD PLAIN
* NEAR STUDY AREA
0 2000 4000 6000
Horizontal Scale in Feet
AMWUA RIVERBED RECHARGE PROJECT
AGUA FRIA RIVER
CDM
environmental engineers, scientists, planners, & management consultants
Figure 3
T5N
T4N
R1E
R1W
MERIDIAN
A'
A
Agua
Fria
River
PLEASANT
LAKE
PEORIA
CORPORATE BOUNDARY
MARINETTE
CANAL
BEARDSLEY
GILA AND SALT RIVER
32
5
8
17
20
29
30
18
6
24
25
12
36

NEW RIVER

The New River recharge site technically has recharge capabilities with a few major drawbacks. The recharge area, located several miles east of the Agua Fria site, is a long, narrow 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 basinn located 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.

Mounding does not appear to be a problem at the New River site. Based on a 30-day wet-dry cycle, the groundwater mound beneath the proposed recharge area was estimated to be 100 feet, well below the area weighted depth to groundwater of 450 feet (Table 2). Depth to groundwater in the study area ranges from 250 to 500 feet (Table 2). A localized cone of depression is apparent in the southern portion of the study area, and depth to water 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 27,000 gpd/ft, while the southern part is as high as 100,000 gpd/ft (Table 2). Average transmissivity is 60,000 gpd/ft, based upon 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 recharge area width is estimated to average 800 feet.

TABLE 2

PHYSICAL CHARACTERISTICS
NEW RIVER RECHARGE AREA

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	ND	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

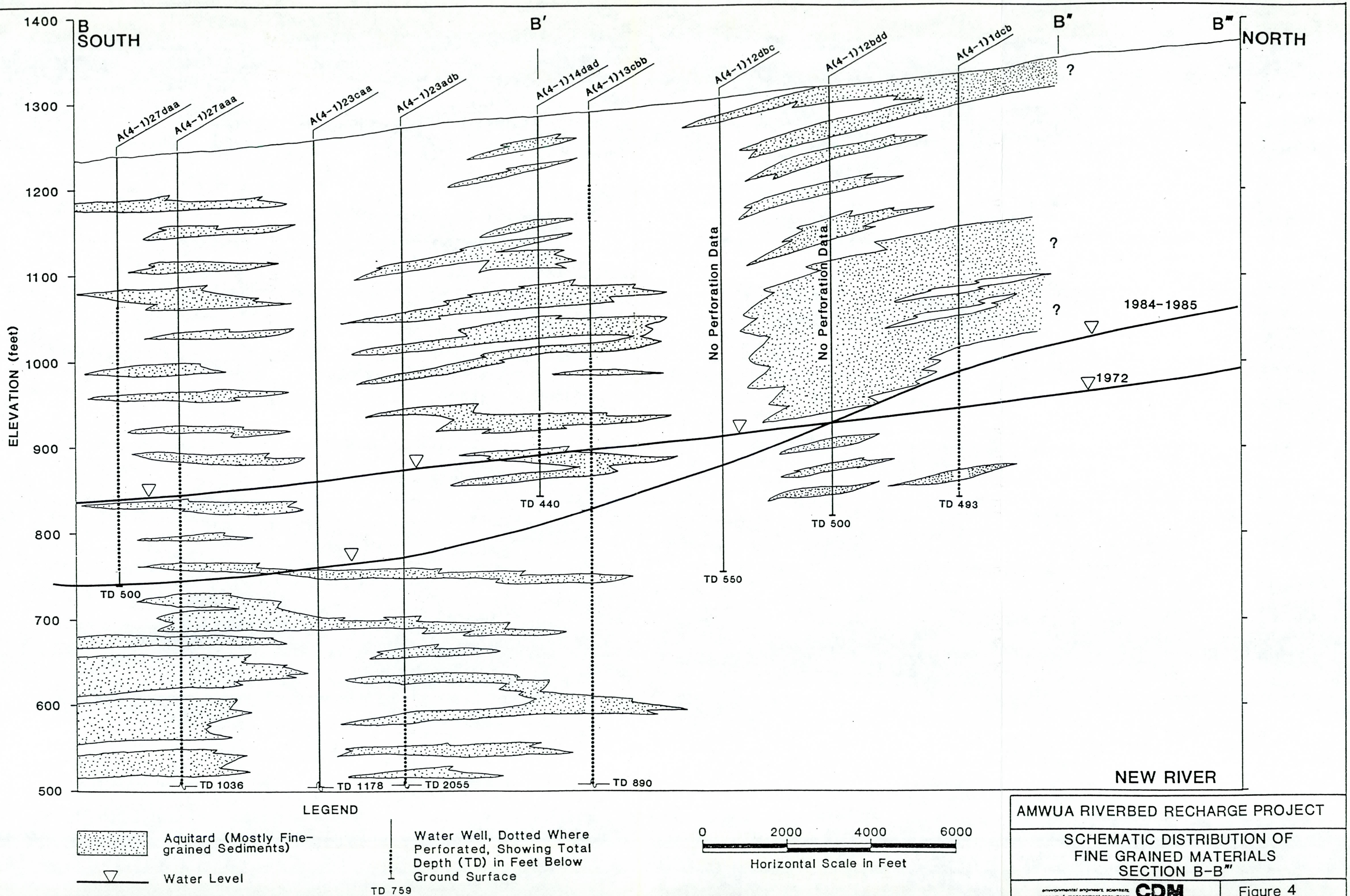
a Measured to the nearest 10 feet; 1984 data.
b Approximate amount of water that can be stored above the 1984 water table.
c Exceeds one of the primary or secondary drinking water standards, or other problems in proximity of the recharge area.
d Area weighted; considered representative value for recharge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

Storage capacity at New River is estimated to be about 20,000 af 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 af/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 219,000 af/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 2).

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 units 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 few wells in the area. The southern areas of the New River site show a potential problem with DBCP in groundwater (Plate 3). This area was cropped heavily with citrus groves and still contains some citrus farm land (MAG, 1979). Applications of DBCP were common for control of nematodes. Of primary concern when recharging CAP water is prevention of contaminating CAP water when mixing with groundwater contaminated 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. If present, these point sources could potentially cause a problem with groundwater quality by recharge mounding or deep percolation. A gravel pit in the southern portion of the study area should be checked for evidence of illegal dumping.



AMWUA RIVERBED RECHARGE PROJECT

SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION B-B‴

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Figure 4

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

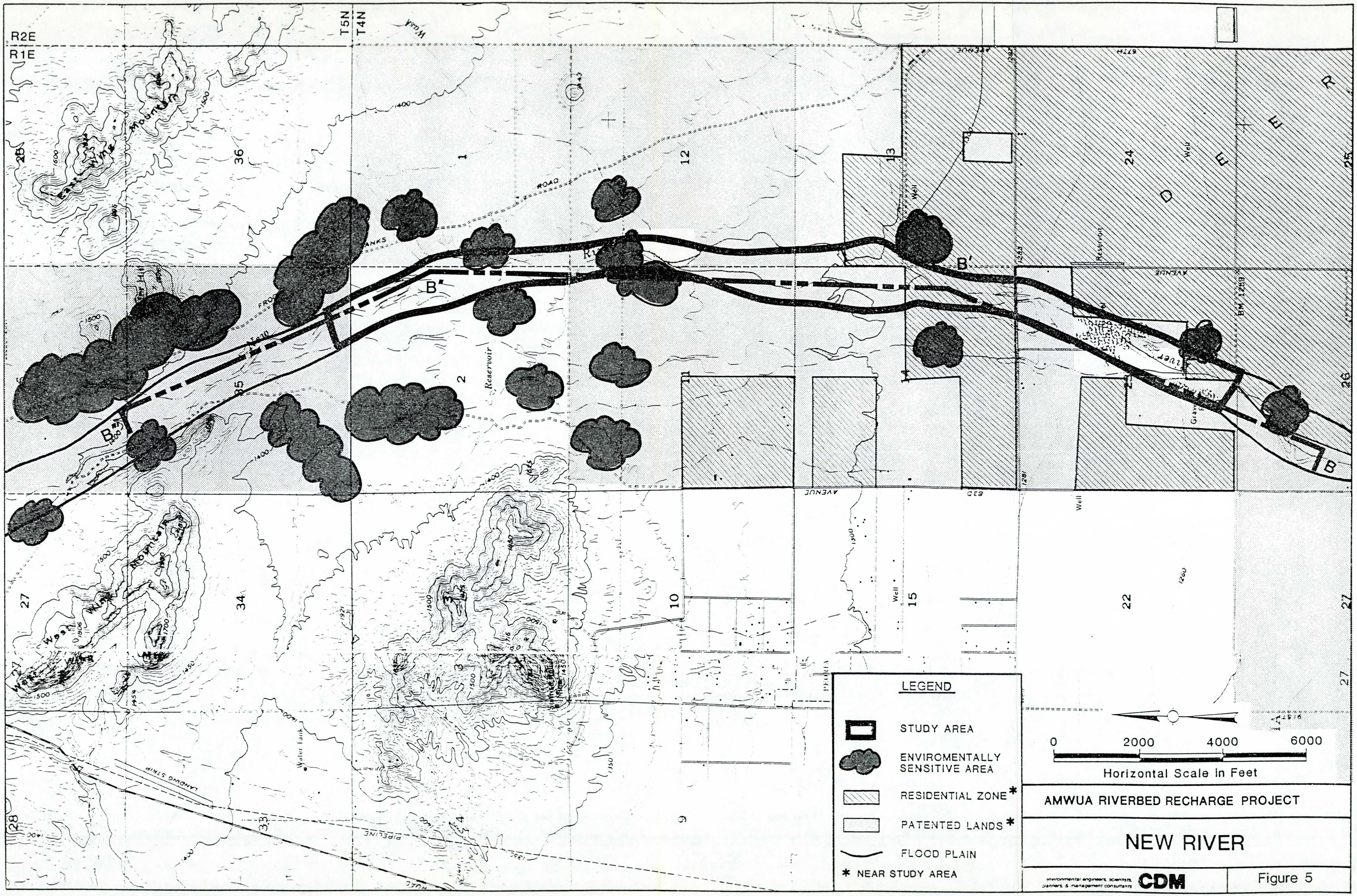
The New River site is in proximity to some residential areas where zoning is less than 20,000 ft^2/dwelling. The southern third of the site is mostly zoned residential, and may be a problem (Figure 5). The northern two-thirds of the New River site is relatively free of residential zoning less than 20,000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

Much of the land in the New River site is privately owned (Figure 5). The most northerly 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 to contend with. 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 and, 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. Perhaps, the length of any future recharge site could be shortened to avoid the above-mentioned problems. Conveyance structures are also a problem which could prove costly. Unlike some of the other sites which are locateed away from the CAP Aqueduct, the New River site is not in close proximity to a major conveyance facility which can bring CAP water indirectly to the site. All these drawbacks may limit the New River site as a recharge area.

LOWER SKUNK CREEK

The Skunk Creek recharge area is a desirable recharge area with some major drawbacks. The site is about four miles east of the New River site, one mile west of Interstate 17, and just north of Deer Valley Road (Plate 1). Although the Lower Skunk Creek site is a large facility, it is not near a


R2E
R1E
T5N
T4N
LEGEND
STUDY AREA
ENVIROMENTALLY SENSITIVE AREA
RESIDENTIAL ZONE*
PATENTED 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
B
B'
Reservoir
Well
LANDING STRIP
PIPELINE
ROAD
AVENUE
35
36
34
33
27
28
1
2
3
4
9
10
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27

major supply source of CAP, and conveyance facilities would be needed. There are also some problems with land ownership, possible and potential quality degradation, and residential proximity. These problems will be discussed with other recharge criteria in the following paragraphs.

Sustained infiltration rates within the Skunk Creek site are moderate in comparison to the other sites. Infiltration ranges from 1.7 to 3.6 ft/day, with an area weighted mean of 1.9 ft/day (Table 3). Most of the recharge site lies within Township T4S, R2E, Section 15, behind a flood control dam where infiltration is estimated to be 1.7 ft/day. Infiltration near the mountainous area in the southeast portion of the study area is as high as 3.6 ft/day, probably due to less fine-grained sediment accumulation in the more elevated areas.

Mounding does not appear to be a problem at the Skunk Creek site. Estimated transmissivity ranges 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 beneath the Skunk Creek facility would be about 150 feet, based on a 30-day wet-dry cycle. This was well below the average depth to water of 500 feet beneath the site (Plate 2, Table 3).

Recharge at the Skunk Creek site could allow for a substantial recovery in water levels downgradient of the site. Two miles south of the Skunk Creek site is a large groundwater depression caused by substantial well water withdrawals (Plate 2). CAP water recharge would help reduce groundwater overdraft in this area.

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 af, or about 50 af/acre. This is the largest storage capacity per acre of all ten sites. Lateral movement from the site would allow up to about 190,000 af/year of CAP water to be recharged, based on a recharge rate of 1.0 ft/day, over an area of 520 acres, and a 30-day wet-dry cycle.

TABLE 3

PHYSICAL CHARACTERISTICS
SKUNK CREEK RECHARGE AREA

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	1.7	75	.10	19,000	380	no	ND
	16	500	1.8	50	.10	4,500	90	no	possible nitrate
	21	500	3.6	10	.10	2,500	50	no	ND
	22	530	NA	50	.10	0	0	no	ND
RANGE	NA	480 - 530	1.7 - 3.6	10 - 75	.10 - .15	NA	NA	NA	NA
MEAN (d)	NA	500	1.9	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.
ND No data.
NA Not applicable.

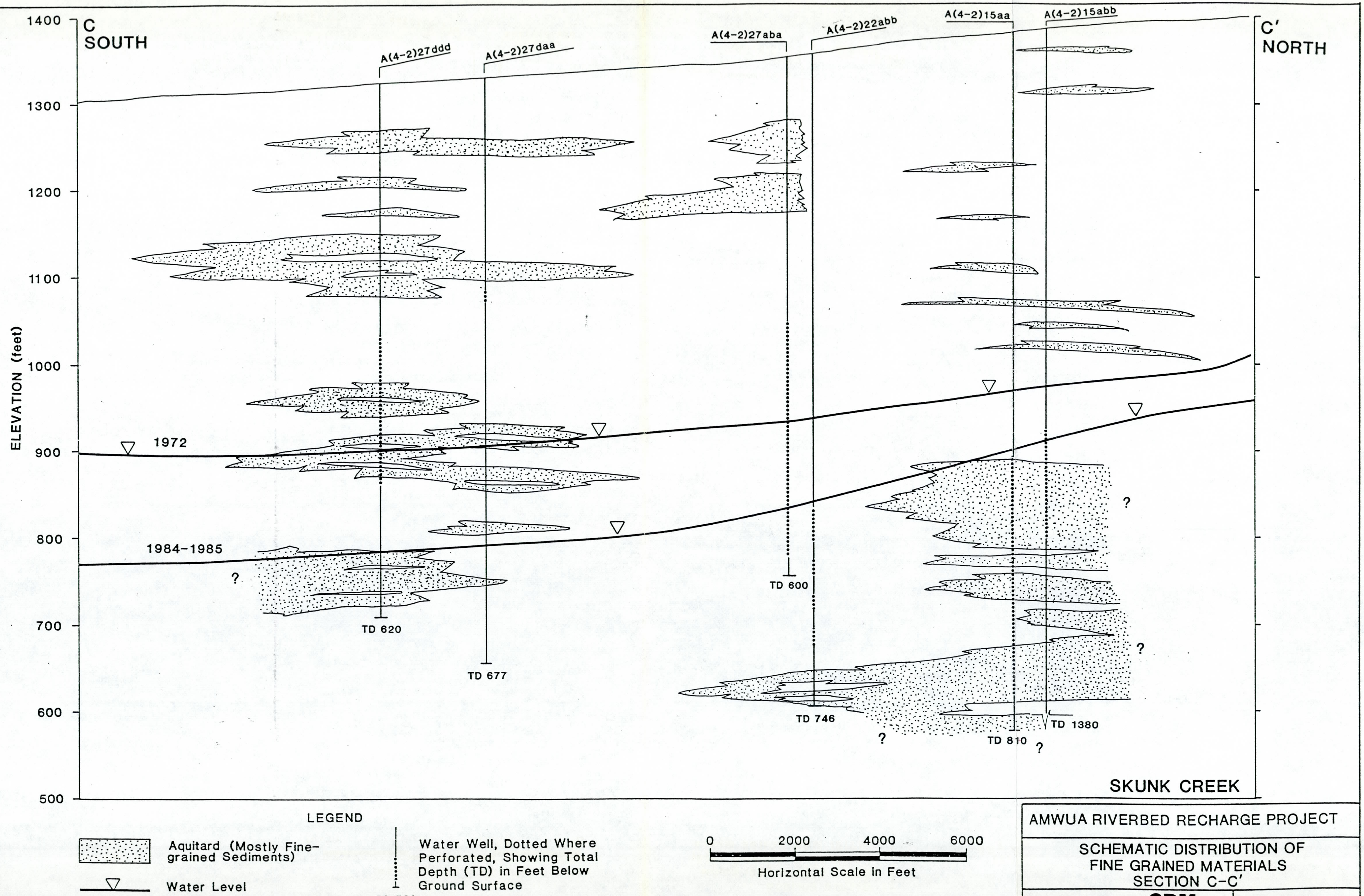
Perched water will probably not be a problem at the Skunk Creek site. A geologic cross section (Figure 6) shows few lenses of fine-grained material above the 1984 water table, indicating perched conditions would probably not result from CAP water recharge. More fine-grained material occurs downgradient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

Groundwater quality in the vicinity of the Lower Skunk Creek site indicates there may be a few problems. Data directly beneath the Skunk Creek site is lacking, but well waters about 1.5 miles west and 2 miles northeast indicate elevated nitrate content (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. However, about 1 mile upstream of the site is a landfill in the flood plain of the creek. However, during conveyance in the stream channel, significant amounts of CAP water will percolate through the channel bottom. Because the landfill is so close to the river chanel, recharge 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 between the aqueduct and the spreading facilities.

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

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.



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SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION C-C'

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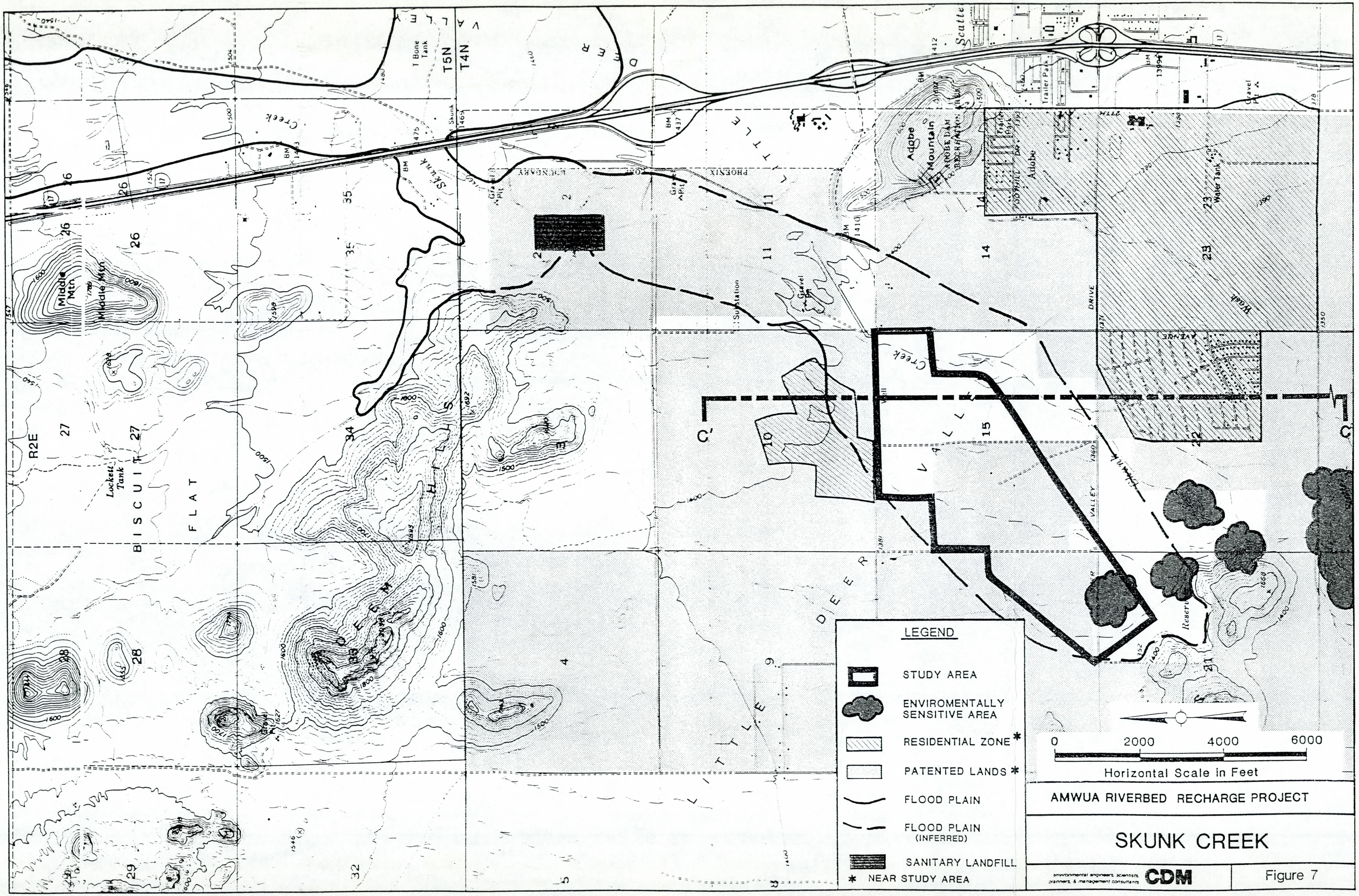
Figure 6



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SKUNK CREEK

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Figure 7

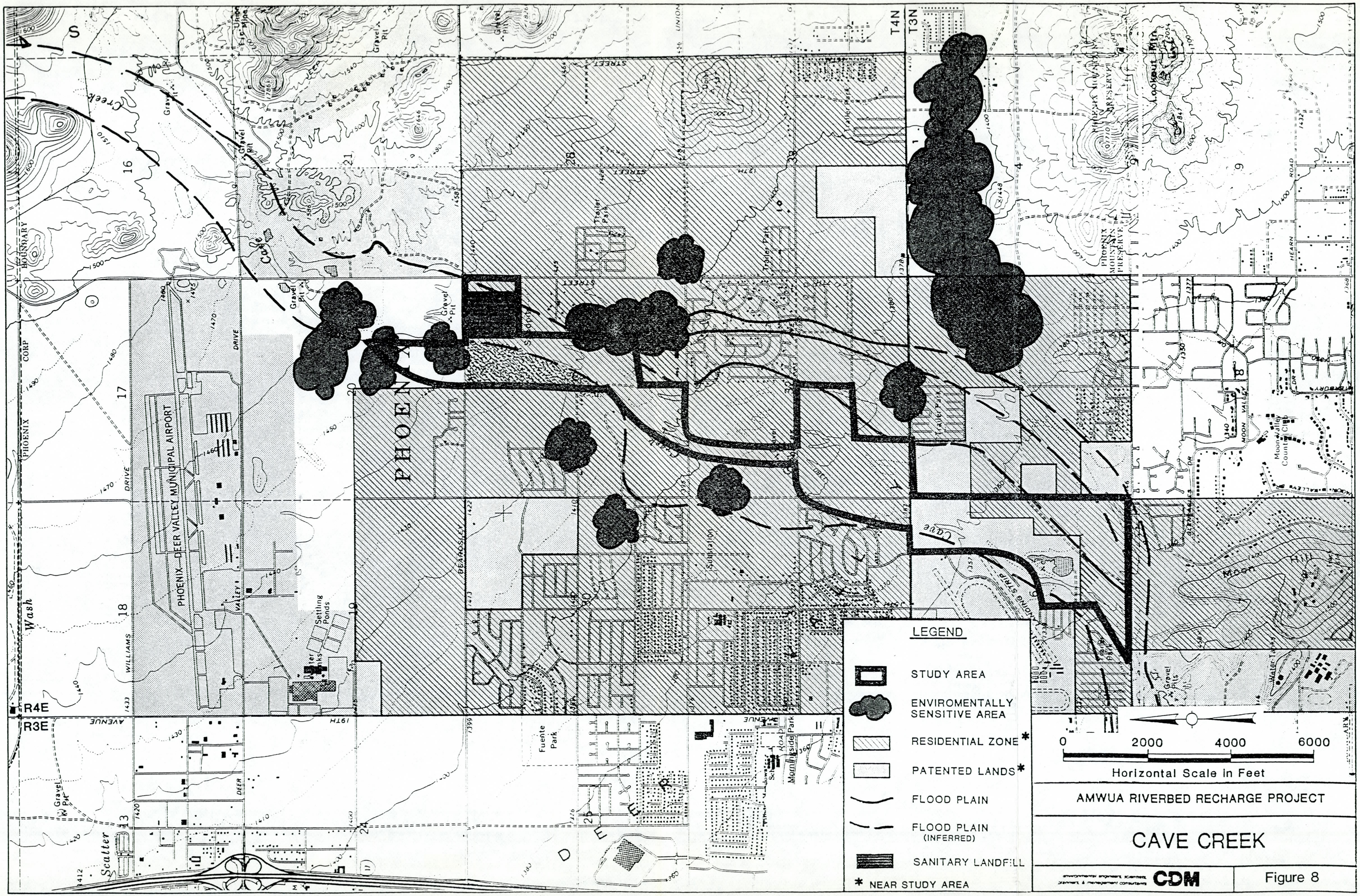
Over half of the Lower Skunk Creek site is privately owned. Land acquisition for this site could be moderately expensive because of the private land.

In summary, the Lower 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 have elevated nitrate concentrations. Finally, considerable land is privately owned, making land acquisition more costly. But 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.

CAVE CREEK

Because of their close proximity to each other, 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 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 1.5 to 2.1 ft/day with a weighted mean of 2.0 ft/day. The lower sites ranges from 1.8 to 3.0 ft/day with a weighted mean of 2.3 ft/day. 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.


LEGEND
STUDY AREA
ENVIROMENTALLY SENSITIVE AREA
RESIDENTIAL ZONE *
PATENTED 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-DEER VALLEY MUNICIPAL AIRPORT
PHOENIX
Cave Creek
Moon Hill
Moon Valley Country Club
Settling Ponds
Fuente Park
T4N
T3N
R4E
R3E
Lookout Mtn
Trailer Park
Gravel Pit

Both Cave Creek sites have a potential mounding problem. A cross section reveals evidence of fine-grained layers which are fairly extensive at both sites (Figure 9). 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 decrease from north to south from about 14,000 gpd/ft to 10,000 gpd/ft. Similarly, the specific yield decreases from 0.10 to 0.07. Using this hydraulic data and reducing the infiltration rates to 1.0 ft/day and 1/2 ft/day for the upper and lower sites, respectively, the corresponding recharge mounds would be 138 feet ad 380 feet above the water table. These values assume a 30-day wet-dry cycle.

The estimated annual recharge rates are 88,000 af/year for Upper Cave Creek and 175,000 af/year for Lower Cave Creek, based on the adjusted recharge rates of 1.0 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 af or about 27.5 af/acre, which is a low value compared to the other sites (TABLE 4). The lower site has a storage capacity of 11,200 af, or 28.0 af/acre, which is also comparatively low (Table 5).

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 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 is a potential threat to groundwater quality in the area. 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.

TABLE 4

PHYSICAL CHARACTERISTICS
UPPER CAVE CREEK RECHARGE AREA

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	1.5	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	1.5 - 2.1	10 - 30	.07 - .10	NA	NA	NA	NA
MEAN (d)	NA	275	2.0	14	.10	NA	NA	NA	NA
TOTAL	NA	NA	NA	NA	NA	6,600	240	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.

ND No data.

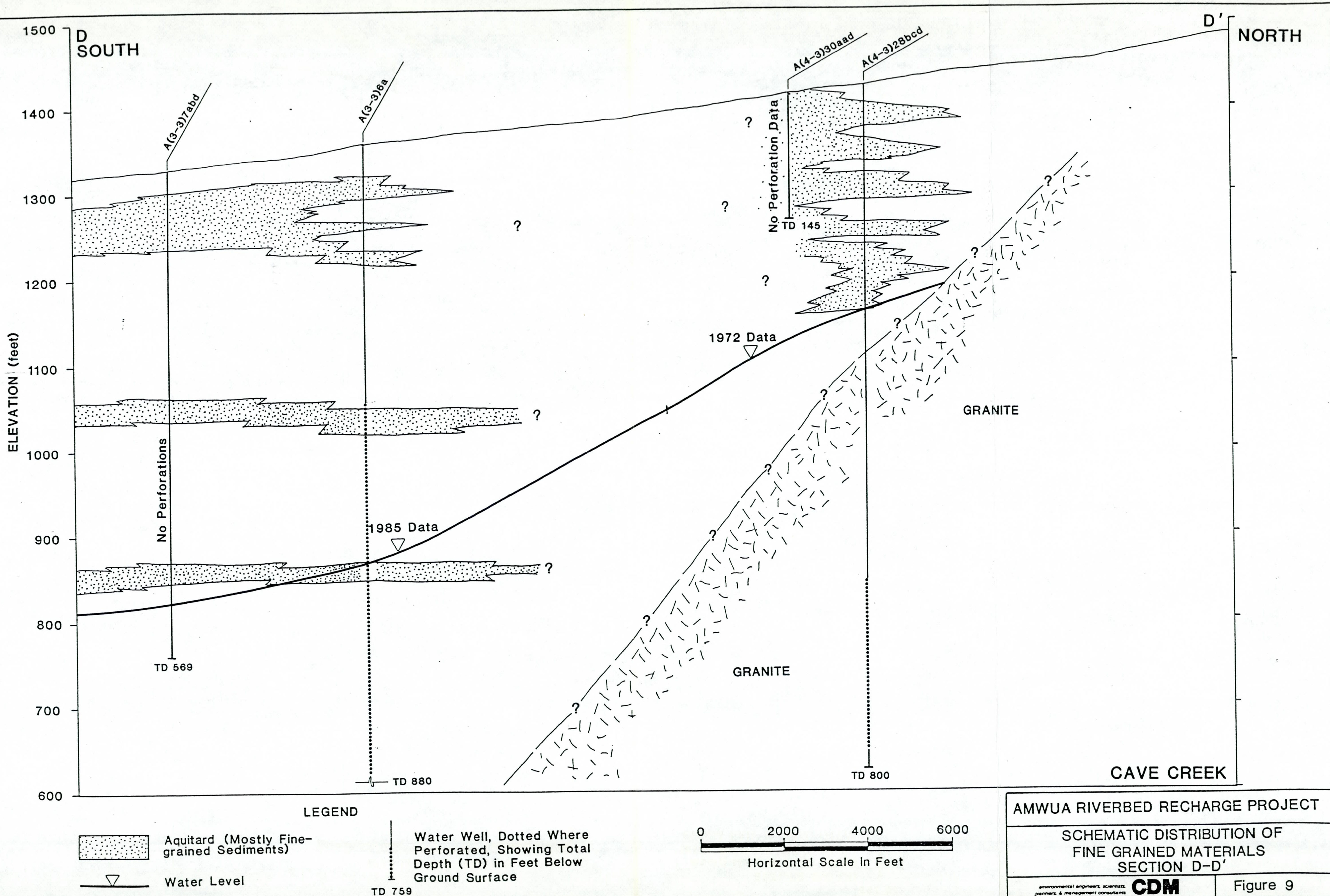
NA Not applicable.

TABLE 5

PHYSICAL CHARACTERISTICS
LOWER CAVE CREEK RECHARGE AREA

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

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.
ND No data.
NA Not applicable.



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SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION D-D'

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Figure 9

Several environmental sites were identified in the Cave Creek study areas. Thes inspections would be necessary to initiate recharge activities in this area.

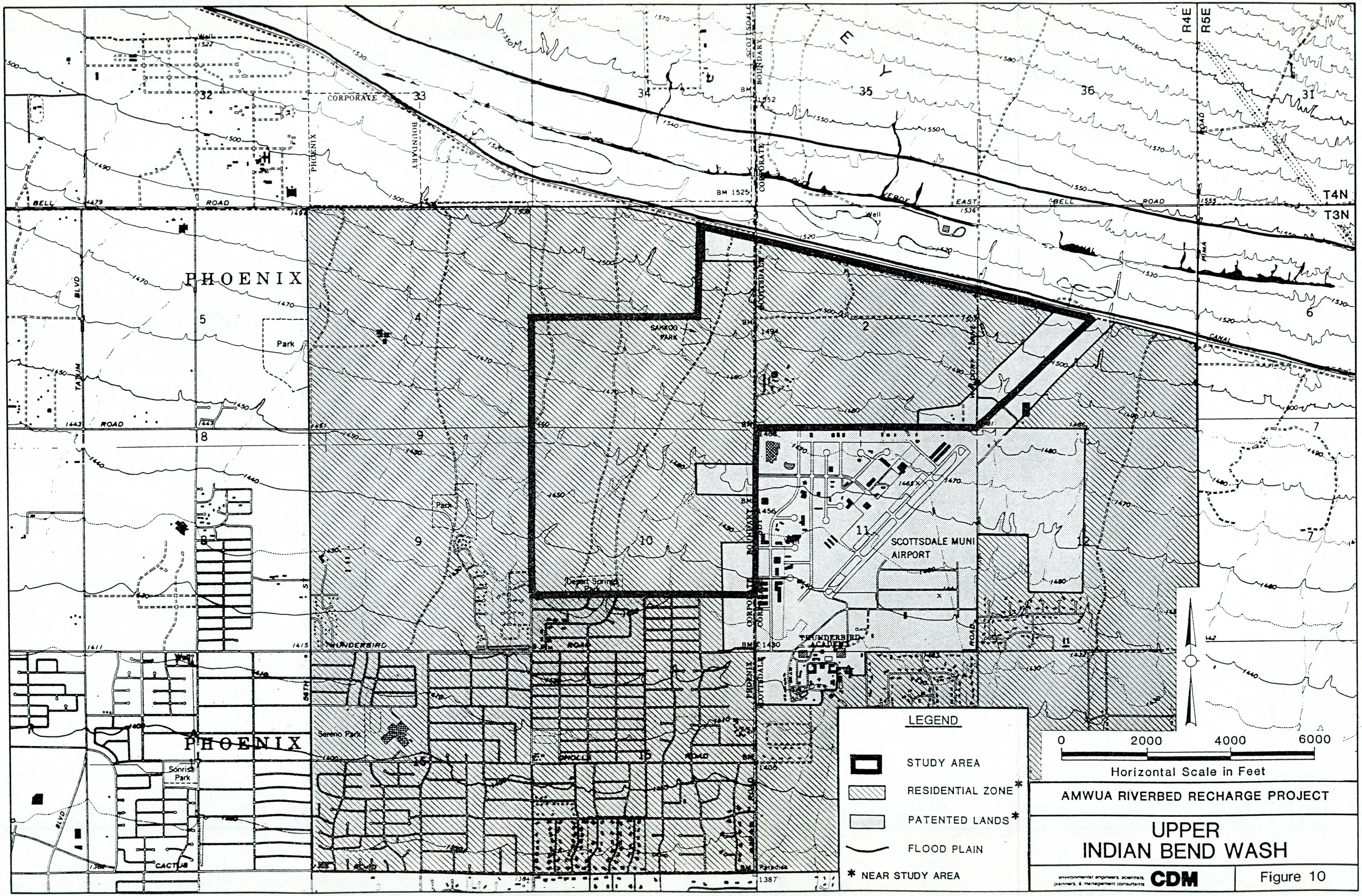
One major drawback at the Cave Creek sites is the large amount of residentially zoned acreage within the area. With the exception of some non-residential areas in the southern portion of Lower Cave Creek, both sites are residentially dominated (Figure 8). Land ownership in the Cave Creek areas is almost completely dominated by private 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. Down-gradient water quality is contaminated with VOCs and high nitrates. Finally, 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.

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 has some severe limitations which will be discussed in the next few paragraphs.

Infiltration rates vary from 2.5 to 3.1 ft/day with an area weighted mean of 2.8 ft/day. The area consists of several braided stream channels which eventually converge into Indian Bend Wash several miles downstream. Because of these numerous channels, the infiltration rates are some of the highest among the ten proposed recharge sites.



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UPPER INDIAN BEND WASH

CDM

Figure 10

Using the maximum estimated infiltration rate of 2.8 ft/day, the Upper Indian Bend site has a potential mounding problem. By adjusting the recharge rate to 1.3 ft/day mounding will equal the depth to water of 430 feet (Table 6). 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.

Based on the adjusted recharge rate of 1.3 ft/day, which will limit the rise of the recharge mound to below land surface, and a potential recharge area of 1,430 acres, the potential annual recharge rate is 680,000 af/year.

Available storage capacity was calculated to be 55,000 af based on a 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 af/acre, one of the higher values among the ten recharge sites (Table 12). Lateral movement of recharge water from the site will allow considerably higher annual recharge rates.

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 fine-grained layering, perching could cause further mounding in the area.

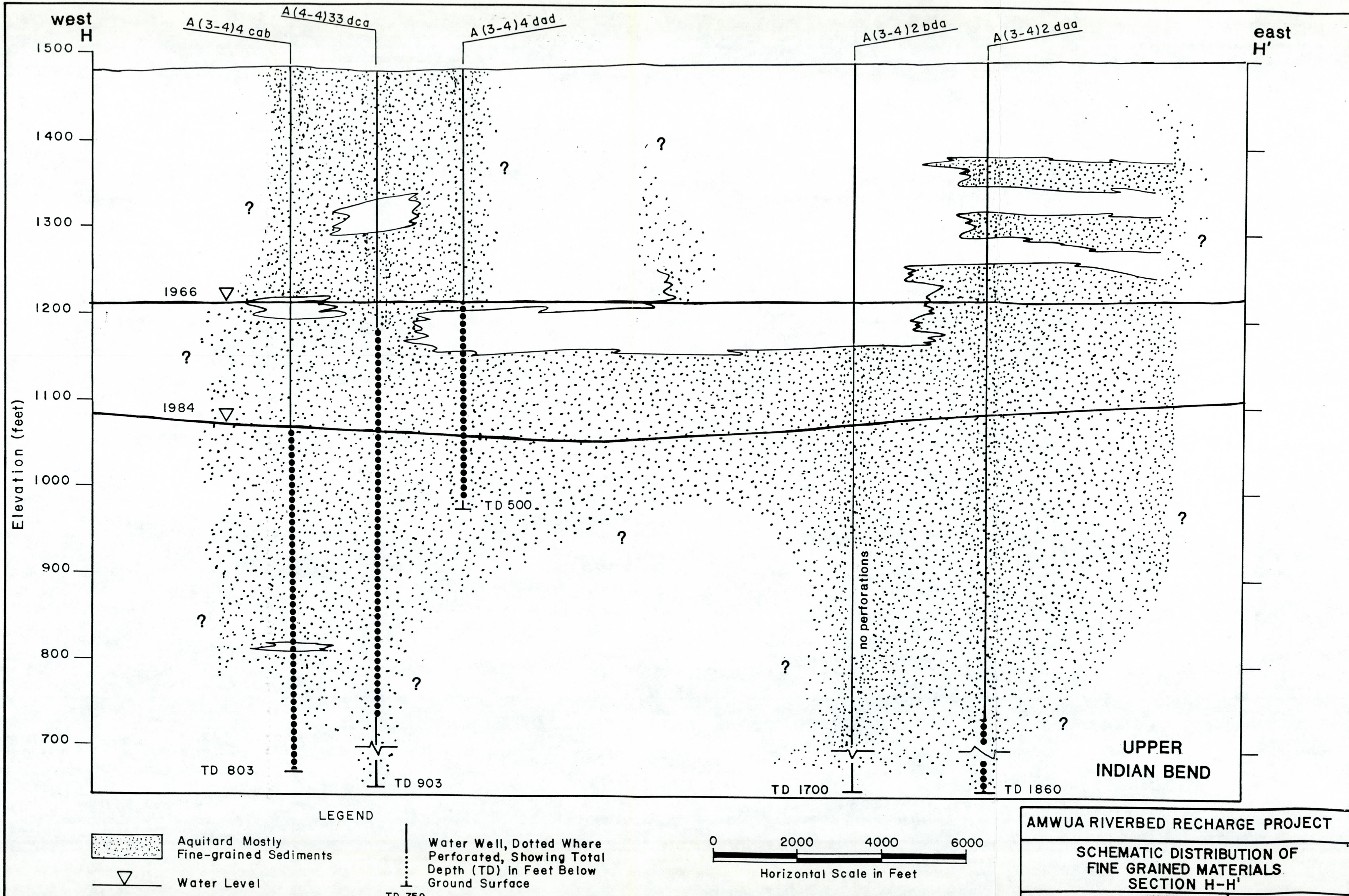
Groundwater quality appears good in the vicinity of the Upper Indian Bend site, with the exception of hexavalent chromium. A zone of excessive hexavalent chromium in groundwater is present beneath the southern portion of the study area and in groundwater downgradient of thee site (Plate 3). This condition has been attributed to naturally occurring chromium. Higher chromium contents were founnd 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 the lower conglomerate units (MAG, 1979). This presents quite a problem when recharging CAP water, especially because the shallower units are higher

TABLE 6

PHYSICAL CHARACTERISTICS
UPPER INDIAN BEND RECHARGE AREA

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	2.5	10	.10	4,000	105	yes	ND
	2	440	3.1	15	.10	20,250	460	yes	Cr = .010 ug/l
	3	440	2.8	15	.10	17,000	390	yes	ND
	10	420	2.5	5	.07	14,000	475	yes	Cr = .034 ug/l
	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	2.5 - 3.1	5 - 15	.05 - .10	NA	NA	NA	NA
MEAN (d)	NA	430	2.8	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.
ND No data.
NA Not applicable.



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SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION H-H'

CDM

Figure 11

with hexavalent chromium. 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 in the vicinity of the Upper Indian Bend Wash site. However, the Scottsdale Municipal Airport may possibly be a potential source of TCE, as has been the case for airports in many other areas.

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.

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 sustained maximum recharge rate is only 0.25 ft/day, lowest of all the recharge sites.

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

TABLE 7

PHYSICAL CHARACTERISTICS
LOWER INDIAN BEND RECHARGE AREA

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.

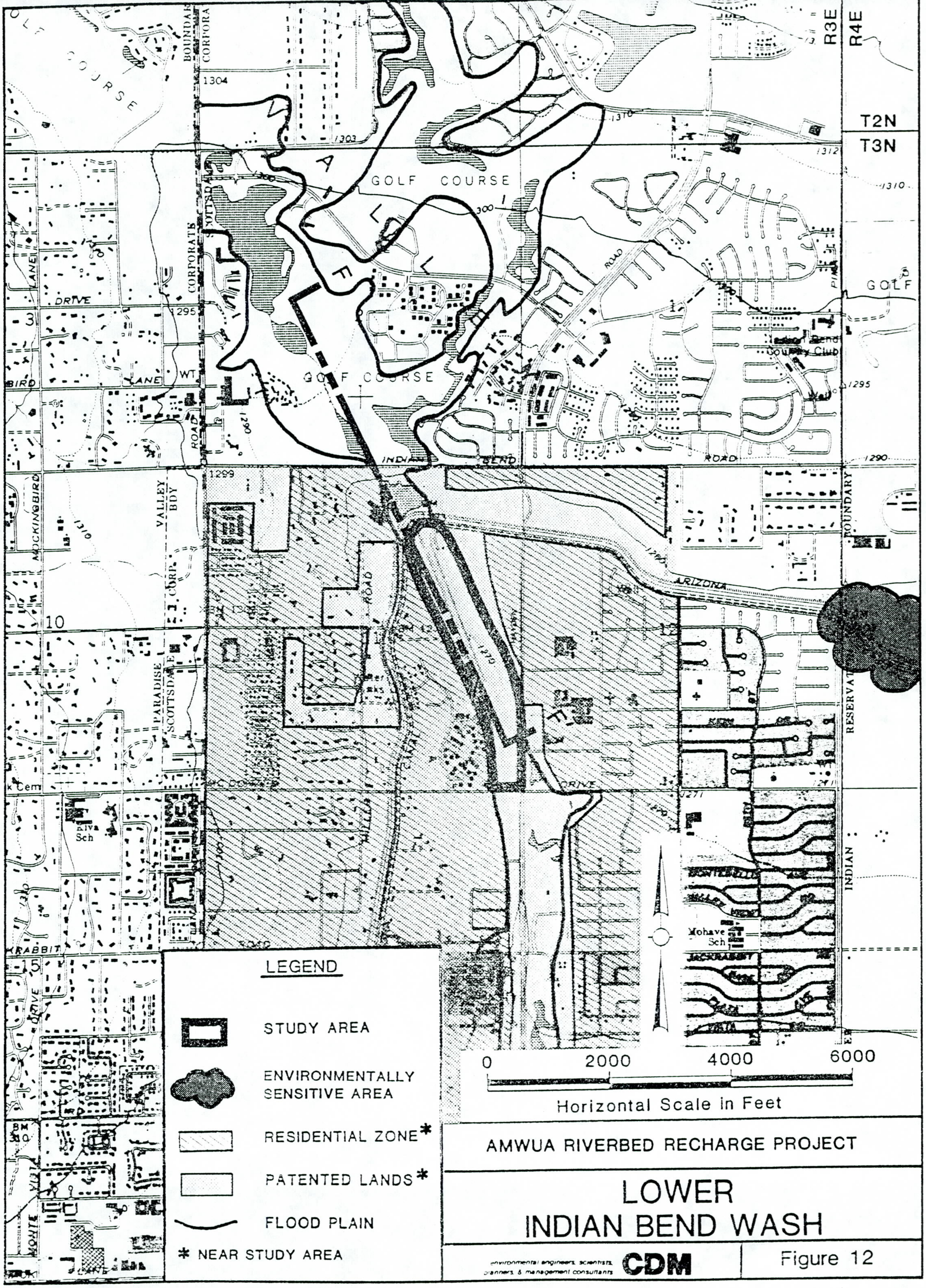
c Exceeds one of the primary or secondary drinking water standards, or other problems in proximity of the recharge area.

d Area weighted; considered representative value for recharge site

* Estimated.

ND No data.

NA Not applicable.


R3E
R4E
T2N
T3N
GOLF COURSE
GOLF COURSE
Indian Bend Country Club
INDIAN BEND ROAD
ARIZONA CANAL
SCOTTSDALE CORPORATE BOUNDARY
PARADISE VALLEY CORP. BDY
SALT RIVER INDIAN RESERVATION BOUNDARY
Kiva Sch
Mohave Sch
MCDONALD DRIVE
JACKRABBIT
LEGEND
STUDY AREA
ENVIRONMENTALLY SENSITIVE AREA
RESIDENTIAL ZONE*
PATENTED LANDS*
FLOOD PLAIN
* NEAR STUDY AREA
0
2000
4000
6000
Horizontal Scale in Feet
AMWUA RIVERBED RECHARGE PROJECT
LOWER
INDIAN BEND WASH
environmental engineers, scientists, planners, & management consultants
CDM
Figure 12

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.

Storage capacity 1,530 af is low because of the small area of recharge (Table 7). This value is translated to 17.0 af/acre, the lowest among the recharge sites. The annual recharge rate, which is calculated as a product of the daily recharge rate (.25 ft/day) and the total area (90 acres), is 3,000 af/year, the lowest among the potential sites.

Extensive fine-grained layering occurs beneath and in the vicinity of the recharge site (Figure 13). This indicates a great potential for mounding CAP water recharged at this site. In addition, perched water has been detected in the areas around the site, probably from canal seepage.

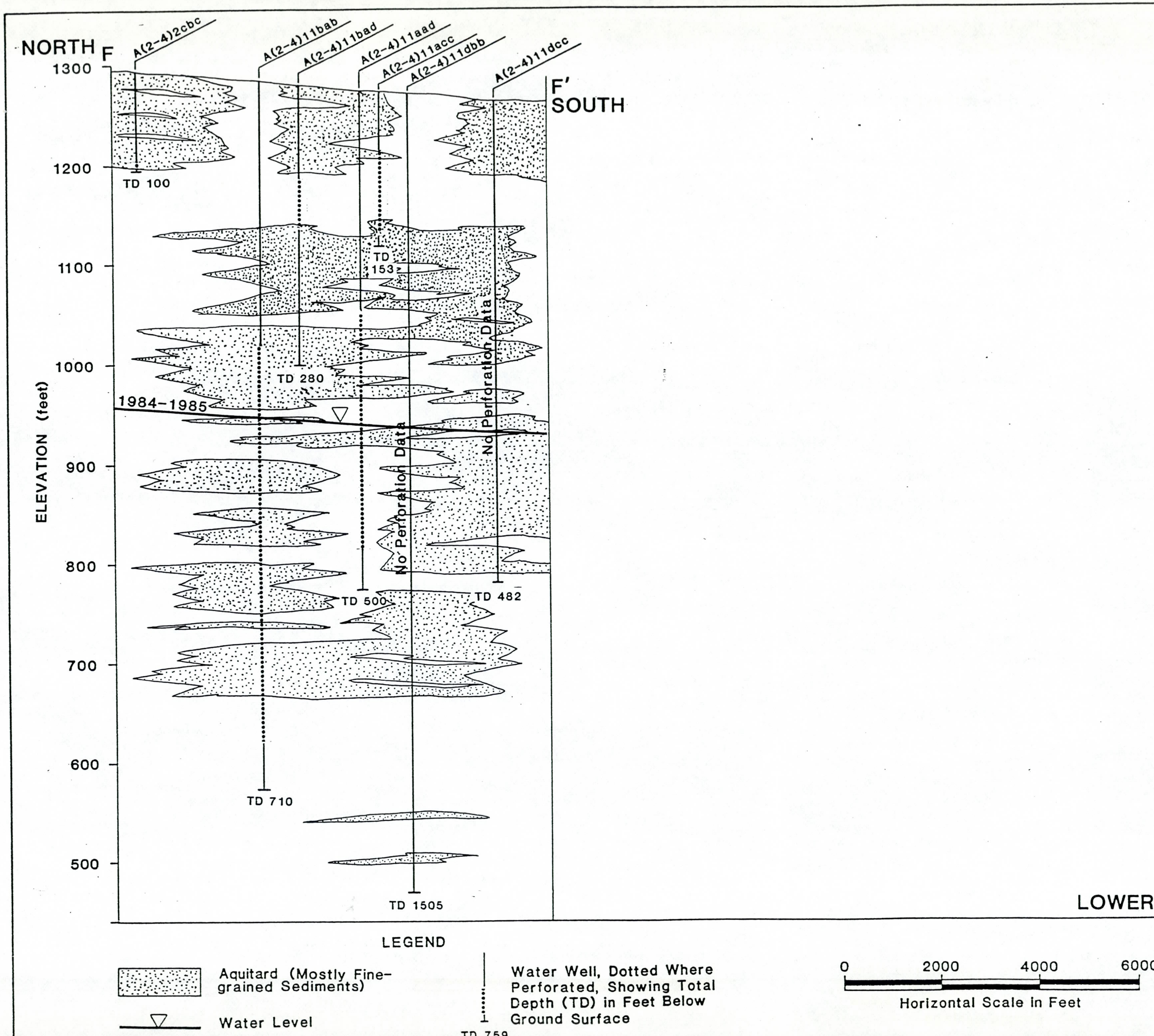
There are water quality problems near the Lower Indian Bend site, but data is lacking directly beneath the site. Two miles south of the recharge site, VOCs are present and total dissolved solids (TDS) are elevated. This currently may not cause a problem because the site is above a localized cone of depression (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. Residential zoning surrounds the Indian Bend site. The land within the recharge site is zoned as a public park, but is currently undeveloped.

In conclusion, the Lower Indian Bend site may have problems recharging CAP water. Documented perched water in the area, a small recharge site, proximity to residential neighborhoods, and potential water quality problems necessitate ranking this site low.

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.



LOWER INDIAN BEND WASH

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SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION F-F'

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Figure 13

The recharge sites are immediately downstream of the junction of the Salt-Gila and Granite Reef Aqueduct (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, cover 810 acres in the Upper Salt River area and 2,515 acres for Lower Salt River area. For these reasons, these sites are prime candidates for CAP recharge.

Sustained 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 2.4 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 af/acre, a low value when compared to the other sites. The lower site storage capacity is much larger at 71,300 af 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

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

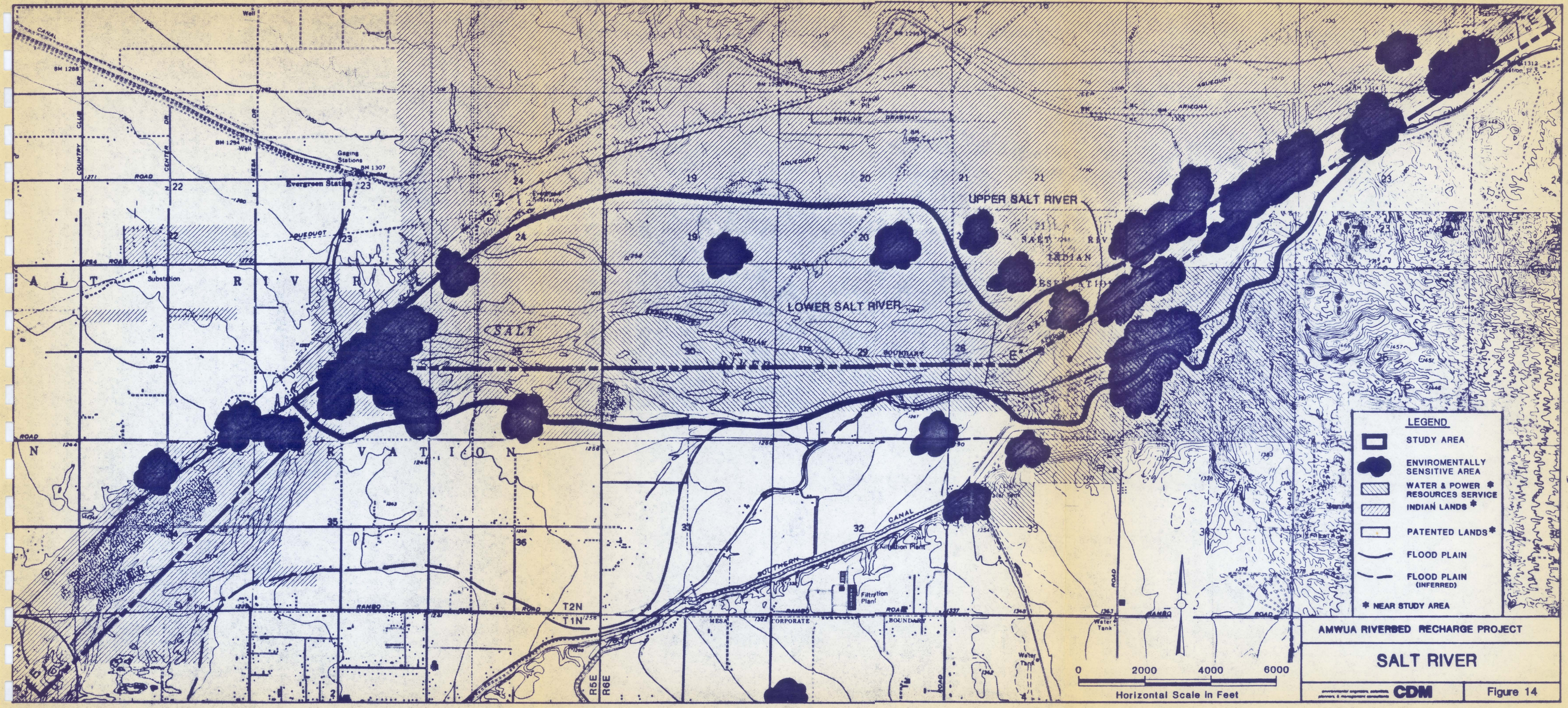
a Measured to the nearest 10 feet; 1984 data.
b Approximate amount of water that can be stored above the 1984 water table.
c Exceeds one of the primary or secondary drinking water standards, or other problems in proximity of the recharge area.
d Area weighted; considered representative value for recharge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

TABLE 9

PHYSICAL CHARACTERISTICS
LOWER SALT RIVER RECHARGE AREA

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	NA	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	2.4	56	.09	NA	NA	NA	
TOTAL	NA	NA	NA	NA	NA	71,300	2,515	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.
ND No data.
NA Not applicable.

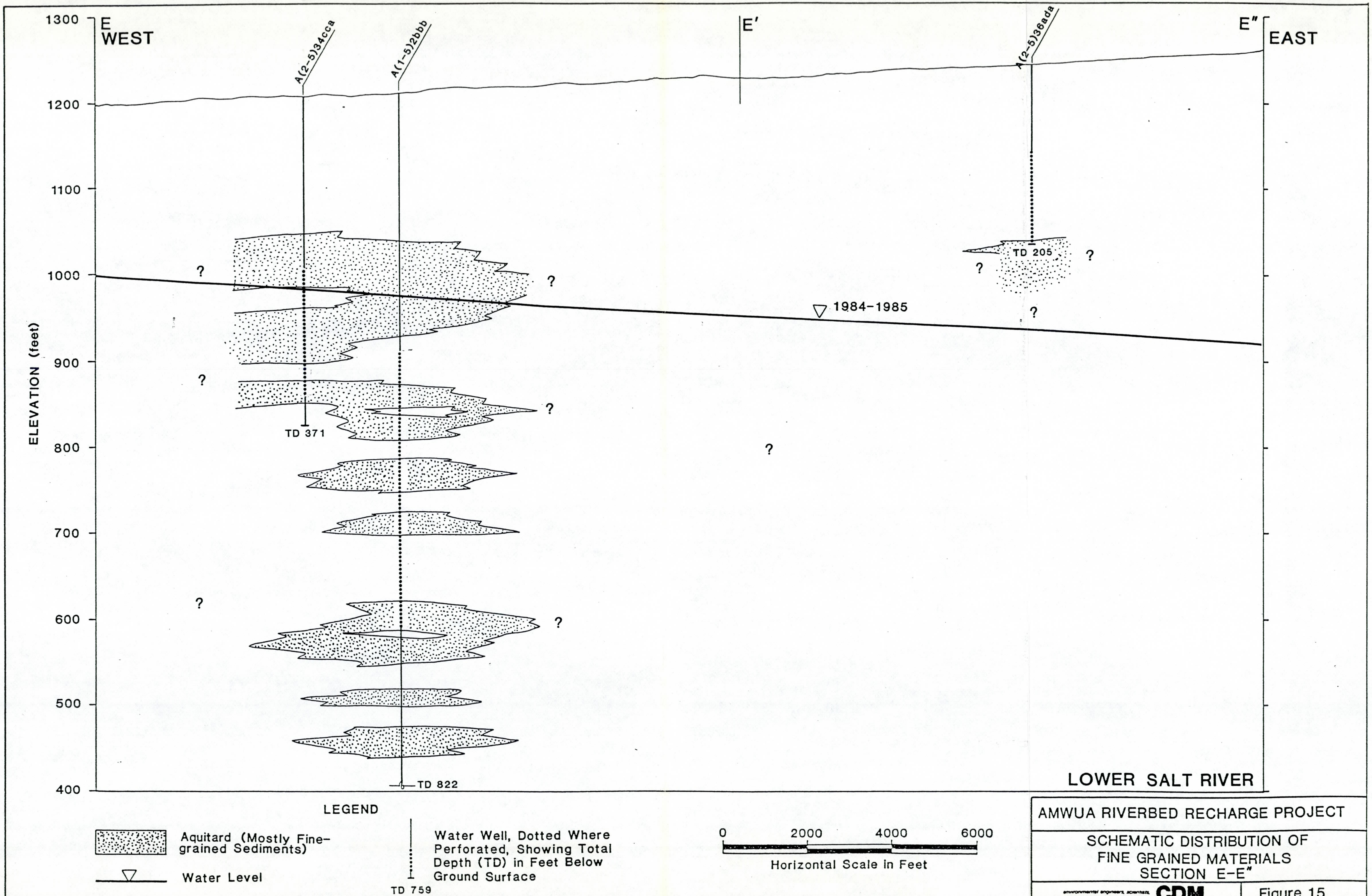


UPPER SALT RIVER
LOWER SALT RIVER
SALT RIVER INDIAN RESERVATION
Evergreen Station
Gaging Stations
AQUEDUCT
SOUTHERN CANAL
Filtration Plant
RAMBO ROAD
T2N
T1N
R5E
R6E
LEGEND
STUDY AREA
ENVIROMENTALLY SENSITIVE AREA
WATER & POWER RESOURCES SERVICE *
INDIAN LANDS *
PATENTED LANDS *
FLOOD PLAIN
FLOOD PLAIN (INFERRED)
* NEAR STUDY AREA
0 2000 4000 6000
Horizontal Scale in Feet
AMWUA RIVERBED RECHARGE PROJECT
SALT RIVER
CDM
Figure 14

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 296,000 af/year. Based on a 30-day wet-dry cycle, a limited infiltration rate to prevent mounding to the land surface of 1.0 ft/day, and a surface area of 2,515 acres, the annual recharge rate for the Lower Salt River site could be as much as 918,000 af/year.

Perched water may be a problem for both Salt River sites. The Upper Salt site has extensive non-continuous and continuous 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, high fluorides 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 detected 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 contaminated downgradient groundwater. This problem will have to be addressed if CAP water is to be recharged at these sites.



AMWUA RIVERBED RECHARGE PROJECT

SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION E-E″

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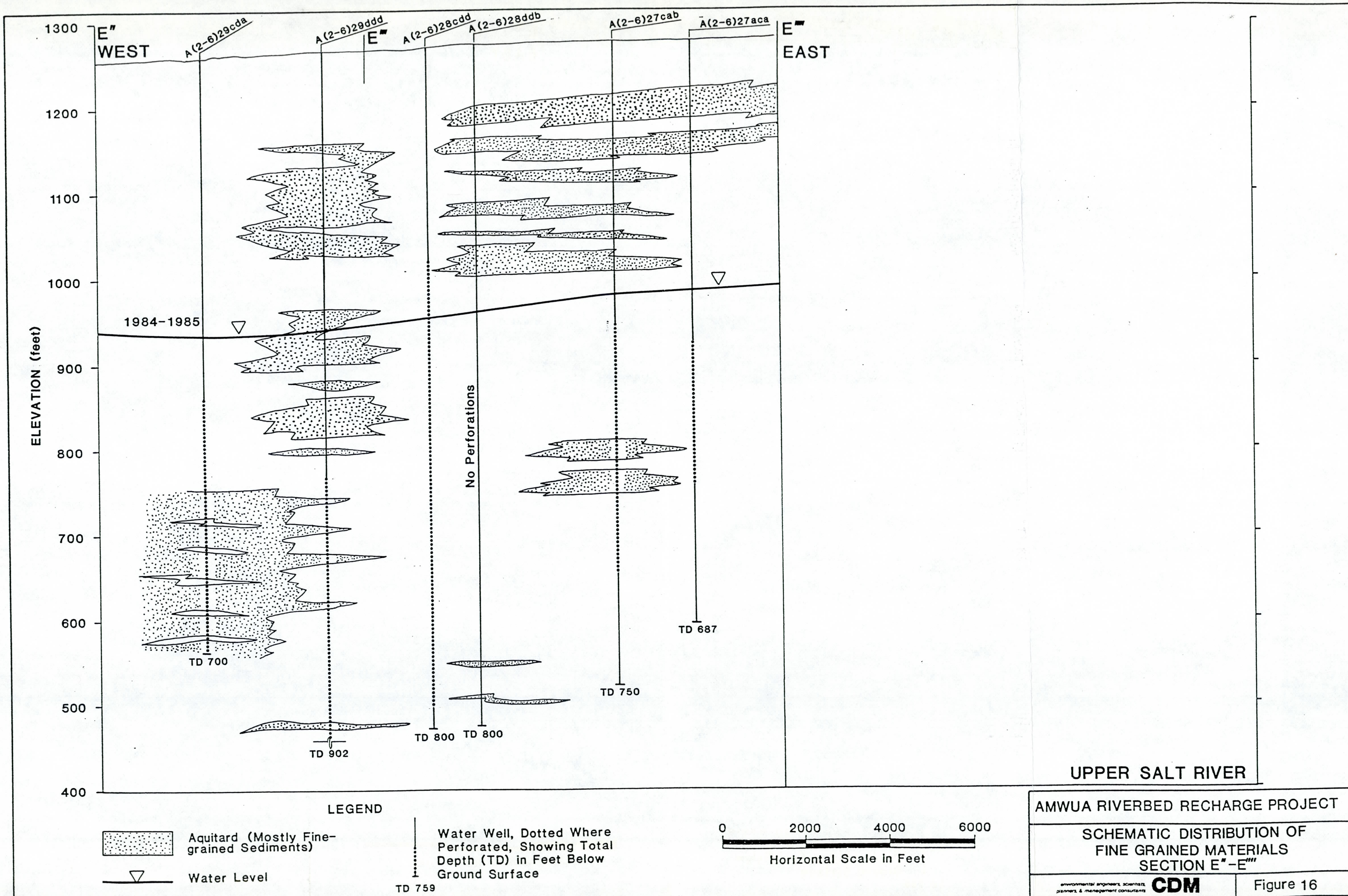
Figure 15



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

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Figure 16

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 downward migrating effluent. No landfills were identified in the area, but illegal dumps should be investigated before recharge commences.

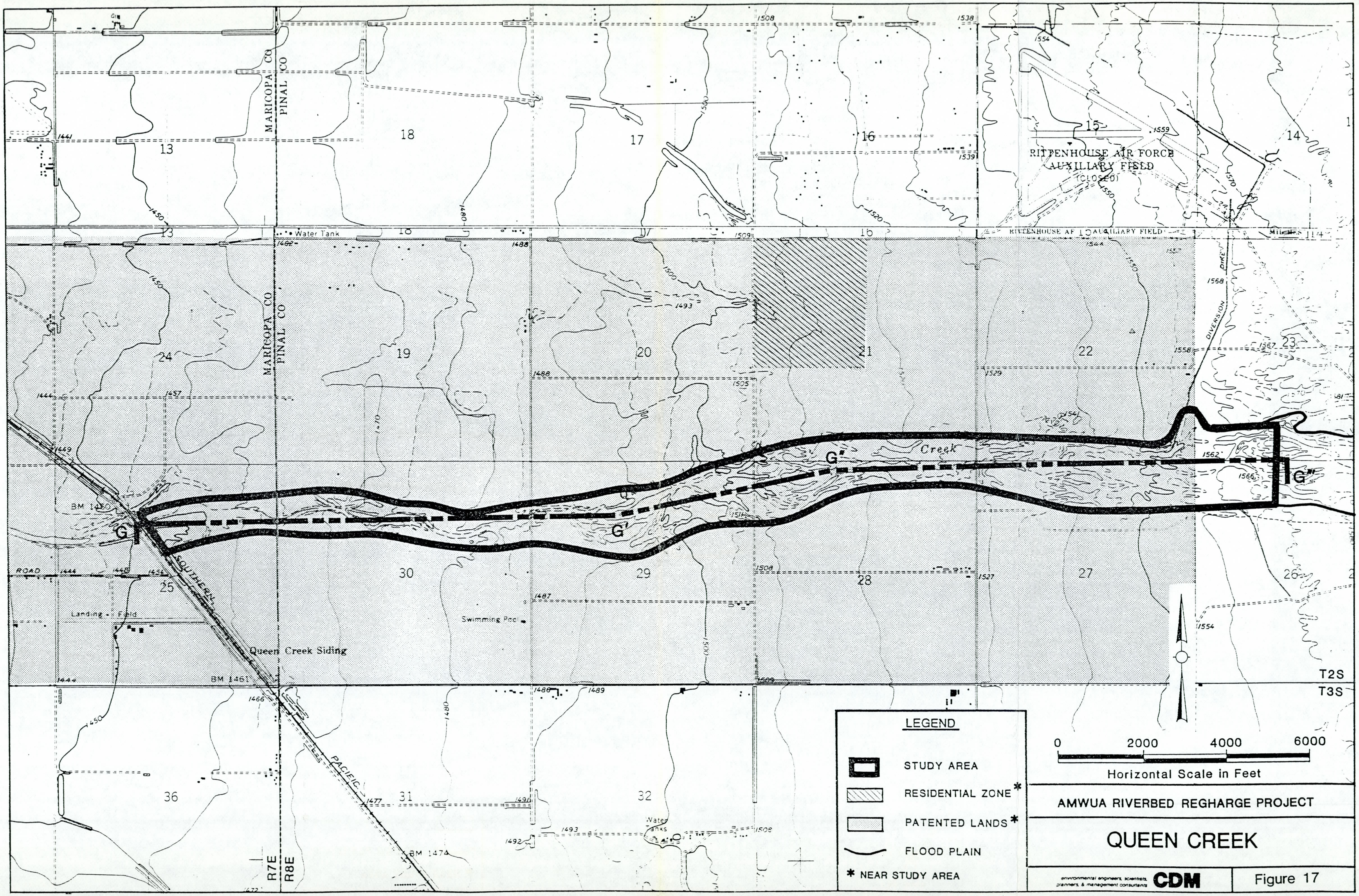
Environmentally sensitive areas are scattered among the Salt River recharge sites. Most of the sites are concentrated in the upper recharge area (Figure 14). Archeological clearances will probably be necessary in these areas.

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

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 major drawback is poor water quality of downgradient receiving water. Perhaps, a system of barrier wells could capture CAP water before it reaches the contaminated downgradient water. Water treatment may be another solution. This issue will need discussion, analysis, and decisions.

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 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.



AMWUA RIVERBED REGHARGE PROJECT

QUEEN CREEK

Figure 17

Estimated sustained 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 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 af, or about 46.0 af/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 candidate 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 386,000 af/year. This amount is third highest among the recharge sites next to Agua Fria and Lower Salt River.

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.

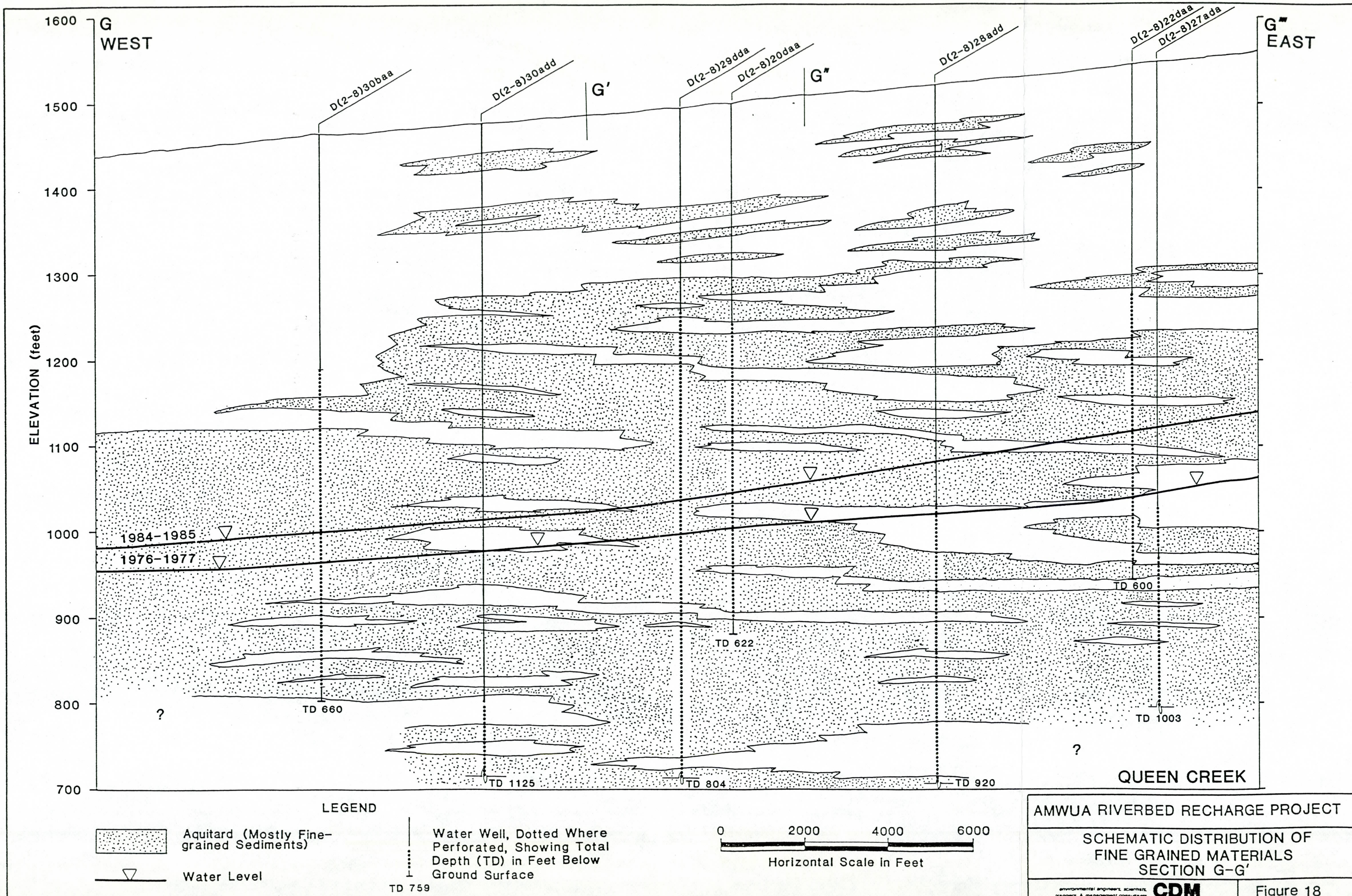
Groundwater quality does not appear to be a problem near the Queen Creek site. Although no groundwater samples were available directly beneath the site, several sample results were examined within one-half to two miles north and south of the site. Total dissolved solids (TDS), nitrate, fluoride, and other inorganic constituents were good (Plate 3). However, about two miles north of the western edge of the site, one well had high

TABLE 10

PHYSICAL CHARACTERISTICS
QUEEN CREEK RECHARGE AREA

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

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.
ND No data.
NA Not applicable.



AMWUA RIVERBED RECHARGE PROJECT

SCHEMATIC DISTRIBUTION OF FINE GRAINED MATERIALS SECTION G-G′

environmental engineers, scientists, planners, & management consultants **CDM**

Figure 18

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. If CAP is recharged at this site, close monitoring should be established to prevent contamination of CAP water with DBCP.

Landfills and sewage treatment facilities are not in close proximity to 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 with two major drawbacks. The site is close to the CAP canal, it is large and has a large recharge potential, it is free from residential and environmental problems, and groundwater quality is good near the site. However, perched water could be a problem when CAP recharge occurs, and more importantly, private land dominates the area.

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. Sustained 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. 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. 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

TABLE 11

SUMMARY OF PHYSICAL CHARACTERISTICS FOR POTENTIAL RECHARGE AREAS
IN THE AMWUA RIVERBED RECHARGE STUDY

LOCATION	DEPTH TO WATER (a) (feet)		INFILTRATION RATE (ft/day)		TRANSMISSIVITY (kgpd/ft)		SPECIFIC YIELD		STORAGE CAPACITY (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	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	40.0	495	possible	DBCP in southern portion
Skunk Creek	480-530	500	1.7-3.6	1.9	10-75	64	.10-.15	.10	50.0	520	possible	High NO3 1 mi. upgradient
Upper Cave Creek	270-300	275	1.5-2.1	2.0	10-30	14	.07-.10	.10	27.5	240	possible	Data deficiences
Lower Cave Creek	400	400	1.8-3.0	2.3	10	10	.05-.10	.07	28.0	400	possible	TCE .5-1.0 mi. S.
Upper Indian Bend Wash	300-440	430	2.5-3.1	2.8	5-15	11	.05-.10	.09	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	17.0	90	yes	High Cr 1 mi. east
Upper Salt River	310	310	1.9	1.9	70-110	81	.07-.10	.08	24.8	810	possible	TCE, DBCP, F & Cl .5-1.0 mi. downgradient
Lower Salt River	180-320	315	1.9-2.5	2.5	20-100	56	.05-.10	.09	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	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.

fine-grained materials which lie beneath most of the recharge sites. Storage capacities vary from 17.0 af/acre at Lower Indian Bend Wash to 50.0 af/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 2,550 acres at Lower Salt River. A site over 200 acres is 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 a 30 day wet-dry cycle. This means the estimated maximum sustained infiltration rate (Column 3, Table 12) is reduced by half (Column 4, Table 12). Three sites, Agua Fria, Upper Indian Bend Wash, and Lower Salt River had to have their recharge rates reduced even further because of mounding considerations. Annual recharge rates range from 5,000 af/year at Lower Indian Bend Wash to 920,000 af/year at Lower Salt River. Agua Fria, Upper Indian Bend Wash, and Queen Creek also potentially have enormously high annual recharge rates of 785,000 af/year, 680,000 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 is 3.74 million acre-feet. Based on conceptual designs of the sites, which will be discussed in Chapter 4, recharge potential for Agua Fria and Upper and Lower Salt River will decrease. The Agua Fria design site can potentially recharge 415,000 acre-feet per year, and the Salt River conceptual sites can potentially recharge 430,000 acre-feet per year of CAP water.

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 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.

TABLE 12

RECHARGE CAPABILITIES OF
ALTERNATIVE RECHARGE SITES

Recharge Site	Design Recharge Area (ac.)	Estimated Maximum Sustained Recharge Rate (ft/day)	Estimated Average Sustained Infiltration Rate[a] (ft/day)	Annual Recharge Rate (kaf/yr)[b]	Annual Recharge Rate (kaf/yr)[c]
Agua Fria River		3.2	1.0[d]		785
In-stream	610			225	
Off-stream	515			190	
New River					
In-stream	515	2.5	1.2	225	225
Skunk Creek					
Off-stream	520	1.9	1.0	190	190
Upper Cave Creek		2.0	1.0		90
In-stream	50			20	
Off-stream	190			70	
Lower Cave Creek		2.3	1.2		175
In-stream	90			40	
Off-stream	305			135	
Upper Indian Bend					
Off-stream	1,430	2.8	1.3[d]	680	680
Lower Indian Bend					
In-stream	90	0.2	0.1	5	5
Upper Salt River					
In-stream	295	1.9	1.0	110	300
Lower Salt River		2.4	1.0[d]		920
In-stream	565			205	
Off-stream	310			115	
Queen Creek					
In-stream	775	2.7	1.4	385	385

(a) Based upon a 1:1 wet-dry application cycle
(b) Based on conceptual design recharge areas
(c) Based on entire study areas listed in Table 11
(d) Recharge rate is limited by rise in groundwater recharge mound

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 recharge capabilities of each site (Table 12) was also 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.

Substantial amounts of surplus CAP water are currently 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.

TABLE 13

AMWUA RECHARGE SITE EVALUATION MATRIX

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	mod	none	high	good	possible	yes	yes	yes	mod
Upper Cave Creek	high	none	low	good	possible	yes	yes	yes	significant
Lower Cave Creek	high	none	low	poor	possible	yes	yes	yes	significant
Upper Indian Bend Wash	high	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.

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

	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		●				●		●	●		

LEGEND

● Applies

◐ Partially Applies

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 recharge capabilities of each site (Table 12) was also 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.

Substantial amounts of surplus CAP water are currently 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.

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.

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.

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.

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.

Conveyance Facilities

In general, the candidate recharge sites were selected on the basis of their proximity to the CAP 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 constructed within the flood plain of the river channel, upstream of the candidate recharge facility. This 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, from 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 turn-out 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 New River, Cave Creek, Salt River, and Queen Creek. For the remaining recharge sites along the Agua Fria River, Skunk Creek, and Indian Bend Wash, new turn-out facilites will be required. For ease of implementation, it was assumed that temporary siphon conduits would be installed at all locations requiring a turn-out facility. The temporary siphon conduits could be replaced by a more permanent turn-out facility, if the long-term viability of recharge is determined for a site. For the existing turnouts and the temporary siphons, water flow rate measurement devices or diversion structures would have to be constructed.

CONCEPTUAL DESIGNS

Utilizing the engineering criteria 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 study area, which was 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 recharge sites.

Agua Fria River

Although this recharge site 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.

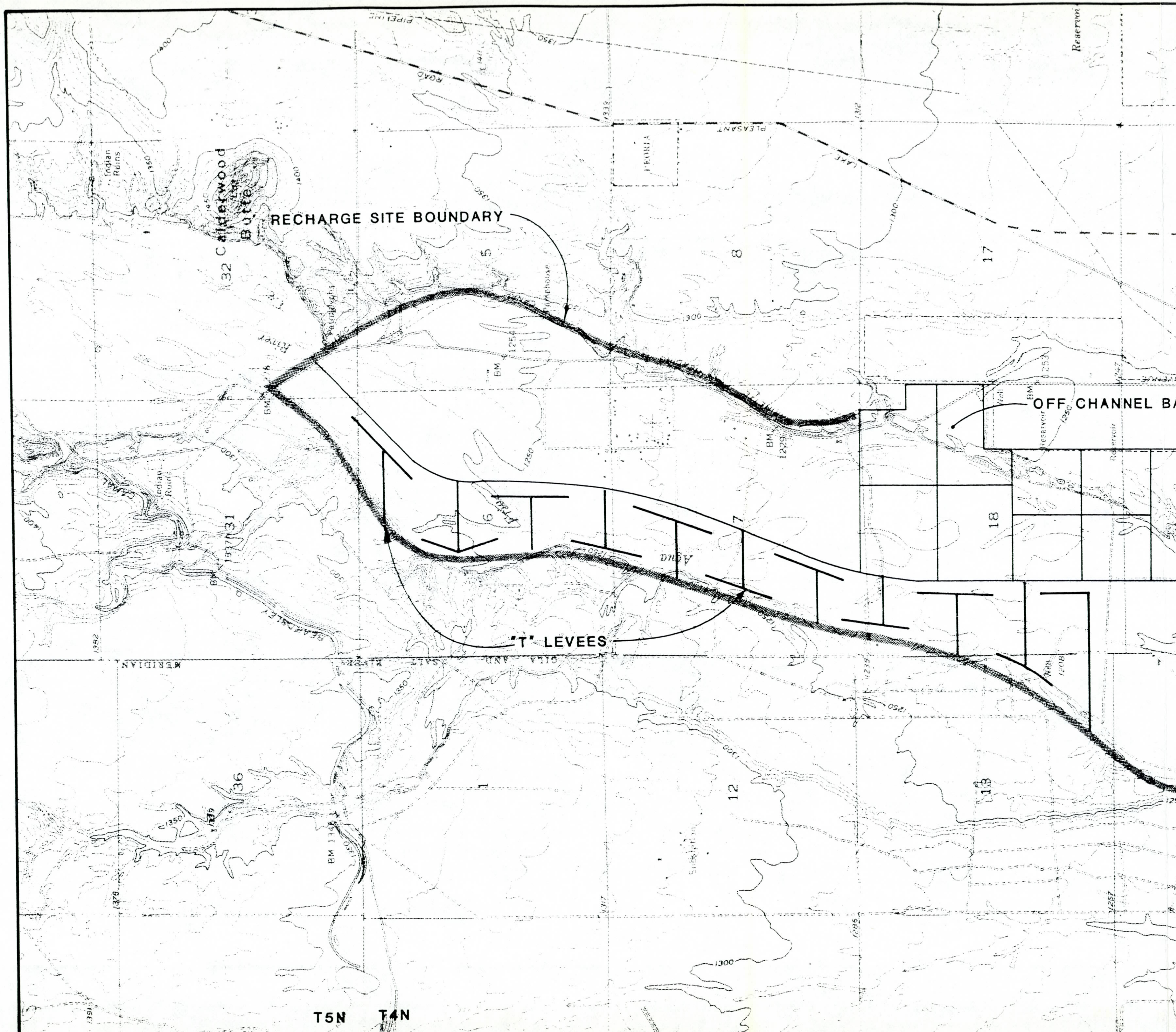
In the northwestern portion, as shown on Figure 19, the spreading facility consists of a 3-mile long riverbed "T" levee, comprising about 610 acres. In the southeastern portion of the recharge facility, where public lands were also available immediately adjacent to the flood plain of the river, a more 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 from the CAP into the Beardsley Canal using siphons. The water would then be discharged from the Beardsley Canal near the upper reaches of the recharge facilities. For the "T" levee system, the capacity of the siphons would be about 225 cubic feet per second (cfs). The siphon capacity for the off-channel facilities would be about 190 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.

Total capacity of Beardsley?

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.



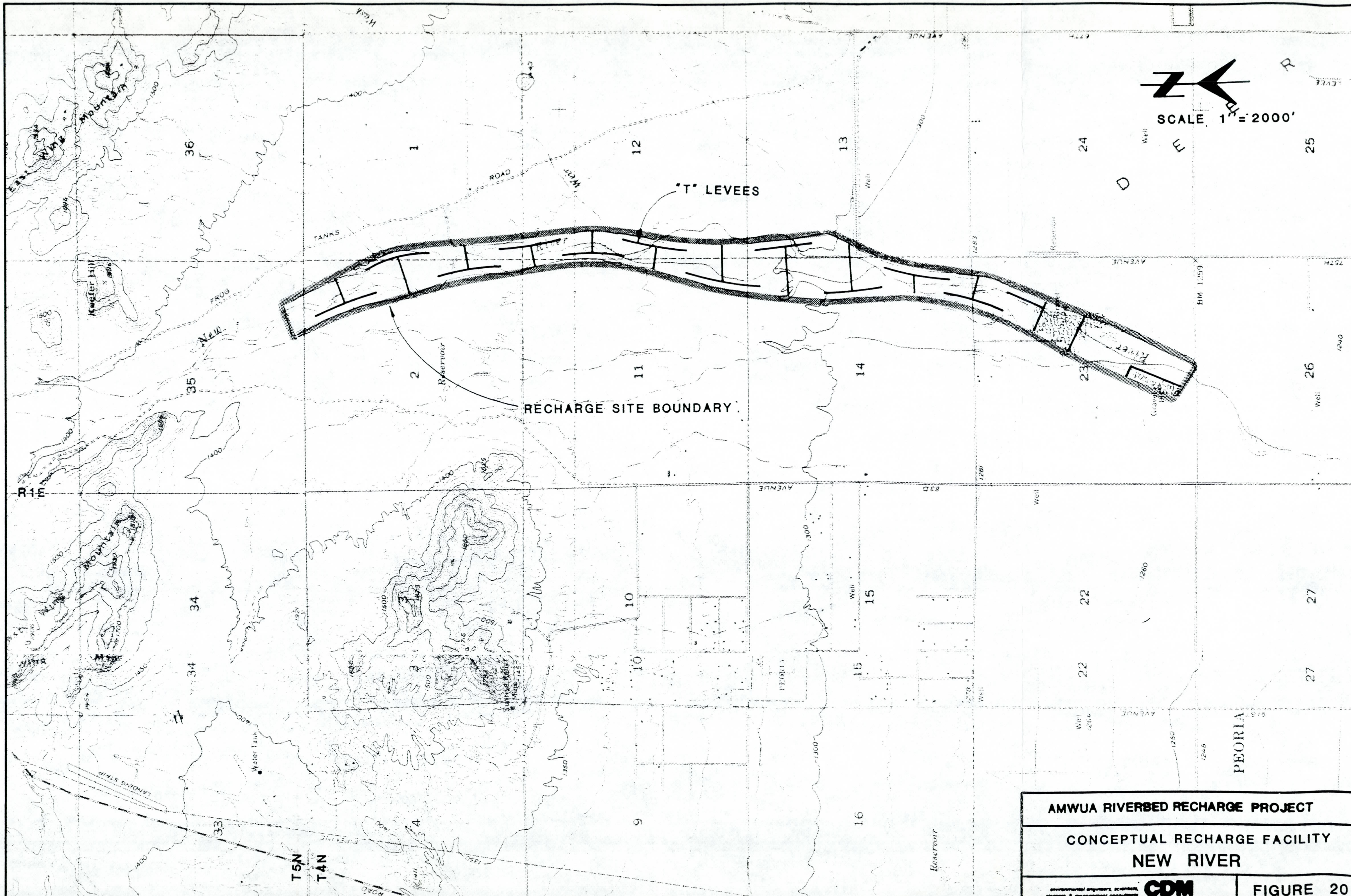
AMWUA RIVERBED RECHARGE PROJECT

CONCEPTUAL RECHARGE FACILITY

AGUA FRIA RIVER

CDM

FIGURE 19


SCALE 1" = 2000'
"T" LEVEES
RECHARGE SITE BOUNDARY
R1E
T5N
T4N
PEORIA
AMWUA RIVERBED RECHARGE PROJECT
CONCEPTUAL RECHARGE FACILITY
NEW RIVER
CDM
FIGURE 20

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 sub-basin and be trapped. Total capacity of the diversion would be 225 cfs.

Skunk Creek

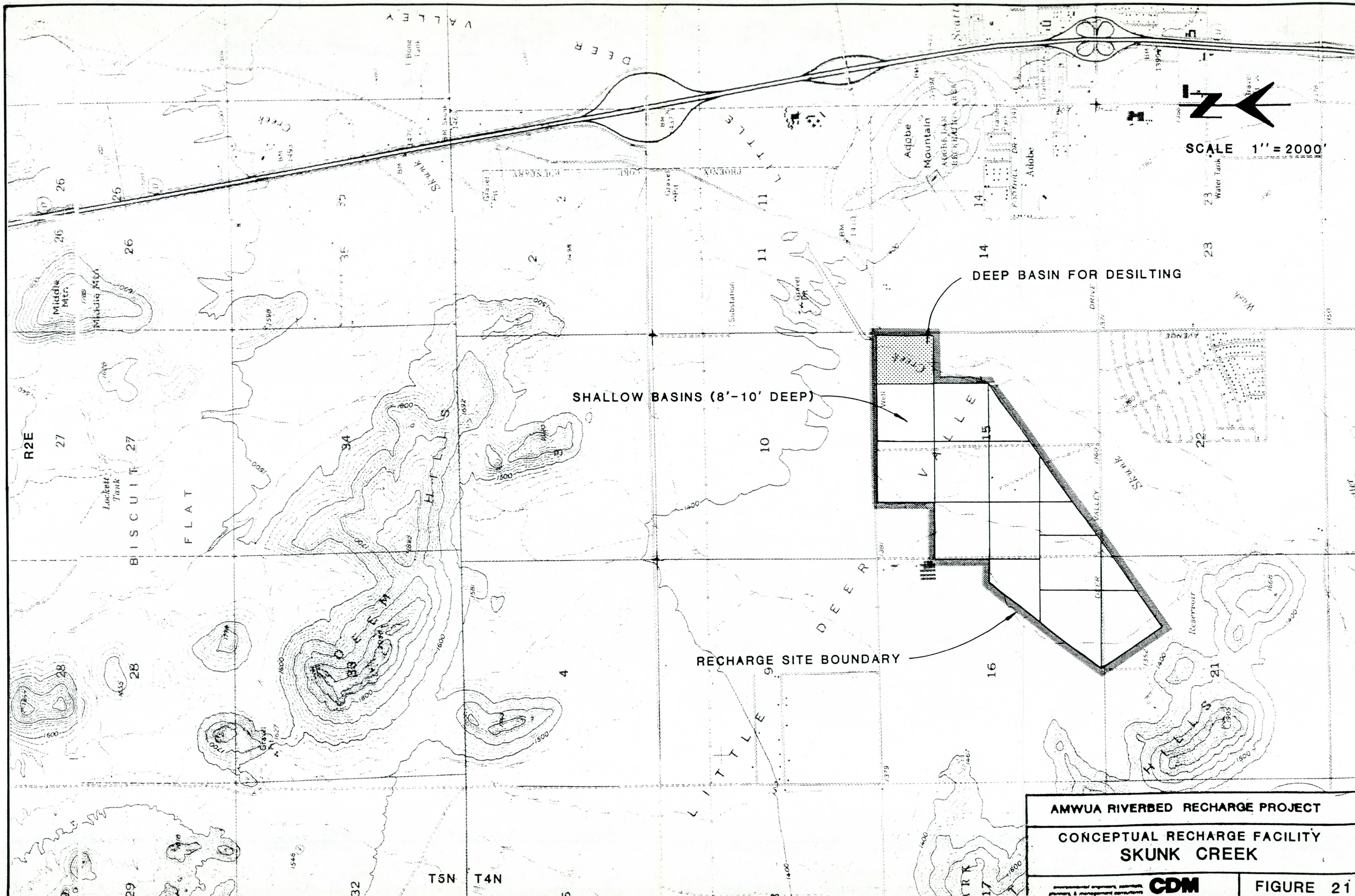
The recharge system for Skunk Creek is located behind Skunk Creek flood control dam. The type of spreading facility deemed the most appropriate for this site is shallow off-channel basins, as shown on Figure 21. About 520 acres of shallow basins were laid out and include fifteen 30- to 40-acre basins. 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 siphon system will have to be constructed. The siphon would require a capacity of up to 225 cfs. Like the New River system, 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 channel will have a capacity of 225 cfs and will be about 19,000 feet long.

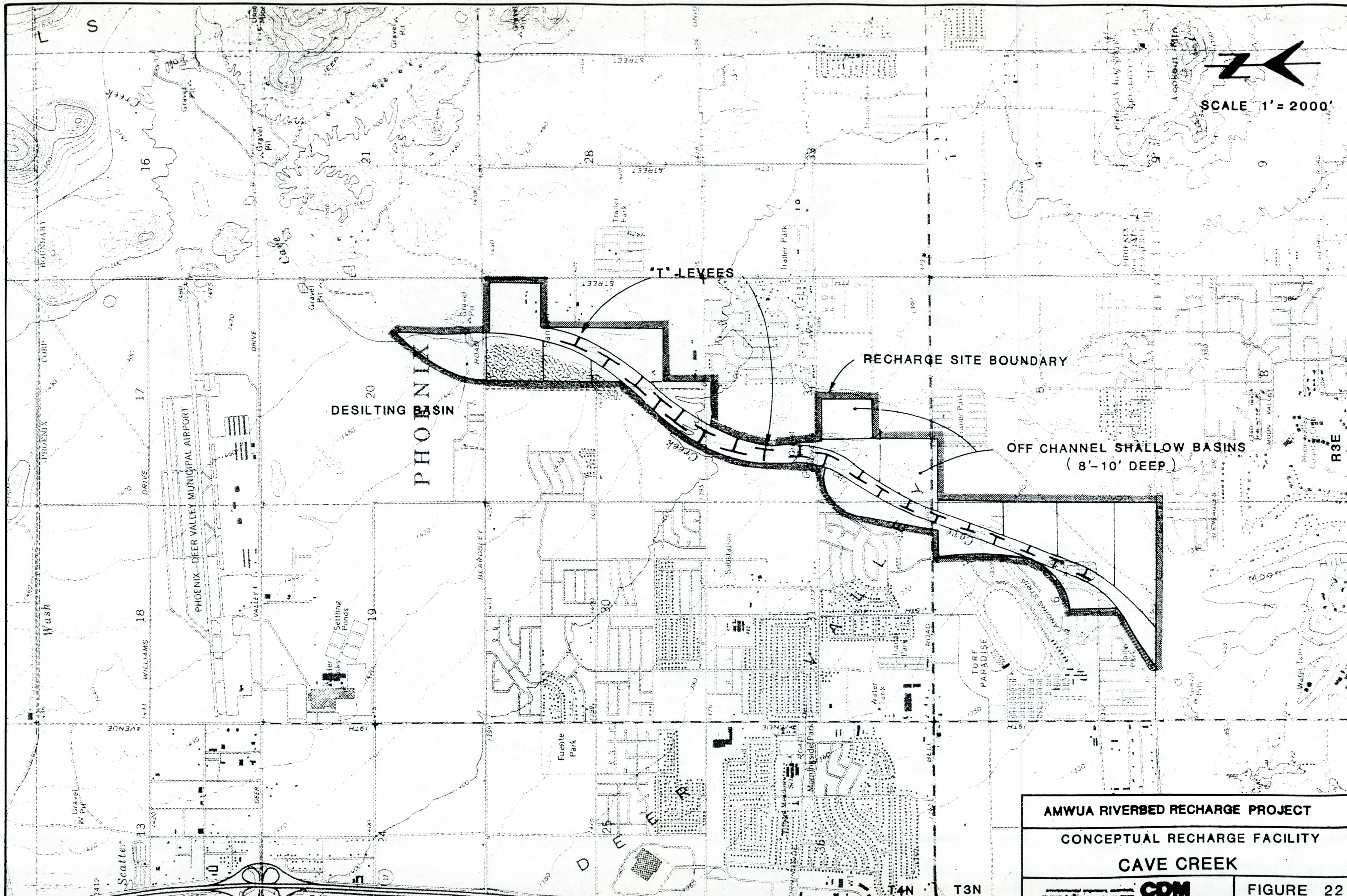
Cave Creek

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 basinns 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 constructed in the CAP at Cave Creek. However, because a landfill is present just upstream of the



SCALE 1'' = 2000'
DEEP BASIN FOR DESILTING
SHALLOW BASINS (8'-10' DEEP)
RECHARGE SITE BOUNDARY
AMWUA RIVERBED RECHARGE PROJECT
CONCEPTUAL RECHARGE FACILITY
SKUNK CREEK
CDM
FIGURE 21
R2E
T5N
T4N
Adobe Mountain
Middle Mtn.
BISCUIT FLAT
Lockett Tank
DEER VALLEY
LITTLE DEER



SCALE 1' = 2000'
"T" LEVEES
RECHARGE SITE BOUNDARY
DESILTING BASIN
OFF CHANNEL SHALLOW BASINS
(8'-10' DEEP)
PHOENIX
PHOENIX-DEER VALLEY MUNICIPAL AIRPORT
TURF PARADISE
R3E
T4N
T3N
AMWUA RIVERBED RECHARGE PROJECT
CONCEPTUAL RECHARGE FACILITY
CAVE CREEK
CDM
FIGURE 22

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 70 cfs for the off-channel system. The capacity of the channel required to supply the Lower Cave Creek facilities is about 40 cfs for the in-channel system and about 135 cfs for the off-channel system. The final capacity of the channel would be dependent on which of the recharge facilities are constructed along Cave Creek.

Upper Indian Bend Wash

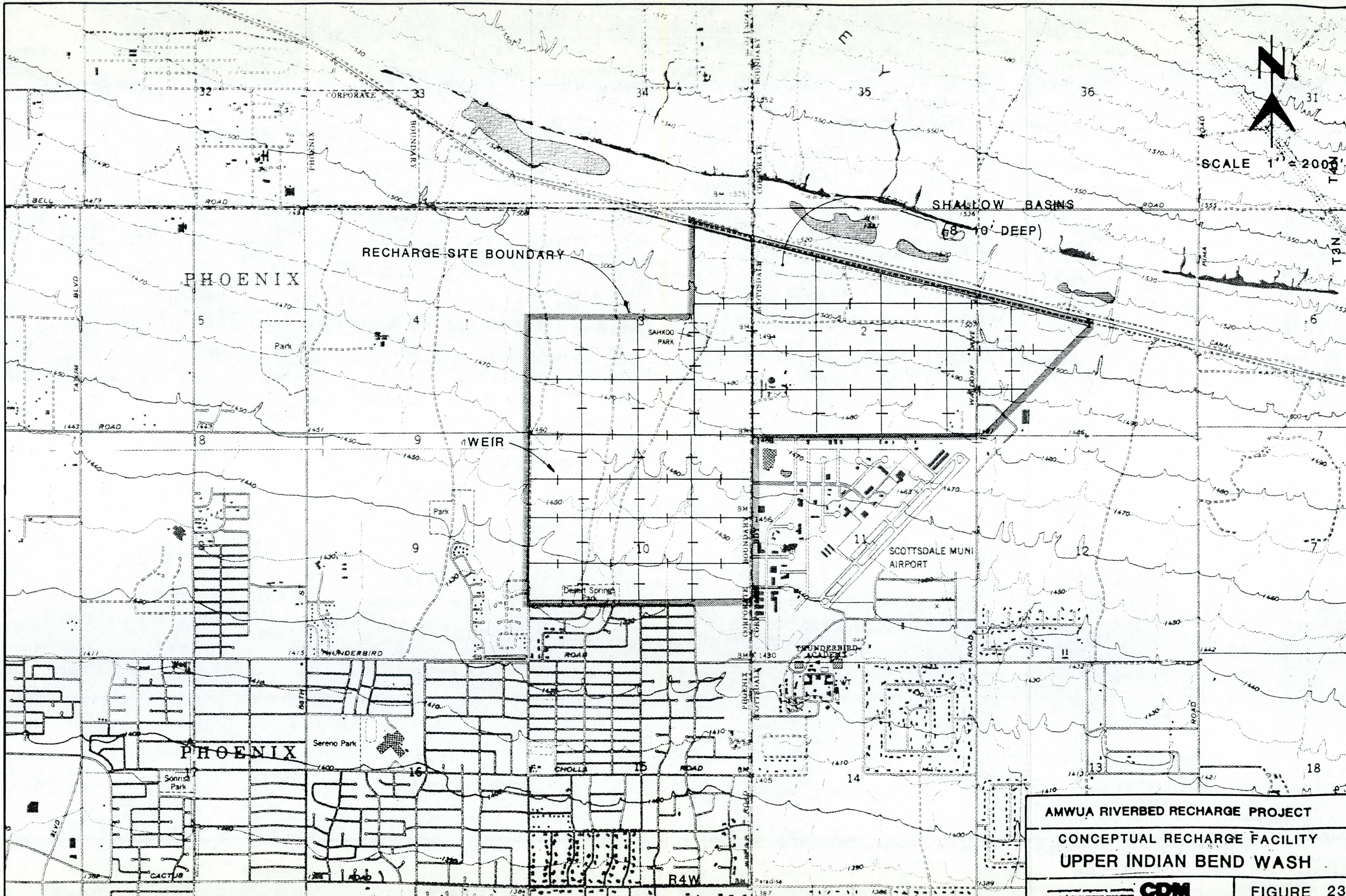
This facility is located immediately adjacent to the CAP, but does not lie within the flood plain of the river. As a result, the most appropriate recharge facility for this site is the shallow off-channel basins (Figure 23). About forty 30- to 40-acre shallow basins were laid out within the boundary 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 siphon system with a capacity of about 680 cfs will be required to divert CAP water into the Upper Indian Bend Wash spreading facilities.

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 siphon having a capacity of about 5 cfs.
release gates.

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



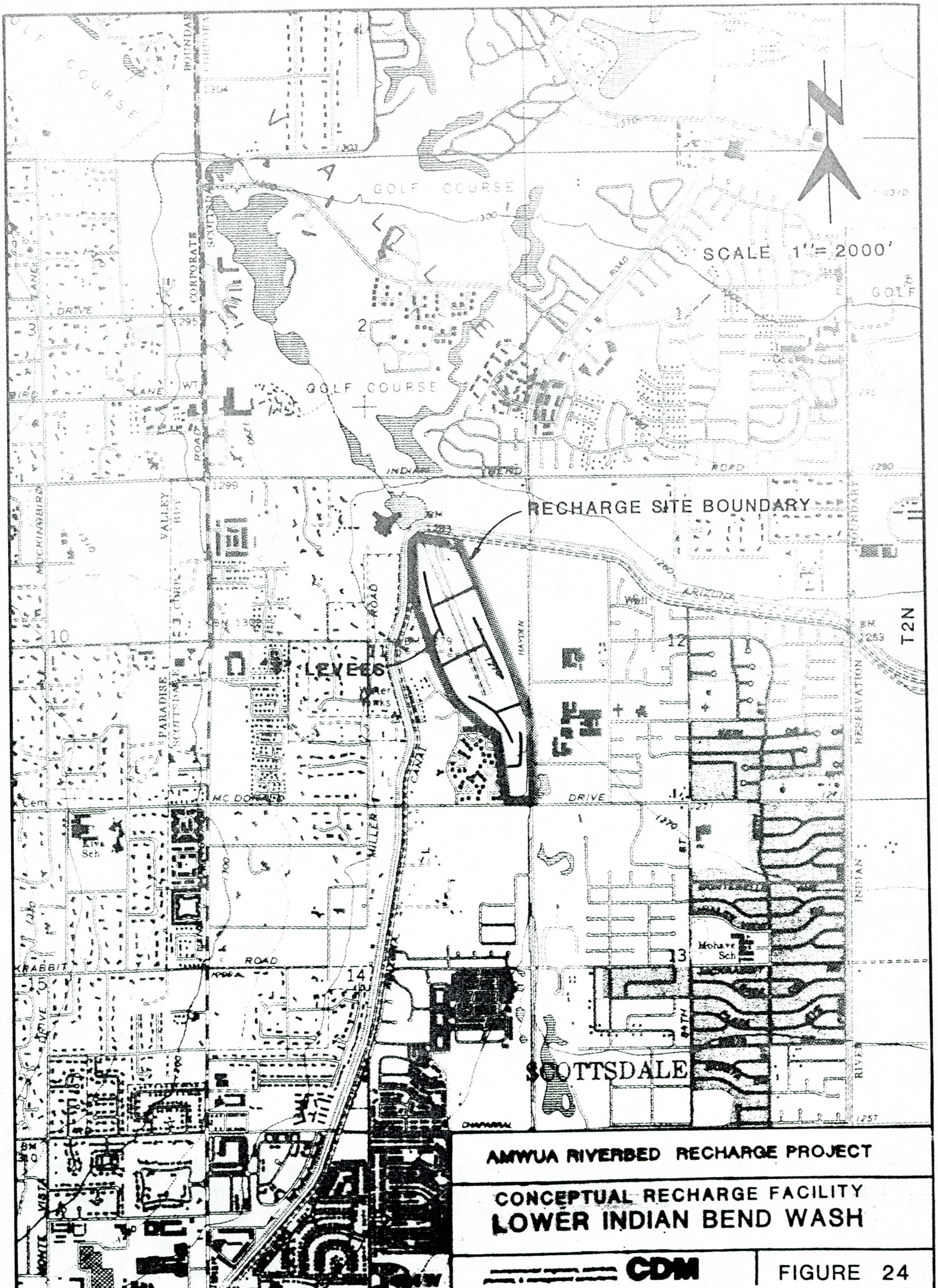
AMWUA RIVERBED RECHARGE PROJECT

CONCEPTUAL RECHARGE FACILITY

UPPER INDIAN BEND WASH

CDM

FIGURE 23



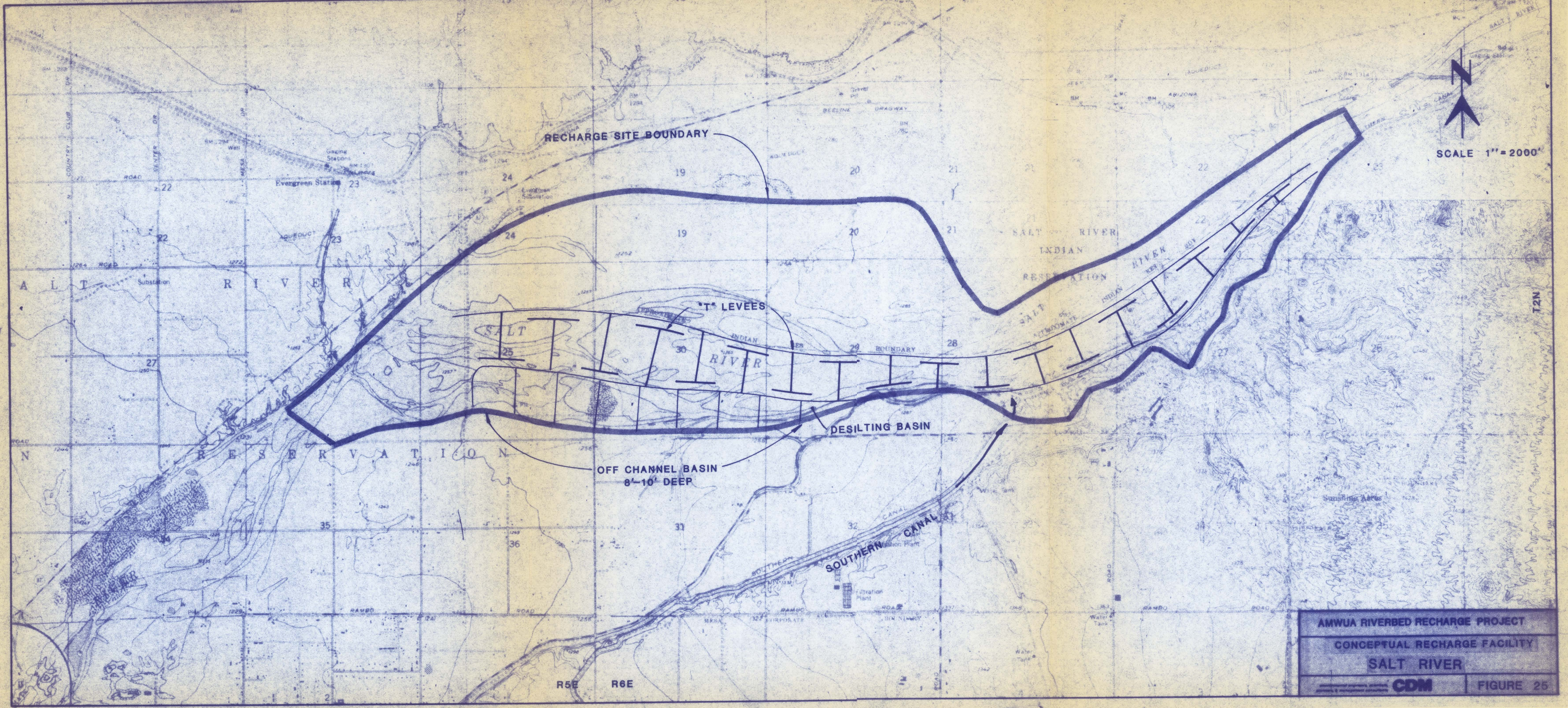
AMWUA RIVERBED RECHARGE PROJECT

CONCEPTUAL RECHARGE FACILITY

LOWER INDIAN BEND WASH

CDM

FIGURE 24


RECHARGE SITE BOUNDARY
"T" LEVEES
DESILTING BASIN
OFF CHANNEL BASIN
8'-10' DEEP
SALT RIVER
SALT RIVER INDIAN RESERVATION
SOUTHERN CANAL
Evergreen Station
SCALE 1" = 2000'
T2N
R5E
R6E
AMWUA RIVERBED RECHARGE PROJECT
CONCEPTUAL RECHARGE FACILITY
SALT RIVER
CDM
FIGURE 25

area of this recharge facility is approximately 295 acres. CAP water would be diverted through an existing turnout 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 110 cfs.

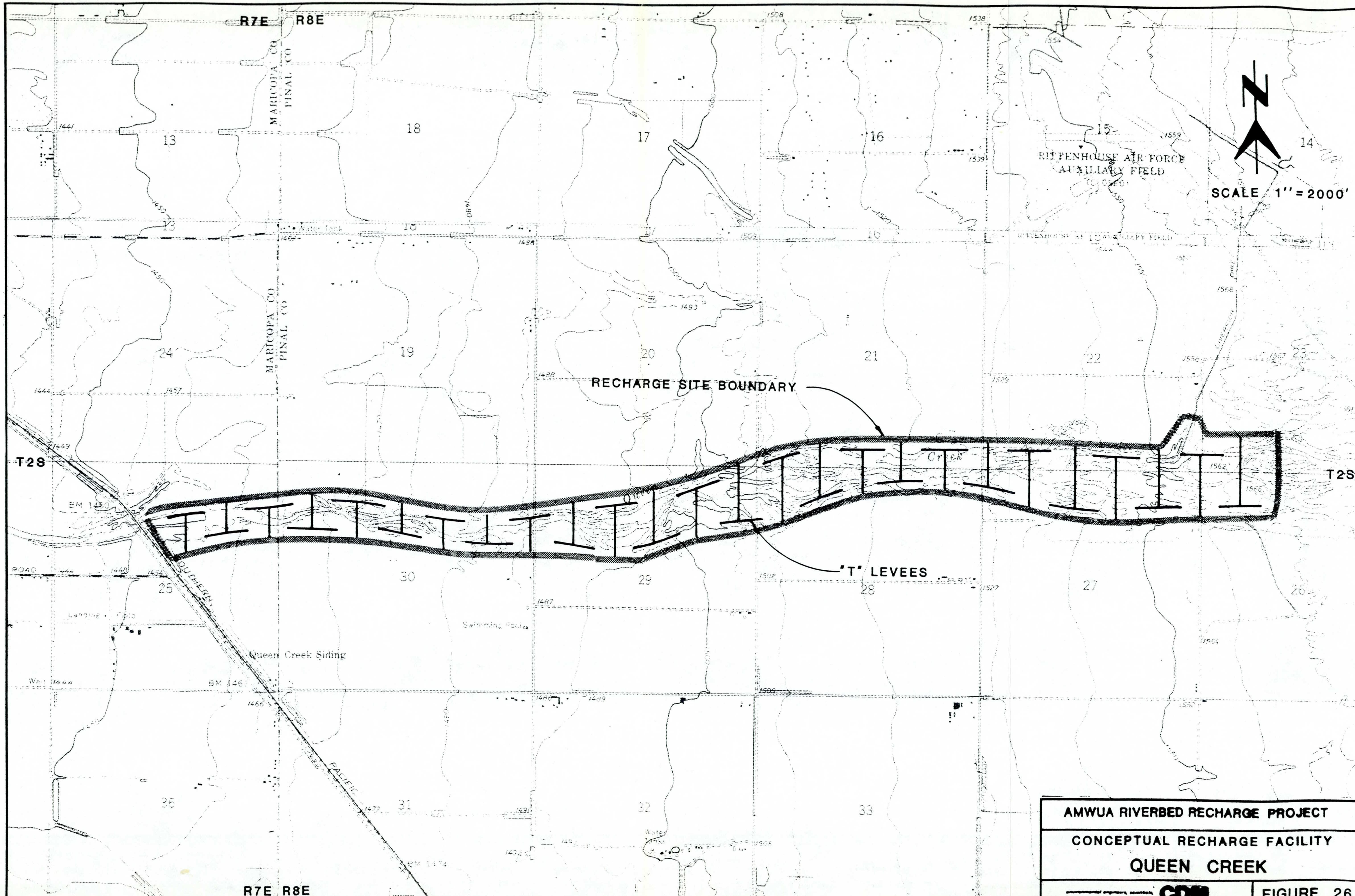
Lower Salt River

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 existing turnout at 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, the second way to get CAP water to the lower facilities is via the Southern Canal, which runs along the south side of the Salt River. The water would have to be siphoned out of the Southern Canal into the spreading facilities. For the in-stream facilities, the siphon would have a capacity of about 205 cfs. For the off-channel facilities, the siphon would have a capacity of about 115 cfs.

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 385 cfs of the turnout capacity would be required to supply water to the spreading basins.



AMWUA RIVERBED RECHARGE PROJECT

CONCEPTUAL RECHARGE FACILITY

QUEEN CREEK

CDM FIGURE 26

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 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.

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 15. As can be seen from the table, the cost to construct recharge facilities varies between $140,000 for Lower Indian Bend Wash to $6,883,000 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 the purchase of private land.

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 complicate and lengthen the implementation schedule of any recharge project requiring private lands. For the purpose of this study, the requirement of private land to develop a recharge site may be a potential constraint and a potential significant additional cost. These sites which overlie private land are indicated on Table 15.

TABLE 15

PRELIMINARY CAPITAL COST ESTIMATES FOR AMWUA RECHARGE SITES

RECHARGE SITE	DESIGN AREA (ac)	RECHARGE RATE (kaf/yr)	CAPITAL COSTS ($ x 1000) CANAL TURNOUT	CONVEYENCE FACILITIES	EARTHWORK	INTER-BASIN FACILITIES	CONTINGENCY FACTOR (30%)	LAND PROBLEMS	TOTAL COSTS
AGUA FRIA RIVER									
In-Stream Facilities	610	225	125	0	400	NA	158		683
Off-Stream Facilities	515	190	109	0	1,150	390	495		2,145
NEW RIVER									
In-Stream Facilities	515	225	125	3,260	360	NA	1,124	++	4,869
SKUNK CREEK									
Off-Stream Facilities	520	190	109	4,200	735	250	1,588	+	6,883
UPPER CAVE CREEK									
In-Stream Facilities	50	20	34	450	110	NA	178	++	772
Off-Stream Facilities	190	70	56	1,570	280	95	600	++	2,601
LOWER CAVE CREEK									
In-Stream Facilities	90	40	43	500	160	NA	211	++	914
Off-Stream Facilities	305	135	85	1,680	395	135	689	++	2,984
UPPER INDIAN BEND WASH									
Off-Stream Facilities	1,430	680	327	0	2,025	690	913	++	3,955
LOWER INDIAN BEND WASH									
In-Stream Facilities	90	5	27	0	80	NA	32	++	140
UPPER SALT RIVER									
In-Stream Facilities	295	110	74	0	250	NA	97		421
LOWER SALT RIVER									
In-Stream Facilities	565	205	116	0	310	NA	128		554
Off-Stream Facilities	310	115	76	0	630	215	276		1,198
QUEEN CREEK									
In-Stream Facilities	755	385	196	0	660	NA	257	++	1,113

NOTES:
1. Earthwork is initial cost of construction at $2.50 per cu. yd.
2. Turnouts include flow measurement devices.
3. Recharge rates assume 1:1 wet to dry cycle.
4. + = probable significant additional land costs.

Operation and Maintenance Cost

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. 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.

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 16). 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 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/acre-foot annual operation and maintenance cost is assumed.

Annualized Cost

So that the costs of implementing recharge programs at the candidate sites can be compared on the basis of the amount of water which is recharged, the capital cost for each facility was annualized. The capital cost for each site (exclusive of land) shown on Table 15 is annualized based on a 25-year repayment period and an interest rate of 8 percent.

TABLE 16

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					
			Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}
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

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

The annualized cost for each facility is experessed in dollars per acre-foot of water recharged on Table 17. [The cost of private land, if required, has not been determined, 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 significantly 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, Agua Fria, and Upper Indian Bend Wash, with costs ranging from $4.25 to $4.55 per acre-foot. However, the Queen Creek and Upper Indian Bend Wash sites will probably cost somewhat more than indicated because of land acquisition. The most expensive facility is Skunk Creek at $7.05 per acre-foot.

The annualized cost difference (in dollars per acre-foot of water recharged) between the least and most expensive facilities is only $2.80 per acre-foot, which is insignificant when compared to the cost of purchasing the water from CAP. Consequently, re-ranking of the recharge sites, as indicated on Table 14, is unnecessary based on the costs developed in this section.

TABLE 17

ANNUALIZED CAPITAL AND O&M COSTS

RECHARGE SITE	PRIVATE LAND CONSIDERATIONS	RECHARGE RATE (kaf/yr)	CAPITAL COST ($ x 1000) TOTAL	CAPITAL COST ($ x 1000) ANNUALIZED	ANNUAL COST ($/AF) CAPITAL	ANNUAL COST ($/AF) O & M	ANNUAL COST ($/AF) TOTAL
.GUA FRIA RIVER							
In-Stream Facilities		225	680	64	0.28	4.00	4.28
Off-Stream Facilities		190	2,145	201	1.06	4.00	5.06
:EW RIVER							
In-Stream Facilities	++	225	3,140	294	1.31	4.00	5.31
;KUNK CREEK							
Off-Stream Facilities	+	190	6,191	580	3.05	4.00	7.05
JPPER CAVE CREEK							
In-Stream Facilities	++	20	518	49	2.43	4.00	6.43
Off-Stream Facilities	++	70	1,663	156	2.23	4.00	6.23
.OWER CAVE CREEK							
In-Stream Facilities	++	40	754	71	1.77	4.00	5.77
Off-Stream Facilities	++	135	2,488	233	1.73	4.00	5.73
JPPER INDIAN BEND WASH							
Off-Stream Facilities	++	680	3,961	371	0.55	4.00	4.55
.OWER INDIAN BEND WASH							
In-Stream Facilities	++	5	140	13	2.62	4.00	6.62
JPPER SALT RIVER							
In-Stream Facilities		110	421	39	0.36	4.00	4.36
LOWER SALT RIVER							
In-Stream Facilities		205	554	52	0.25	4.00	4.25
Off-Stream Facilities		115	1,198	112	0.98	4.00	4.98
QUEEN CREEK							
In-Stream Facilities	++	385	1,151	108	0.28	4.00	4.28

NOTES: 1. + = Probable significant additional costs
++ = Substantial addional costs
2. Capital costs ammortized at 8% over 25 years.

All ten sites evaluated during the screening process can be used to recharge CAP water. None of the sites had 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 were 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 overriding 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 535,000 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, CDM recommends that preliminary designs be prepared for in-channel facilities on the Agua Fria and Salt Rivers.


AMWUA RIVERBED RECHARGE PROJECT
STUDY AREAS, TOPOGRAPHY AND MUNICIPAL PLANNING AREAS
CDM
environmental engineers, scientists, planners & management consultants
PLATE 1
LEGEND
STUDY AREA
FLOODPLAIN BOUNDARY
MUNICIPAL PLANNING AREA BOUNDARY
0 6000 12000 18000
Scale in Feet
PHOENIX
GLENDALE
SCOTTSDALE
TEMPE
MESA
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
CAVE CREEK
INDIAN BEND WASH
SALT RIVER
SALT - GILA AQUEDUCT
QUEEN CREEK
GRANITE REEF AQUEDUCT
ARIZONA CANAL
BEARDSLEY CANAL
ROOSEVELT CANAL
T6N
T5N
T4N
T3N
T2N
T1N
T1S
T2S
T3S
R2W
R1W
R1E
R2E
R3E
R4E
R5E
R6E
R7E
R8E


AMWUA RIVERBED RECHARGE PROJECT
DEPTH & ELEVATION OF GROUND WATER (1984)
CDM
environmental engineers, scientists, planners & management consultants
PLATE 2
LEGEND
STUDY AREA
FLOODPLAIN BOUNDARY
MUNICIPAL PLANNING AREA BOUNDARY
MOUNTAINS - HARDROCK
DEPTH TO WATER (FT.) AND WATER LEVEL ELEVATION (FT. M.S.L.) FOR MEASURED WELLS
DEPTH TO WATER (FT.) AND WATER LEVEL ELEVATION (FT. M.S.L.) FOR MEASURED WELLS WITH PERCHED WATER
DEPTH TO GROUND WATER (FEET BELOW LAND SURFACE)
WATER LEVEL ELEVATION (FEET M.S.L.)
GROUND WATER DEPRESSION
GENERALIZED DIRECTION OF GROUND WATER MOVEMENT
REGIONAL PERCHED WATER ZONES
Scale in Feet
DATA FROM : ARIZONA DEPT. OF WATER RESOURCES, 1986
USGS WRI 78-81, 1976
MAG., 1981)
PHOENIX
GLENDALE
SCOTTSDALE
TEMPE
MESA

WATER QUALITY FOR SELECTED WELLS IN THE SALT RIVER BASIN

LOCATION	SAMPLING DATE	HARDNESS ($CaCO_3$)	Ca	Mg	Na	Cl	NO_3	SO_4	ALK. $CaCO_3$	F	B	TDS	OTHER
A(1,4)11aba	4/82, 8/82	284	62	31	165	285	14.2	102	129	.49	---	800	TCE - 3.8 ug/l
A(1,5)15dcb	8/83	---	40	12	78	120	0.4	46	---	.30	.06	---	Diclorbrometh - 5.7 ug/l, chloroform 5.0 ug/l, EC - 680 ug/l/cm
A(1,6) 7bcc	4/83	198	43	22	182	278	8.0	42	---	.30	---	700	Fe - .270
A(2,6)31cdd	11/69, 6/84	218	62	16	179	266	10.0	33	---	---	---	674	DBCP - 4400 ug/l (6/84)
32aca	8/79	---	--	--	---	---	----	---	---	---	---	---	DBCP - 2.4 ug/l
A(3,1) 5abb	10/82	196	44	21	28	55	12.0	29	130	.20	---	346	----------
9bcb	10/82	183	42	19	35	71	12.0	28	126	.20	---	314	----------
12bbb	4/79	140	31	15	25	18	8.4	25	120	.20	.07	220	----------
A(3,2) 4daa	4/80	150	30	18	64	76	6.6	54	120	1.0	.24	360	Sr - .43
8bbb	6/75	120	24	14	61	48	23.5	22	148	.70	.06	310	----------
A(3,4) 2bbc	1/85	178	27	27	47	42	4.0	10	194	.50	---	290	Cr - .010
9ccd	6/83	130	17	22	44	20	4.9	10	197	.50	.07	260	As - .011, Ba - .014 Cr - .034
21ada	8/85	160	19	27	45	25	5.6	9	265	.50	.06	310	----------
23acd	8/83	81	14	11	39	8	5.3	6	174	.60	.08	210	Ba - .056 Cr - .190 Sr -. 73
29dcd	3/75	164	45	12	37	20	11.0	26	---	.55	---	278	Cr < .010
A(4,1) 5acd	8/83	---	47	15	31	24	8.0	22	---	.20	.07	---	Ba - .043 Sr - .45 EC = 475 umhos/cm
15bbd	4/82	37	10	3	66	19	3.5	21	152	.50	---	236	----------
23daa	4/79	140	34	14	42	34	28.4	27	120	.40	.10	292	DBCP - .14 ug/l
27aaa	7/76	---	--	--	---	---	----	---	---	.20	---	---	EC - 490 umhos/cm T - 30 C
34aba	6/85	210	47	23	46	60	48.7	49	125	.20	.05	340	Ba - .042 Sr. - .72
35bba	4/79	120	27	13	50	27	27.5	34	130	.30	.08	260	DBCP - 1.7 ug/l
A(4,2)11adb	6/83	---	28	16	37	13	22.6	10	---	1.00	.07	---	Ba - .019 Sr - .420 EC - 415 umhos/cm
16abb	6/85	---	--	--	---	---	----	---	166	----	---	---	----------
17aaa	12/83	130	21	19	76	64	50.1	56	---	1.40	---	400	Fe - .30 Zn - .14
23cdb	7/83	---	29	17	40	37	26.6	10	---	.90	---	---	As - .012 Be - .080 Sr - .450
32caa	5/79	65	14	7	69	29	24.0	16	130	.90	.10	265	----------
36cad	2/75	114	22	14	22	11	15.0	6	124	.43	---	190	As - .010 Cr - .030 Fe - .55
A(4,3) 7bcd	11/73	120	23	16	57	22	16.8	41	163	.80	.27	320	----------
36aaa	12/83	106	13	18	35	10	5.3	3	---	.30	---	180	Cr - .097 Fe - .13
A(5,2)35ddc	3/84	94	22	10	57	12	12.8	8	174	.97	---	255	Cr - .037
B(3,1) 9abb	6/84	130	31	12	90	66	28.8	77	108	1.10	.15	370	Ba - .045 Cr - .015 Sr - .70
12bbb	4/79	140	31	15	25	18	8.4	25	120	.20	.07	220	----------
B(4,1)27cbb	7/76	---	--	--	---	---	----	---	---	.8C	---	---	EC - 600 umhos/cm
29acd	3/83	138	48	4	258	32	8.4	133	55	6.0	---	860	As - .040 Fe - .20
33acc	4/79	70	18	6	90	40	12.1	56	< 1	1.4	.14	320	----------
D(2,6)36dbb	8/79	---	--	--	---	---	----	---	---	---	---	---	DBCP - 1.5 ug/l
D(2,7)12dda	8/83	180	54	12	72	99	53.2	60	133	.20	.09	700	Sr - .48
20dad	1/74	110	39	3	110	150	1.7	44	106	.50	.11	420	----------
36ada	7/83	160	50	9	87	150	13.3	50	103	.40	.08	450	Sr - .52 EC - 807 umhos/cm Ba - .039
D(2,8)18dad	7/80	210	62	14	76	150	9.8	52	91	.50	.10	460	Sr - .79
20daa	1/74	230	69	14	63	150	----	54	106	.70	.10	460	Sr - .83
32aba	3/74	250	76	14	80	150	2.7	57	153	.50	.12	---	Mn - .55
34daa	7/83	220	66	13	69	160	1.7	56	116	.20	.08	470	Sr - .72 EC - 788 umhos/cm

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

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


AMWUA RIVERBED RECHARGE PROJECT
LANDFILLS, WASTEWATER TREATMENT FACILITIES AND ENVIRONMENTALLY SENSITIVE AREAS
CDM
environmental engineers, scientists, planners & management consultants
PLATE
4
—LEGEND—
STUDY AREA
FLOODPLAIN BOUNDARY
MUNICIPAL PLANNING AREA BOUNDARY
MOUNTAINS — HARDROCK
WASTEWATER TREATMENT AND/OR DISPOSAL
SANITARY LANDFILL
ENVIRONMENTALLY SENSITIVE AREA
0 6000 12000 18000
Scale in Feet
GLENDALE
PHOENIX
SCOTTSDALE
TEMPE
MESA
AGUA FRIA RIVER
NEW
SKUNK
CAVE
GRANITE
REEF
AQUEDUCT
INDIAN
BEND
WASH
SALT
GILA
CANAL
QUEEN
CREEK
R1E
R2E
R3E
R4E
R5E
R6E
R7E
R8E
R1W
R2W
T6N
T5N
T4N
T3N
T2N
T1N
T1S
T2S
T3S

LEGEND
STUDY AREA
FLOODPLAIN BOUNDARY
MUNICIPAL PLANNING AREA BOUNDARY
MOUNTAINS – HARDROCK
INDIAN Indian Lands or Reservations
STATE State Lands
FEDERAL Federal Lands
MILITARY Military Reservations & Withdrawls Corps of Engineers
RECREATION State & County Park, Wildlife & Outdoor Recreation Areas
PATENTED Patented Lands (Privately Owned Land That Includes Surface Rights)
0 6000 12000 18000
Scale in Feet
GLENDALE
PHOENIX
SCOTTSDALE
TEMPE
MESA
NEW RIVER
SKUNK CREEK
SALT RIVER
INDIAN BEND WASH
QUEEN CREEK
GRANITE REEF AQUEDUCT
SALT - GILA AQUEDUCT
ARIZONA CANAL
PATENTED
STATE
FEDERAL
INDIAN
MILITARY
RECREATION
R2W R1W R1E R2E R3E R4E R5E R6E R7E R8E
T6N T5N T4N T3N T2N T1N T1S T2S T3S
AMWUA RIVERBED RECHARGE PROJECT
LAND OWNERSHIP MAP
CDM
environmental engineers, scientists, planners & management consultants
PLATE
5