GROUNDWATER RECHARGE FEASIBILITY INVESTIGATION

Appendix C

Technical Memorandum No. 3

Conceptual Facility Plans and Cost Estimates for Selected Potential Recharge Sites

FLOOD CONTROL DISTRICT of MARICOPA COUNTY 1959

Submitted by

CH2M HILL

in association with

ERROL L. MONTGOMERY & ASSOCIATES

and

L. G. WILSON, RECHARGE SPECIALIST

MARCH 1988

GROUNDWATER RECHARGE FEASIBILITY INVESTIGATION APPENDIX C

TECHNICAL MEMORANDUM NO. 3

CONCEPTUAL FACILITY PLANS AND COST ESTIMATES FOR SELECTED RECHARGE SITES

Prepared for

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
PLANNING & PROJECTS
MANAGEMENT DIVISION

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Errol L. Montgomery & Associates, Inc.
and
L. G. Wilson, Recharge Specialist

March 1988

This Document Has Been Prepared Under the Direction
of a Professional Engineer Registered in the
State of Arizona

Registered Professional Engineer
CERTIFICATE NO. 16248
RICHARD A. HALL
Date Signed 4-8-88
ARIZONA, U.S.A.

N22984.A0

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TECHNICAL MEMORANDUM

TO: Lionel Lewis/Flood Control District of Maricopa County

PREPARED BY: Richard A. Randall/CH2M HILL
Michael J. Rosko/Montgomery & Associates

SUBJECT: Maricopa Recharge Feasibility Investigation
Flood Control District of Maricopa County
TECHNICAL MEMORANDUM NO. 3
CONCEPTUAL FACILITY PLANS AND COST ESTIMATES FOR SELECTED RECHARGE SITES

DATE: March 3, 1988 (Revised March 31, 1988)

PROJECT: N22984.AO

INTRODUCTION

This memorandum presents the conceptualized plans and costs for operating recharge facilities at three selected sites located near existing Flood Control District of Maricopa County (FCD) facilities. Based on previous evaluations and on discussions during a November 18, 1987 meeting, the following three sites were selected by the Review Committee:

- McMicken Dam Detention Area
- Agua Fria/New River to Camelback Road
- Queen Creek from CAP to Rittenhouse Road

Following are assessments for each site. Each assessment is based on previously selected criteria, a facilities plan, and estimated project costs.

PROJECT LOCATIONS AND RECHARGE SPECIFICS

Areas for locating recharge facilities were previously selected based on suitable hydrogeologic conditions, availability of recharge water, suitable land use and soils, and institutional factors. The locations of the study areas are shown on Figure 1. To develop a conceptual recharge project within each of the three study areas requires the selection of a project location and a determination of the project specifics. The objective is to develop a project plan, for each site, to recharge water for storage that is economical and environmentally sound. The priority criteria used to locate the recharge projects were areas with suitable soils and high infiltration rates, lands that are publicly owned, and lands that are presently undeveloped and where recharge might be an acceptable use during the next 20 years. Project specifics include sources of water to be recharged, expected modes of operations, and expected benefits to be derived from the project.

An important criterion for assessing recharge site suitability is the rate of recharge. Generally, one of two things controls the rate of recharge. First is the infiltration rate at the land surface. The second control is the effect of recharge groundwater mounding up to the land surface. Evaluation of this latter condition is quite intensive and

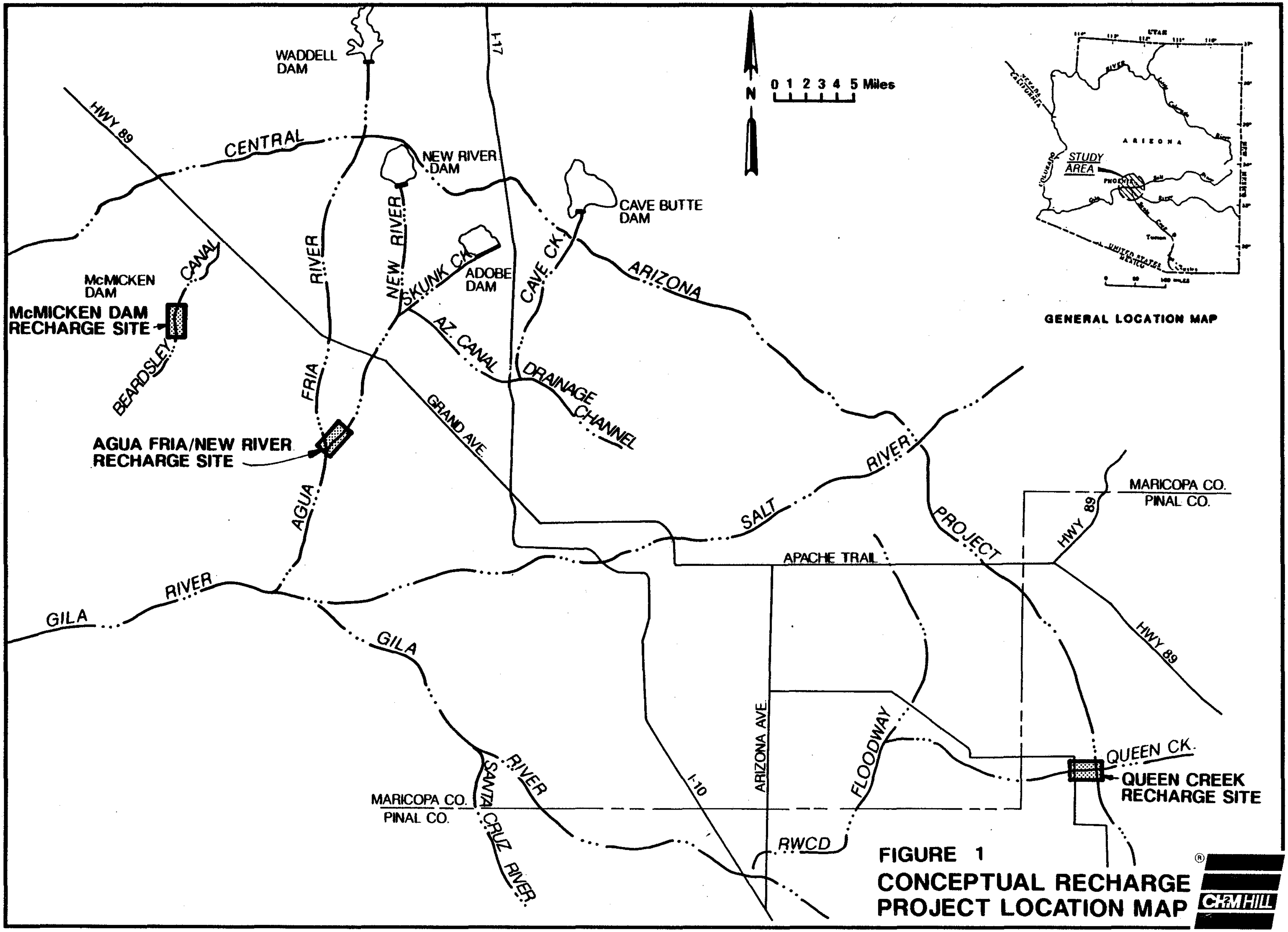


FIGURE 1
CONCEPTUAL RECHARGE PROJECT LOCATION MAP

technical and beyond the scope of work herein. This evaluation is necessary before final design of any recharge site and evaluation of unit recharge cost. The findings during extensive site data collection and analysis may even dictate that another recharge method (i.e., injection wells), be used. For this assessment, surface spreading is the assumed recharge method and the estimated infiltration rates at the land surface are considered the controlling factors for site assessments and economic evaluations.

McMICKEN DAM RECHARGE PROJECT

The McMicken Dam recharge project is located between the McMicken Dam detention levee and the Beardsley Canal about one mile south of Bell Road as shown on Figure 1. Selection of this location within the study area was based primarily on finding the best soils for high infiltration rates, publicly owned lands, and undeveloped lands.

The recharge water source is Central Arizona Project (CAP) water transported via the Beardsley Canal. The possibility of purchasing excess surface water during wet years from the Maricopa Water District (MWD) also exists. The project would be operated to maximize recharge depending on availability of water and conveyance capacity in the Beardsley Canal. The major benefit of recharging CAP water is the underground storage of an imported water supply. A benefit from recharging excess water from MWD would be conservation of a local surface water supply.

AGUA FRIA/NEW RIVER RECHARGE PROJECT

The Agua Fria/New River recharge project is located at the confluence of New River and the Agua Fria River between Glendale Avenue and Camelback Road as shown on Figure 1. An advantage of this location is that it allows diversion of floodwaters from both the Agua Fria River and New River watersheds for recharge. This location also has soils with high infiltration rates. Most of the land is publicly owned, and the property is undeveloped.

CAP water would be conveyed via the Salt River Project (SRP) Grand Canal. CAP water could also be conveyed to the project via the SRP Arizona Canal or within the Agua Fria River channel. Floodwaters and spills from Waddell Dam could also be recharged. Additional diversions and upsizing of hydraulic structures within the recharge project will be required to accommodate the intermittent floodwater flows. Project benefits include underground storage of imported waters and the conservation of floodwaters. An added benefit is that artificially recharging floodwaters at the project site will reduce the amount of natural recharge that occurs downstream which is contributing to high groundwater levels and waterlogging in the Buckeye area.

<u>QUEEN CREEK RECHARGE PROJECT</u>

The Queen Creek recharge project is located on both sides of the Queen Creek channel immediately west of the CAP Salt-Gila Aqueduct and adjacent to Queen Creek Road as shown on Figure 1. The location is close to the CAP source water, has favorable soils for recharge, and is mostly on public lands. Much of the stream channel has ongoing sand and gravel operations and most of the off-channel areas are farmed.

The sole recharge source is CAP water. Scarce floodwater flows and existing sand and gravel operations in the stream channel make floodwater recharge impractical. Underground storage of imported water is the major project benefit.

DETERMINING SITE SUITABILITY

Many factors are necessary to determine recharge site feasibility. For specific sites herein, we have assessed hydrogeology, soils and infiltration rates, and land ownership to evaluate technical suitability of the selected sites.

HYDROGEOLOGY

Potential Groundwater Storage and Recovery Volumes

Groundwater storage resulting from recharge operations occurs via rise in water level and saturation of sediments in the vadose zone. The vadose zone is the zone of soils and rocks which lie between land surface and groundwater level. The vadose zone contains residual amounts of groundwater held in pore spaces by hygroscopic and capillary forces. In this memorandum, these residual amounts of groundwater are termed the "initial moisture content".

For the purpose of evaluating impacts of recharge, the vadose zone is divided into a lower part - the "drained zone", and an upper part - the "historic vadose zone". The "drained zone" is defined herein to be the lower part of the present-day vadose zone, that part which was saturated prior to 1952 in the Salt River Valley, but which has been drained due to decline in groundwater levels. The upper part of the present-day vadose zone was not saturated in 1952. This part of the vadose zone, above the top of the drained zone, is defined herein as the "historic vadose zone".

Sediments in the drained zone are estimated to have initial moisture content equal to specific retention. Specific retention is the ratio of volume of water which sediments will retain after being saturated and then allowed to drain under the force of gravity, to the total volume of the sediments, and is expressed in percent.

In areas adjacent to natural recharge sites, such as along large ephemeral stream channels, sediments in the historic vadose zone are estimated to have larger initial moisture content than locations where periodic natural recharge is not believed to occur.

Estimating the amount of recharge water that could safely be stored underground without harming other landowners is beyond the scope of this investigation. Instead, unit volumes for storage and recoverable water per acre of land surface area have been calculated for comparisons between sites and do not represent total storage volumes for the site.

<u>Potential Groundwater Storage</u>. The volume of potential groundwater storage in the vadose zone was computed as the product of potential increase in saturated thickness, areal extent on a per acre basis, and the difference between initial moisture content and porosity of the vadose zone. Maximum potential increase in saturated thickness would extend from the modern water level to land surface. Modern water level is approximated by the reported November-December 1984 groundwater level, except in those areas where more recent data exist.

<u>Potentially Recoverable Groundwater</u>. The volume of potentially recoverable groundwater which could be stored in the vadose zone was computed as the product of potential increase in saturated thickness, areal extent on a per acre basis, and specific yield of the sediments. Specific yield is the ratio of the volume of water which can be drained by

gravity from saturated sediments, to the total volume of the sediments, and is expressed in percent. The sum of specific yield and specific retention is equal to the porosity of the sediments. The difference between the volume of potential groundwater storage and the volume of potentially recoverable groundwater is the volume of water required or "invested" in the vadose zone prior to reaching a water content equal to specific retention.

Losses to Surface Evaporation. Losses of recharge water occur due to surface evaporation within the basins. These losses are generally reported as a percentage of the water recharged and generally range from 2 to 6 percent. For this investigation the percentage of losses to evaporation is computed based on an estimated evaporation rate of 6 feet per year (U.S. Department of Commerce, 1968) and the estimated annual recharge rate for the site as defined herein.

Transmissivity

Aquifer transmissivity is included in the hydrogeologic conditions criteria for site suitability as an indication of the ability of the aquifer to transmit the recharged water, and as an indication of the lithology of the aquifer. Areas, where transmissivity is large, are favorable for recharge operations. Saturation of the Upper Alluvium unit from recharge operations would be expected to result in an increase in the magnitude of transmissivity. Aquifer transmissivity for areas in the Salt River Valley have been estimated from the results of pumping tests and from groundwater modeling investigations conducted by the Arizona Department of Water Resources and the Water Resources Division of the U.S. Geological Survey.

Existing Groundwater Contamination

Recharge operations should not be conducted where the recharge water may mix with contaminated groundwater. Recharge operations should not cause the migration of an existing contaminant plume into the capture zone of water supply wells in the area. Recharge operations should not be conducted where the recharge water may saturate an active or abandoned landfill and result in formation and movement of leachate from the landfill to the aquifer.

The locations of known landfills and known areas of groundwater contamination near the proposed recharge sites have been identified. The direction of the regional groundwater flow pattern at these areas has been estimated from available water level data. No attempt has been made to determine the degree of contamination that may exist or the impacts created by proposed recharge activities. Additional site specific hydrogeologic investigations will be required for areas where groundwater contamination exists or is suspected.

SOILS AND INFILTRATION RATES

The major factor in determining the suitability of soils for recharge by spreading methods is the long-term infiltration rates. Infiltration is primarily a function of soil texture and structure. Certain geochemical reactions that can occur between the recharge water and the soil minerals can also affect infiltration rates. Infiltration rates for project soils have been investigated, but little effort has been spent on the geochemical aspects. The level of effort required to determine the potential for geochemical reactions at the project sites is beyond the scope of this assessment.

Infiltration rates during recharge by surface spreading methods are determined primarily by the permeability of surface soils (0 to 5 feet), although long-term infiltration rates can be affected by impediments to subsurface flow, such as fine-grained silt or clay lenses that may exist beneath the site. Presence of these confining layers is addressed in the hydrogeologic evaluations for the project sites. For the purposes of this investigation, data from the Soil Conservation Service (SCS) soil surveys have been used to determine the soil characteristics down to 5 foot depth and to estimate infiltration rates during recharge. In the SCS soil survey reports (USDA, 1974, 1977) estimates of permeability for different soil types are given. Available data on infiltration rates were evaluated, and where possible, a correlation between SCS permeability estimates and measured infiltration rates was determined.

Several studies on stream channel infiltration rates have been conducted in Arizona and basin infiltration rates have been reported. Studies conducted in the Salt River below Granite Reef Dam to 48th Street indicated an average infiltration rate of greater than 2.5 feet/day which declined to 1.1 feet/day after two weeks (Briggs, 1966). Studies on a 20-mile reach of Queen Creek (Babcock, 1941) found rates from 0.14 to 2.09 feet/day, with an average of 1.08 feet/day for short-term flooding events. Rates for pools remaining in the channel averaged 0.91 feet/day.

Bouwer (1980) reported infiltration rates of 1 to 3.5 feet/day with an average of 2.0 feet/day at the Flushing Meadows recharge project. The soils in the area are sandy loam to loamy fine sand with an SCS estimated permeability of 2 to 6 inches/hour.

The Tucson Demonstration Recharge Project (Randall, 1987) which recharges reclaimed wastewater has reported infiltration rates of 0.8 to 1.0 feet/day. Basin soils are loam to sandy loam with SCS permeability of 0.6 to 2.0 inches/hour.

Based on the experience mentioned above and reported infiltration rates at other areas, estimates of long-term infiltration rates were made and cross-referenced with SCS permeability and infiltration estimates with a soils suitability classification number used for a general classification of project soils.

Table 1

INFILTRATION RATES REFERENCED TO SCS PERMEABILITIES

Infiltration Classification Number	SCS Permeability Estimate (in/hr)	Long-Term Infiltration Estimate (ft/day)
1	2.0 - 6.0	2.00
2	0.6 - 2.0	0.75
3	0.2 - 0.6	0.25

The classification numbers are used on soils maps contained in this memorandum. For the purpose of this investigation where soil horizons with different permeabilities were reported, the lowest permeability determined the classification number. It should be noted that in some cases the removal of the top one to two feet of soil during construction of the recharge basins could result in a higher permeability where underlying soils are more permeable. Soils descriptions and delineation on soils maps are contained in the descriptions for each project site.

LAND OWNERSHIP AND USE

Recharge by spreading methods requires large parcels of land for construction of recharge facilities. The current land use, future land use, type of ownership, and number of different ownerships within the project area will impact recharge project feasibility and costs. For this investigation, land ownership was determined from records at the County Assessor's Office for both Maricopa and Pinal counties. The current land use was determined from aerial photography. Speculations on future land use were made based on land use observed in the surrounding area and discussions with landowners.

CONCEPTUAL DESIGN CRITERIA

In an effort to tap all available resources for recharge design criteria, team members researched literature, held discussions with recharge operators, and made field visits to operating facilities. Prior to development of recharge facilities plans, members of the project team met and discussed the major issues affecting the conceptual designs. Major issues discussed were annual recharge rates, sizing basins and hydraulic structures, basin operations plan, floodwater diversion structures, and impacts of land ownership. Project team members are indebted to the staff at Los Angeles County Flood Control District for their suggestions and assistance in developing the recharge facilities design criteria and in providing construction details of hydraulic structures.

FLOODWATER DIVERSION STRUCTURE

A floodwater diversion structure must be able to divert water during moderate flow conditions and open fully during high flow conditions without causing a restriction in the channel. For diversions in wide channels and shallow water depths, the use of inflatable rubber dams has increased in recent years. Advances in weather resistant rubber compounds, air inflation and exhaust systems, and reliable emergency deflation mechanisms have reduced the maintenance requirements and operational shortcomings experienced with the an earlier generation of rubber dams. Los Angeles County has several rubber dam diversions for recharge purposes that have performed well for a number of years. They have installed several new inflatable dam diversions during the past two years. Based on these experiences, an air inflated rubber dam is the assumed diversion structure on New River at the Agua Fria/New River Recharge Project site. A dam length of 250 feet was assumed, which is approximately equal to the width of the existing stream channel.

CONVEYANCE FACILITIES AND TURNOUTS

For the three projects discussed herein the recharge water will be taken from either the Beardsley Canal, the CAP aqueduct, or diversions of floodwater and spills from the SRP Grand Canal. Delivering recharge water to the spreading facilities will require canal turnouts and conveyance facilities. Canals, pipelines, turnouts, and division boxes similar to those commonly used in irrigation distribution systems were assumed. The criteria used in sizing and configuration of these structures is consistent with the standards contained in Design of Small Canal Structures (USBR, 1978).

PUMP STATIONS

Where the canal water levels are below the land surface or the recharge basins are upgradient from the canal, pump stations are required. A typical pump station will consist of a concrete turnout/intake structure with a trash rack, multiple vertical turbine pump units, electrical controls, a discharge pipe with flow meter, and site fencing. Multiple pumps with one smaller unit having a variable speed driver would provide the flexibility needed to match delivery rate with basin demands.

SPREADING BASINS

Two types of spreading basins are commonly used: temporary basins constructed in the active stream channel, referred to as in-channel levees and permanent basins constructed off-channel. An in-channel levee system consists of a series of levees constructed perpendicular to the direction of flow. One end is tied to the bank and the other end extends upstream parallel to the opposite bank. Water released upstream flows into the system of levees that spill around the upstream levee segment to the downstream levees. The spacing of the levees is such that the maximum water depth is about 5 feet and the backwater in each levee reaches the toe of the upstream levee to maximize the wetted area. In-channel levees are subject to periodic washout during flooding events and there is no provision for draining the basins in between recharge cycles.

Off-channel basins are constructed in areas outside the stream channel or within the less active channel or floodway areas. A series of basins are interconnected with spillway structures such that the recharge water is introduced into the upgradient basin and flows downgradient from one basin to the next. For design purposes a maximum water depth for off-channel basins ranges from 3 to 5 feet. A drain structure is also constructed between basins to allow quick drainage of basins between recharge cycles to maximize the drying period.

BASIN INFLOW AND DRAINAGE RATES

To determine basin inflow rates the long-term infiltration rates for each basin are calculated. The areal extent of each soil type within the basin is determined and a weighted average infiltration rate is computed using the estimated infiltration rates shown on Table 1. The design recharge rate (DRR) is intended to approximate the average recharge rate over time and can be used to calculate the volume of water recharged annually. The design filling rate (DFR) is an approximation of the rate needed to fill a basin within 24 hours. In calculating the DFR it is assumed that the average infiltration rate is 75 percent of the DRR and the average water depth is 3 feet. The DFR is used to size turnouts, conveyance facilities, and interbasin spillway structures. The design drainage rate (DDR) is an approximation of the flow rate needed to drain a basin within 2.5 days. In calculating the DDR it is assumed that the average infiltration rate is 25 percent of the DRR. The DDR is used to size drainage structures and conveyance facilities for drainage water.

BASIN RECHARGE OPERATIONS

The basic goal for basin operations is to maximize the volume of water recharged by maximizing the hydraulic loading rate. Bouwer (1980) reported that maximum hydraulic loading at Flushing Meadows was obtained with flooding periods of 2-3 weeks alternated with drying periods of about 10 days in summer and 20 days in winter. Others have reported similar results with wet and dry cycling at other recharge sites. A critical element in recharge cycle times is the drying time required. Quickly draining the basins at the beginning of the drying period reduces the dry cycle time required. For this investigation a 50 percent wetting and drying cycle is assumed. Therefore, the annual recharge rate is computed as: Design Recharge Rate (DRR) x 365 days x 50 percent.

Where floodwaters are being recharged the silt load carried in the water and the potential clogging of the basins is a concern. In those instances where siltation is a problem chemical flocculants are added after the diversion and a siltation basin provided upstream from the recharge basins. The need for chemical addition and siltation basins depends on the silt load carried in the floodwaters and the amount of floodwaters diverted for recharge. The sizing and locations of these facilities have not been identified for this investigation. Additional data on the silt carrying characteristics of the flood flows and refinements to the recharge plan would be required to identify these facilities. Chemical injection equipment could be added near the intake structure and the siltation basin could be located upstream or within the proposed recharge basins.

LEVEE DESIGN

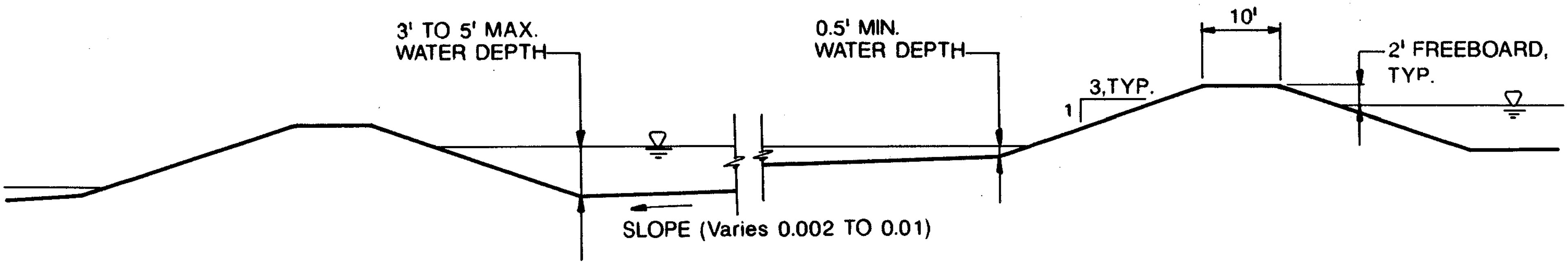
It is assumed that the maximum water depth for levees to retain is 5 feet. A freeboard of 2 feet is assumed for off-channel levees and a 1-foot freeboard for in-channel levees. Recharge basin levees typically have side slopes between 2:1 and 3:1. Maintenance crews at existing recharge projects reportedly prefer the 3:1 slopes because of the ease of maintenance (Wood, 1988). A side slope of 3:1 is used for this investigation. A top width of 10 feet is used for off-channel levees and a 4-foot width is used for in-channel levees. A typical cross-section of an off-channel basin and an in-channel levee is shown on Figure 2.

INTERBASIN SPILLWAY AND DRAIN STRUCTURES

Connecting off-channel basins in series requires a flow conveyance structure between basins while wetting and a drain during drying. A variety of structures have been used over the years at various recharge facilities. For this investigation a design used at Los Angeles County Flood Control District has been selected. This interbasin spillway consists of a concrete lined depression on the levee which acts as a spillway into the next basin. The drain structure is adjacent to the spillway and consists of a concrete turnout structure and sluice gate connected to a reinforced concrete outlet pipe. A drawing of a typical interbasin spillway and drain structure is shown on Figure 3.

MONITORING PROGRAM

A monitoring program is concerned with the quantity and quality of recharge water applied to the site and the water level and quality of groundwater beneath the site. Monitoring requirements will vary from site to site depending on the water source, soil/aquifer conditions, recharge rates, ambient groundwater conditions, and other factors. It is anticipated that at Arizona Department of Environmental Quality (ADEQ) will specify certain monitoring requirements with their Aquifer Protection Permit. The following discussion on monitoring requirements presents certain assumptions made by the project team for the purpose of developing a facilities plan for each site and for estimating project capital and operations and maintenance (O&M) costs.



TYPICAL OFF-CHANNEL BASIN

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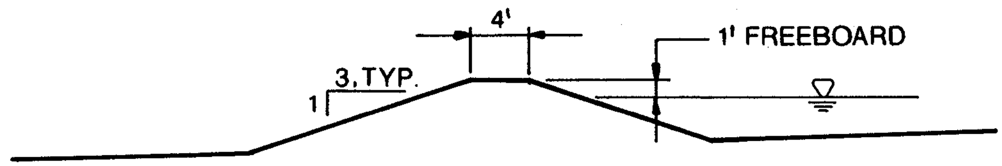

TYPICAL IN-CHANNEL LEVEE

NTS

FIGURE 2

TYPICAL OFF-CHANNEL BASIN & IN-CHANNEL CROSS-SECTIONS

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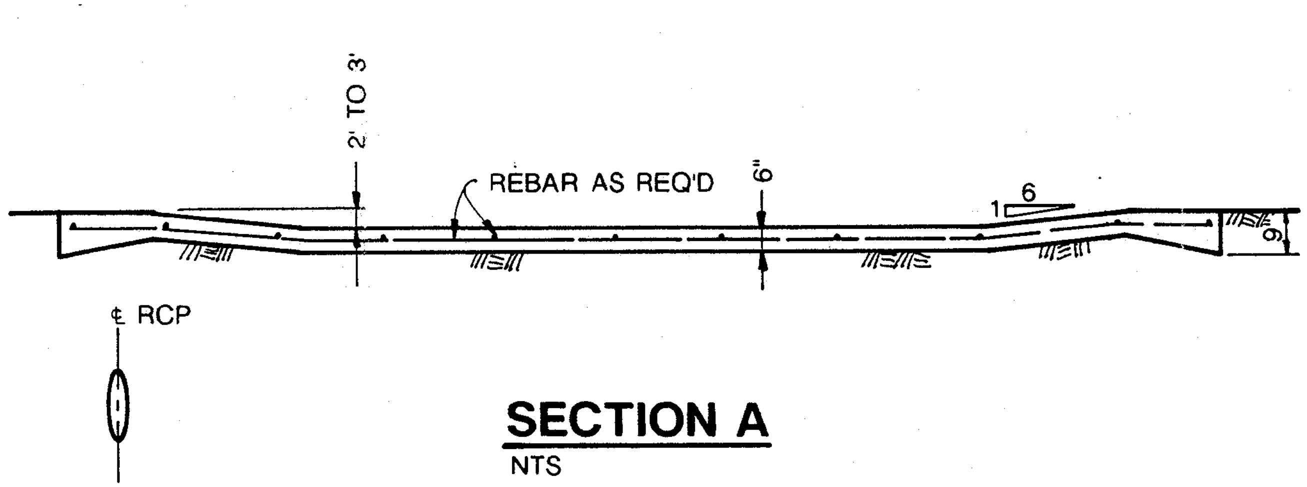
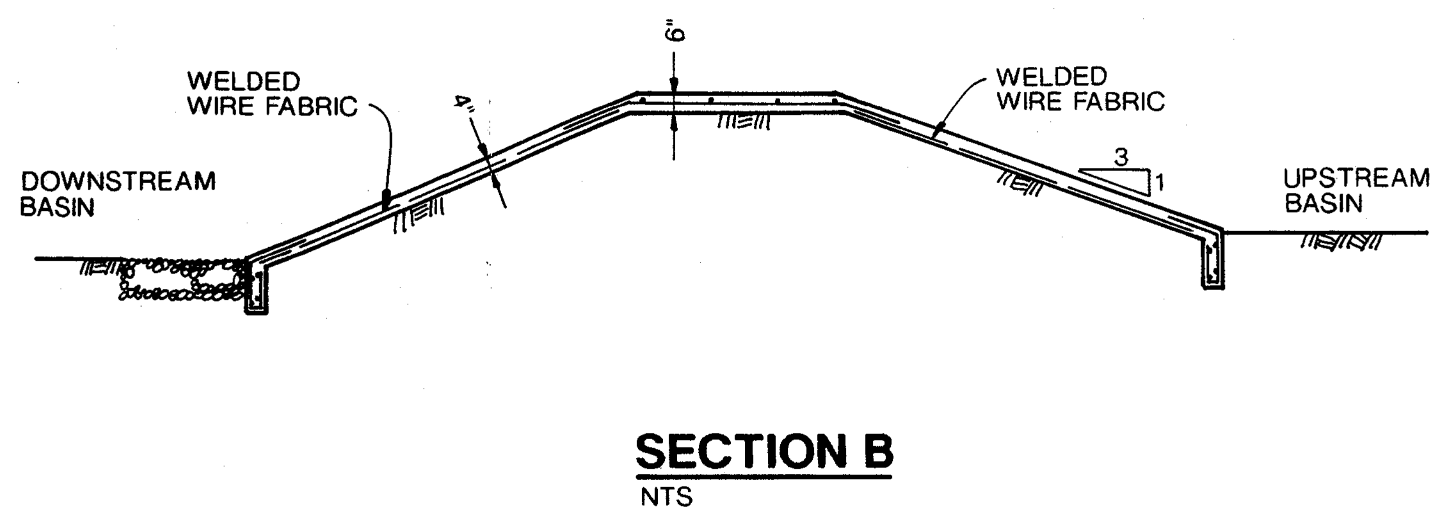
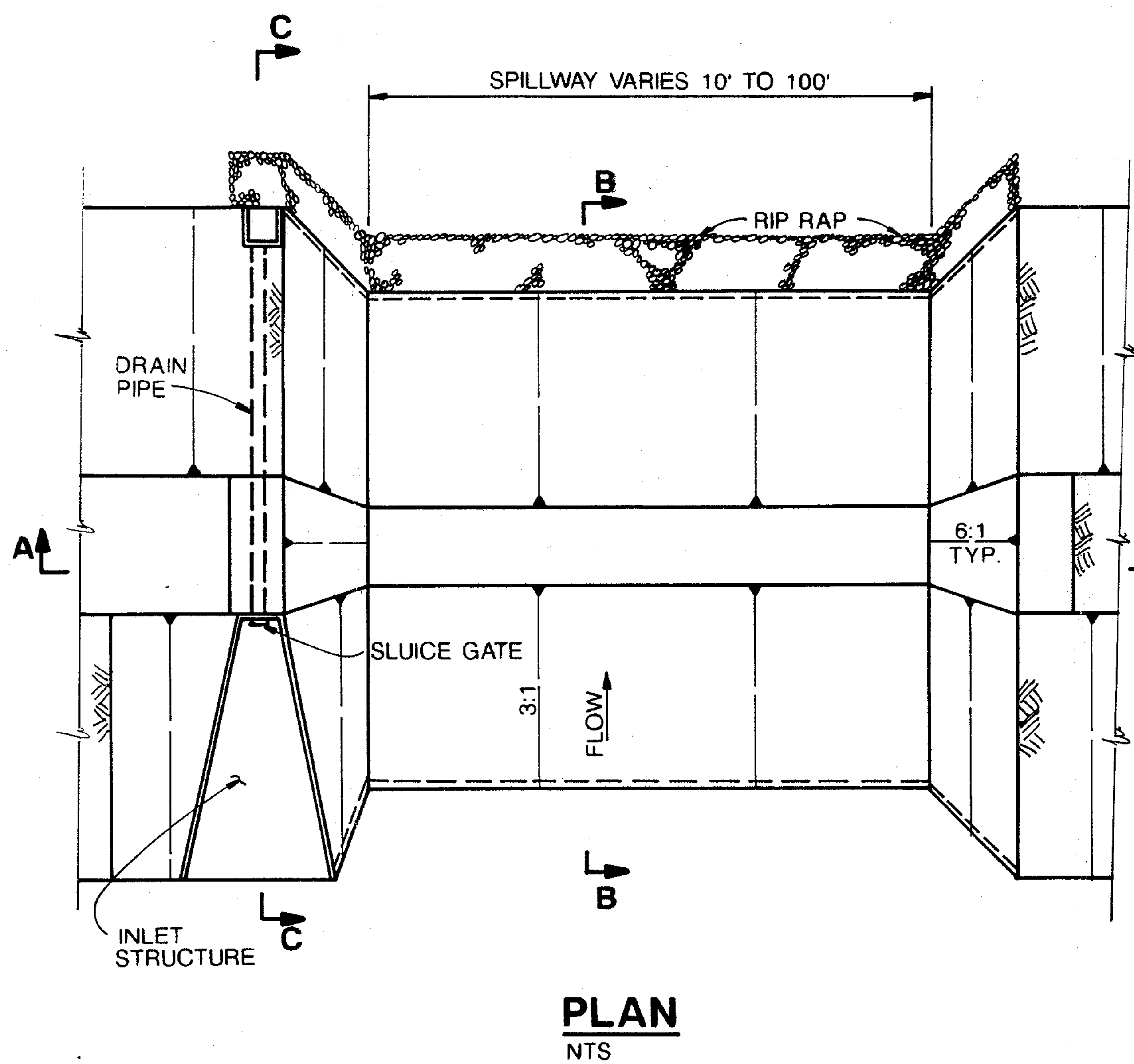






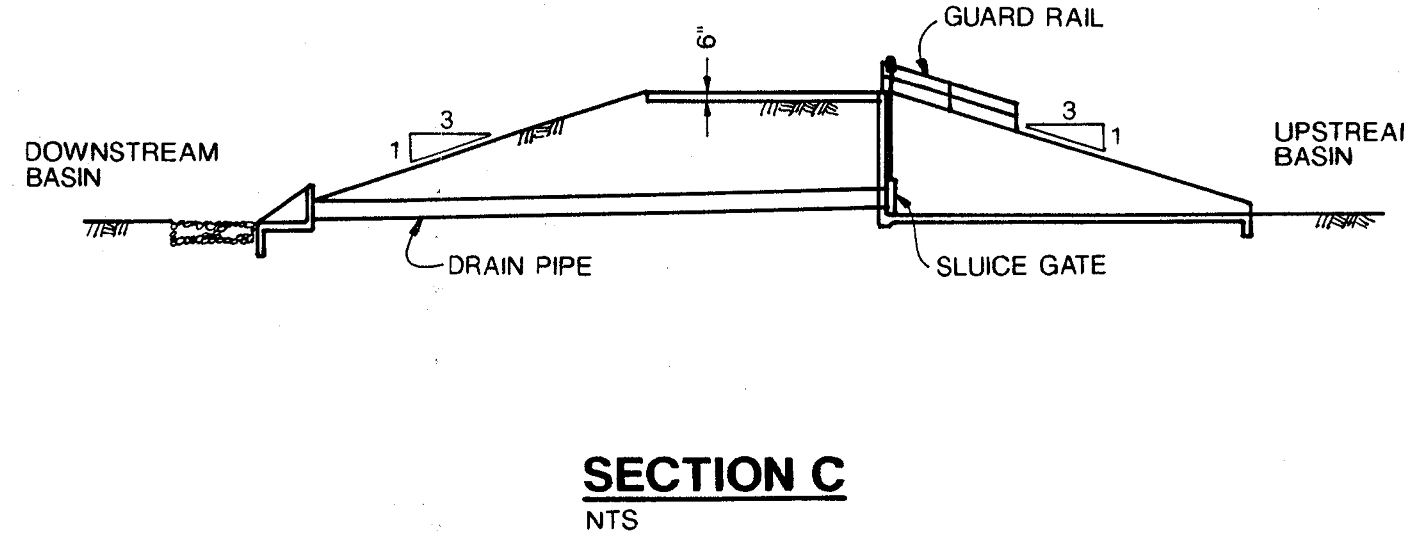


FIGURE 3
INTER-BASIN SPILLWAY & DRAIN STRUCTURE

CH2M HILL

Recharge Source Water

Flow measuring devices are constructed at the inlet to each series of recharge basins. Recharge flows are measured and volumes recorded on a daily basis. Samples of the source water are collected periodically for laboratory chemical analysis.

Monitor Wells

A network of three or more monitor wells would be constructed at each site. Typically the wells would be 4- or 6-inches in diameter and would be drilled about 100 feet below the water table. The wells should be constructed to comply with Arizona Department of Water Resources (ADWR) Construction Standards. A submersible pump would be permanently installed in each well for collecting groundwater samples. A locking cover would be provided to prevent unauthorized access to the well. Tentative locations of monitor wells have been proposed for each recharge site; however, actual locations for monitor wells would not be determined until after additional data has been collected and the locations of the recharge facilities have been finalized.

For this investigation it is assumed that groundwater levels at the monitor wells would be measured monthly.

Arizona Department of Water Resources (ADWR) will specify minimum requirements for groundwater level monitoring through their underground storage and recovery permit. During early phases of recharge operations, more frequent monitoring of groundwater levels may be required. The frequency of water level monitoring will be dictated by the size of the recharge facility and the recharge rates and specific hydrogeologic conditions.

Water Quality Testing

For this investigation it is assumed that monthly samples of groundwater and recharge water would be analyzed for routine constituents listed in Table 2. The samples would be tested quarterly for additional trace constituents which could include trace inorganics, trace organic chemicals, and radiochemicals. Specific requirements of a water quality sampling and testing program will be determined during the permitting process with Arizona Department of Environmental Quality (ADEQ). The sampling frequency and constituents analyzed will depend on the water quality findings for the recharge source water and ambient groundwater.

During early phases of recharge operations more frequent monitoring of chemical quality may be required.

Table 2

ROUTINE CONSTITUENTS TO BE ANALYZED
FOR GROUNDWATER MONITORING PROGRAM

Major Ions	Physical Parameters
Calcium	Total Dissolved Solids
Magnesium	Hardness
Sodium	Alkalinity
Potassium	Temperature (°C) - field
Carbonate	Specific Electrical Conductance - field and lab
Bicarbonate	pH - field and lab
Sulfate	
Fluoride	
Nitrate	
Phosphate	
Silica	

ESTIMATING PROJECT COSTS

Conceptual cost estimates were prepared for recharge facilities using information available from local agencies, vendors, contractors, cost estimating guides, and recent projects of a similar nature. In addition, costs for the inflatable dam used on the Agua Fria Recharge Site were developed from similar installations completed by the Los Angeles County Flood Control District on the San Gabriel River.

Operation and maintenance (O&M) costs were developed from similar facilities operated by the Orange County Water District and Los Angeles County. Typical operation activities include patrols of the facilities during recharge operations, control of diversions, gates, and pump stations. Maintenance activities include repair of flood damaged facilities, weed abatement, pond bed scarification, and removal of sediments. O&M costs in the Los Angeles area range from $5 - 6/ac-ft of water recharged. Infiltration rates for these facilities are substantially lower than those estimated for the three sites presented in this study, so a per-acre O&M cost provides a better comparison. The Orange County facilities cost is about $600 per acre of recharge ponds. The maintenance costs for the Agua Fria/New River recharge project would be higher than the other two, since the in-channel levees at this site are more susceptible to flood damage and heavy siltation. O&M costs for this investigation were estimated to be $600 per acre of ponds for the McMicken Dam Project, $500 per acre of ponds for the Queen Creek project, and $1,000 per acre of ponds for the Agua Fria/New River project.

Energy costs for pumping facilities were estimated using the current commercial rate structure of the Salt River Project for the area which averages to about $0.05 per kilowatt hour.

Land costs for the project sites were estimated based on discussions with realtors, land owners, and Arizona State Land Department. Public lands were assumed to be leased at $300 per acre, and private lands were assumed to be purchased at $15,000 per acre.

Capital costs have been annualized assuming 8 percent revenue bonds with a 20-year maturity and 20 percent initial cost for issuance and bond discount.

The cost estimates shown, and any resulting conclusions on project financial or economic feasibility or funding requirements, have been prepared for guidance in project evaluation and implementation from the information available at the time the estimate was prepared. The final costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions, actual site conditions, final project scope, implementation schedule, continuity of personnel and engineering, and other variable factors. As a result, the final project costs will vary from the estimates of cost presented herein. Because of these factors, project feasibility, benefit/cost ratios, risks, and funding needs must be carefully reviewed prior to making specific financial decisions or establishing project budgets to help ensure proper project evaluation and adequate funding.

McMICKEN DAM RECHARGE SITE

RECHARGE WATER SOURCES

The recharge water source for this site is CAP water. The Beardsley Canal, which carries a mixture of CAP water and water diverted from Waddell Dam, will convey water to the site. The capacity of the Beardsley Canal to carry recharge flows is yet to be determined, but preliminary data indicate that a steady rate of 50 cfs could be safely carried to the site.

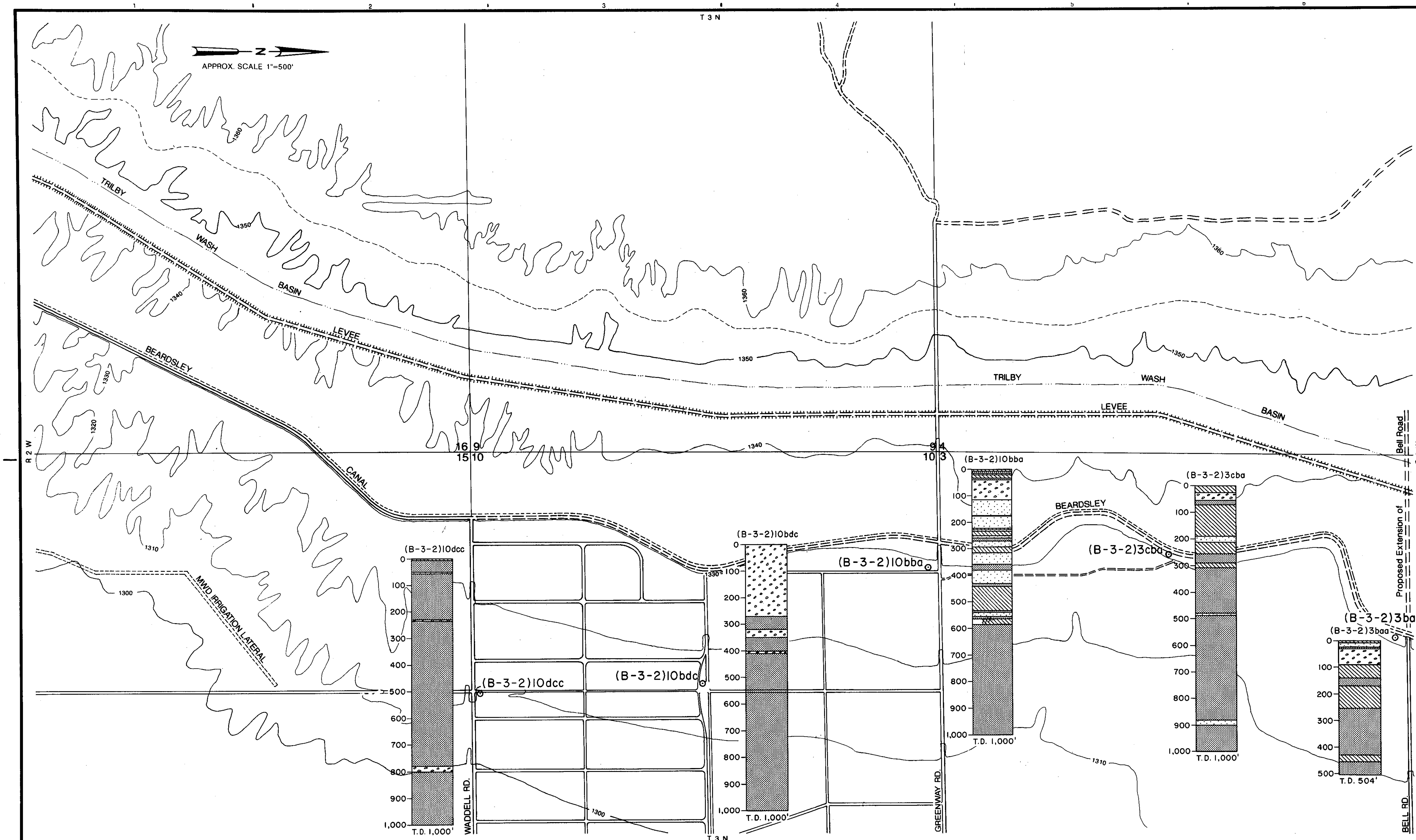
Floodwater availability at this site is low and has high potential for natural recharge. For these reasons and economics, recharge of floodwaters is not a consideration at this site.

SITE SUITABILITY

Hydrogeologic Conditions

The McMicken Dam study area is shown on Figure 4. The McMicken Dam vicinity is herein defined as the entirety of McMicken Dam and associated retention area which surrounds and includes the smaller McMicken Dam study area.

Thickness of the Upper Alluvium unit in the McMicken Dam vicinity ranges from 500 to 700 feet; in this vicinity the Middle Alluvium is believed to be absent (U.S. Bureau of Reclamation, 1977). Depth to the basement complex in the McMicken Dam vicinity is estimated to be more than 1,200 feet (Cooley, 1973). Lithologic data for selected wells in the McMicken Dam study area are summarized on Figure 4. Inspection of the lithologic data indicates that abundant fine-grained sediments including clay, sandy clay,



DSGN	
DR	
CHK	
APVD	

CH2M HILL

Legend

- CLAY, SANDY CLAY, CLAY WITH SAND, CLAY WITH GRAVEL, CLAY WITH CALICHE
- CALICHE, CEMENTED SAND, CEMENTED SAND AND GRAVEL, CEMENTED GRAVEL, CALICHE WITH CLAY
- SAND, CLAYEY SAND, SAND WITH GRAVEL, SANDSTONE
- GRAVEL, GRAVEL WITH SAND, GRAVEL WITH BOULDERS, GRAVEL WITH CLAY, CONGLOMERATE

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GROUNDWATER RECHARGE FEASIBILITY INVESTIGATION

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FIGURE 4

McMICKEN DAM RECHARGE SITE LITHOLOGIC DATA

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and clay with gravel were penetrated during drilling operations.

Depth to groundwater level was measured in 1982 at nine wells located in the McMicken Dam vicinity and ranged from 465 to 504 feet below land surface (Reeter and Remick, 1986); average depth was 484 feet. Depth to groundwater level of 329 feet below land surface was measured in 1982 at a well located less than one mile west from the spillway (Reeter and Remick, 1986). Of the nine wells measured in the McMicken Dam vicinity, four are located in the McMicken Dam recharge study area. Depth to groundwater level was measured in November and December 1984 at four wells in the McMicken Dam study area nd ranged from 477 to 497 feet below land surface (Arizona Department of Water Resources, 1987).

Direction of groundwater movement in 1982 in the McMicken Dam study area was from northwest to southeast. An active solid waste landfill operated by Maricopa County is located about two miles west from the McMicken Dam spillway. Groundwater movement is generally from the solid waste landfill toward the McMicken Dam study area.

Reported pumping rates for wells located within about one-half mile from the study area for years 1985 through 1987 range from about 596 to 1,119 gpm (gallons per minute) (Arizona Department of Water Resources, 1987). Transmissivity was reported to range from about 10,000 to 65,000 gpd/ft (gallons per day per foot of aquifer width at 1:1 hydraulic gradient) for pumping tests conducted in 1958 for wells in Township 4 North, Range 2 West, Section 26, about 1.5 miles northeast from the McMicken Dam study area (DeCook and Resnick, 1958). Transmissivity ranging from 10,000 to 25,000 gpd/ft has been assigned to the eastern edge of the study area for electrical analog analysis of the

Salt River Valley (Anderson, 1968). Transmissivity in the range from 5,000 to 50,000 gpd/ft and specific yield in the range from five to 12 percent were assigned for the Salt River Valley Cooperative Study Modeling Effort (Long, Niccoli, Hollander, and Watts, 1982).

Groundwater samples for laboratory chemical analyses were obtained in 1982 and 1983 from eight wells located in the McMicken Dam vicinity. Total dissolved solids for these samples was estimated from specific electrical conductance and ranged from about 190 to 290 mg/l (milligrams per liter) (Reeter and Remick, 1986). Of the eight wells sampled in the McMicken Dam vicinity, four are located in the McMicken Dam study area. Groundwater samples for laboratory chemical analyses were obtained in 1982 and 1983 from these four wells. Total dissolved solids for these samples was estimated from specific electrical conductance and ranged from about 190 to 200 mg/l (Reeter and Remick, 1986). Groundwater samples for chemical analyses were obtained in 1987 from two wells located in the McMicken Dam study area. Total dissolved solids for these samples was estimated from specific electrical conductance and was about 195 and 205 mg/l (Arizona Department of Water Resources, 1987).

<u>Potential Groundwater Storage and Recovery Volumes</u>

Comparison of altitude of groundwater level for 1952 and for 1984 indicates that average groundwater level decline for the McMicken Dam study area is about 180 feet. Volumes of potential groundwater storage and potentially recoverable groundwater were computed using average specific yield of 10 percent, average specific retention of 30 percent, and average porosity of 40 percent for the sediments in the McMicken Dam study area. Initial moisture content of 13 percent was assigned for the historic vadose zone.

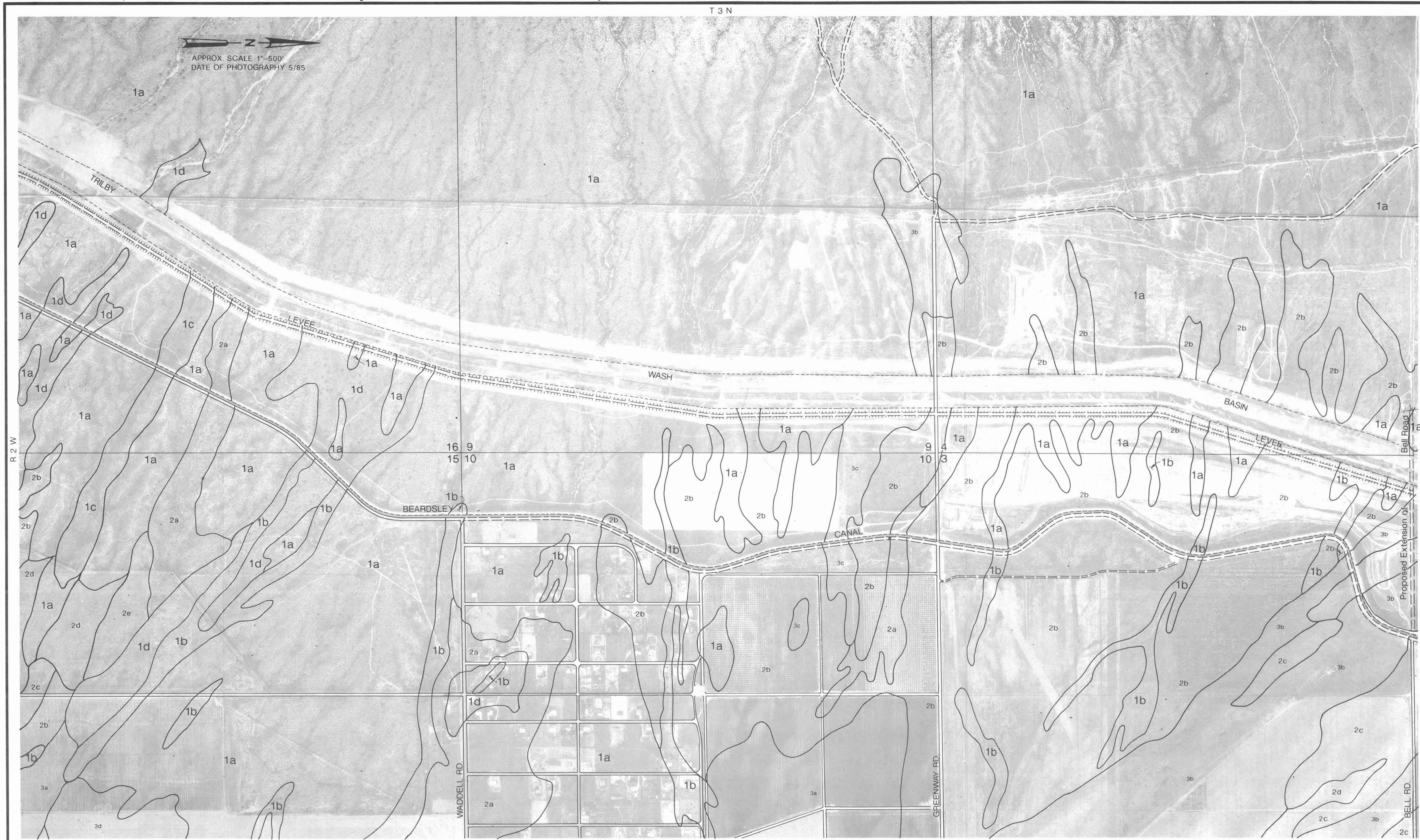
Initial moisture content was assigned based on average moisture content for 11 samples collected in 1952 and 1953 for the Trilby Wash Detention Basin (U.S. Army Corps of Engineers, 1973). Initial moisture content equal to the specific retention of 30 percent was assigned to the 180 feet of the drained zone in the McMicken Dam study area.

Total volume of potential groundwater storage in the drained zone and historic vadose zone is approximately 100 acre-feet of water per acre of surface area. For the 100 acre-feet of groundwater storage, 48 acre-feet would be immediately recoverable groundwater and 52 acre-feet would be "invested" groundwater required to bring the volumetric water content in the historic vadose zone from 13 percent to specific retention.

Assuming the long-term recharge rate at the site is limited only by surface infiltration rates, the estimated losses due to surface evaporation and "investment" in the vadose zone directly beneath the recharge basins would be about four percent for a project life of 20 years.

Soils

There are about 13 different soils classifications within the McMicken study area. A majority of the soils are a sandy loam underlain by a gravelly sandy loam or gravelly sand. A summary of SCS soils information together with a map legend for the different soils classifications is shown on Table 3. A delineation of the different soils is contained on the soils classification map, Figure 5.



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GROUNDWATER RECHARGE FEASIBILITY INVESTIGATION

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FIGURE 5

McMICKEN DAM RECHARGE SITE SOILS CLASSIFICATION MAP

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Table 3

McMICKEN DAM RECHARGE SITE - SCS SOILS INFORMATION

MAP LEGEND	SOIL SERIES & MAP SYMBOLS	SCS DESCRIPTION OF INTAKE RATES	SOILS PROFILE		SCS Permea-bility Estimate (in/hr)
			Depth from surface (inches)	Dominant USDA Texture	
1a	Antho: AdA, AdB, Ae, AkB, AL	Moderately rapid permeability	Ø-6Ø	sandy loam or gravelly sandy loam	2.Ø-6.Ø
1b	Brios: Bs, Bt	Rapid permeability	Ø-14 14-6Ø	sandy loam, sand & gravelly sand	2.Ø-6.Ø 6.Ø-2Ø.Ø
1c	Maripo: Ma	Moderately rapid permeability below a depth of 2Ø to 4Ø inches	Ø-34 34-6Ø	sandy loam gravelly sand	2.Ø-6.Ø 6.Ø-2Ø.Ø
1d	Vint: Vh, Vr	Moderately rapid permeability	Ø-6Ø	loamy fine sand	2.Ø-6.Ø
2a	Agault: Aa	Very rapid permeability below a depth of 2Ø to 4Ø inches	Ø-27 27-6Ø	loam sand	Ø.6-2.Ø >2Ø.Ø
2b	Gilman: GgA	Moderate permeability	Ø-6Ø	loam & very fine sandy loam	Ø.6-2.Ø
2c	Laveen: LcA	Moderate permeability	Ø-6Ø	loam	Ø.6-2.Ø
2d	Perryville: PeA	Moderate permeability	Ø-38 38-6Ø	gravelly loam sandy loam	Ø.6-2.Ø 2.Ø-6.Ø
2e	Rillito: RbA	Moderate permeability	Ø-6Ø	gravelly loam and sandy gravelly loam	Ø.6-2.Ø
3a	Estrella: Es	Moderately slow permeability	Ø-24 24-6Ø	Loam Clay Loam	Ø.6-2.Ø Ø.2-Ø.6
3b	Mohall: Mo, Mp, Mr	Moderate permeability below a depth of 2Ø to 4Ø inches	Ø-35 35-6Ø	clay loam very fine sandy loam	Ø.2-Ø.6 Ø.6-2.Ø
3c	Tremant: Te	15 to 35 percent coarse fragments; moderate perme-ability below a depth of 2Ø inches	Ø-23 23-6Ø	gravelly clay loam gravelly loam	Ø.2-Ø.6 Ø.6-2.Ø
3d	Valencia: Va	Moderately slow permeability	Ø-26 26-6Ø	sandy loam clay loam and sandy clay loam	2.Ø-6.Ø Ø.2-Ø.6

DATA SOURCE: SCS Soil Survey of Maricopa County, Arizona. September, 1977.

Land Ownership and Use

Most of the land between the Beardsley Canal and McMicken Dam is publicly owned and held by the Maricopa Water District and Arizona State Land. The land is undeveloped and is covered with numerous small tributary washes and arroyos which are cut off from upstream drainage by the dam. MWD has leased about 45 acres of this land to the University of Arizona for farming experiments. Approximate property boundaries and ownerships are shown on the property ownership map, Figure 6.

CONCEPTUAL FACILITIES PLAN

Locating the recharge basins for this plan was based primarily on public land ownership and availability of unused land. These lands also have the better soils conditions in the study area. The recharge basins are upgradient from the Beardsley Canal and pumping is required. Beardsley Canal water is pumped through a pipeline up to the division box where it is diverted to the recharge basins. Major features of the McMicken Dam recharge site facilities plan are shown on Figure 7 and listed below:

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FIGURE 6

McMICKEN DAM RECHARGE SITE PROPERTY OWNERSHIP MAP

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Major Features

Canal Turnout & Pump Station (190 cfs, 50 ft. lift)
Conveyance Pipelines (3,500 ft., 60-inch dia.)
Interbasin & Drain Structures (7)
Division Structures (1)

Recharge Basins

Basin A - 90 acres, 1.9 fpd infiltration rate
Basin B - 110 acres, 1.5 fpd infiltration rate

TOTAL 200 acres, 1.7 fpd average rate

ESTIMATED ANNUAL RECHARGE RATE - 61,000 acre-feet/yr

PROJECT COSTS

Estimated costs for capital improvements, land, and operation and maintenance are shown in Table 4. Costs for purchase of the recharge source water are not included.

Table 4
PROJECT COSTS - McMICKEN DAM RECHARGE PROJECT

ITEM	CONSTRUCTION COST
Earthwork for Levees & Channels	$476,000
Hydraulic Structures	$113,000
Pipeline	$459,000
Pump Station	$562,000
Monitor Wells	$143,000
Subtotal	$1,753,000
Contingency (30%)	$526,000
Subtotal	$2,279,000
Engineering and Administration (15%)	$342,000
Construction Cost	$2,621,000
TOTAL PROJECT COST	$2,621,000
Annualized Project Cost (8% Revenue Bonds, 20 yr Maturity, 20% Initial Cost)	$320,000
Operation & Maintenance Cost (200 acres @ $600/ac.)	$120,000
Pumping Cost (1500 HP Maximum Demand, 4,462,000 kwhr/yr)	$222,000
Land Lease Cost: 230 acres @ $300/ac.	$69,000
Total Annual Cost	$731,000
Annual Cost Per Acre Foot, For 56,000 ac. ft./yr. Recharge	$12

RECHARGE WATER SOURCES

The main source of recharge water for the Agua Fria/New River site is assumed to be CAP and SRP surface water and SRP groundwater delivered through the Grand Canal. Enough excess channel capacity exists in the Grand Canal to deliver future SRP demands and recharge facility inflow demands (Phillips, 1988). Excess flow capacities range from 160 cfs to 325 cfs, and the recharge facility requires approximately 100 cfs. A secondary source of recharge water at this site is capture of infrequent flood flows in the Agua Fria and New Rivers. Floodwater recharge potential is discussed in greater detail in the following paragraphs.

Floodwater Recharge Potential

Flooding along the Agua Fria River has been characterized by infrequent but intense events lasting only a few days. High intensity flows of this nature are difficult to utilize by a recharge facility without a fairly substantial storage facility to capture the flows and release them at manageable levels. This site is unique in that a number of upstream reservoirs exist that can provide a degree of attenuation of flood events. These dams include Waddell Dam on the main stem of the Agua Fria River, New River Dam on the New River, Adobe Dam on Skunk Creek (a tributary of New River), and Cave Buttes Dam on Cave Creek. Cave Creek flood flows currently enter the Arizona Canal and are spilled into Skunk Creek near its confluence with New River. The Arizona Canal Diversion Channel (ACDC), currently under construction, will parallel the Arizona Canal and replace its flood carrying task.

Analysis of flood recharge potential required estimating flood flows at the proposed site. A computer spreadsheet was used to analyze daily average flows at a number of stream gages within the drainage basin over a selected number of years and to estimate the effects of existing flood control facilities. Components of the modeling effort are discussed in the following paragraphs.

Hydrology. Streamflow data at six locations in the Agua Fria River drainage basin were used to generate flood flows at the site. These include:

Gage #	Description	Agency[1]	Drainage Area (sq. mil)	Period of Record (Water Year)
09513000	Agua Fria River at Waddell Dam	USGS	1459	1934-87
09513860	Skunk Creek near Phoenix	USGS	64.6	1967-87
Arizona Tail	Arizona Canal Spills	SRP	-	1967-87[2]
09513835	New River at Bell Road, near Peoria	USGS	187	1968-84
Grand Tail	Grand Canal Spills	SRP	-	1967-87[2]
09513970	Agua Fria River at Avondale	USGS	2013	1967-72, 1974-81

[1]USGS: United States Geological Survey.
SRP: Salt River Project
[2]Records prior to 1967 are unknown.

A map of the hydrologic system and gage locations are shown in Figure 8. A study period of October 1966 to September 1981, not including water year 1973, was chosen for analysis (14 years). Water year 1973 was deleted because the Avondale gage was inoperative during that year. Water year 1967 flows were not measured at the New River gage, but all other gages had negligible flow, so it is assumed that the New River gage was similarly dry.

Flows during the 1968-81 period were intermittent at all of the gages. Periods with minimal or no runoff were

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FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FIGURE 7

McMICKEN DAM RECHARGE SITE CONCEPTUAL FACILITIES PLAN

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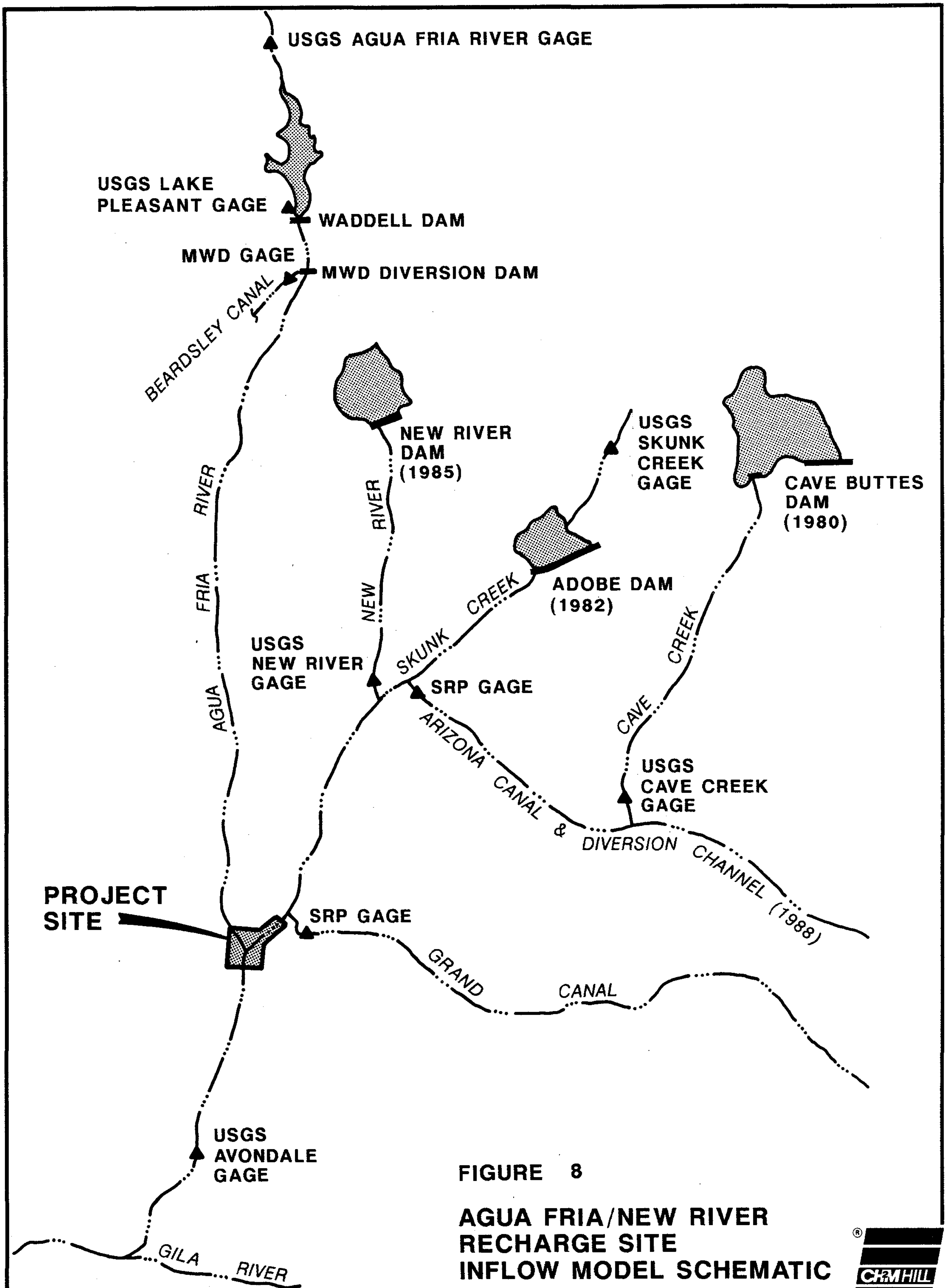

FIGURE 8

AGUA FRIA/NEW RIVER
RECHARGE SITE
INFLOW MODEL SCHEMATIC

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eliminated from analysis, until a total of 17 individual runoff events remained, with durations of up to 23 days. Flows at Avondale varied between 0 and 168,100 acre-feet (ac ft) per event for the 17 events. The total flow at Avondale for the 14 years was 325,000 acre-feet.

Modeling Flow Events. The objective of the modeling effort was to compute the flood flows at the recharge site for varying upstream regulation scenarios. Daily flows were analyzed for the 17 significant runoff events of 1967-1981 (not including 1973). Flows in the major stream channels of the basin are subject to a number of processes in their downstream progression that are difficult to model, including channel losses due to infiltration, channel retention losses due to ponding, channel routing, and inflows between gages. The beds of the major stream channels in the basin are considered movable, so the aforementioned processes are dynamic. Since historic records do not reflect the effects of reservoir routing in New River and Adobe Dam, future flows can be expected to be less severe on the New River. Preliminary planning suggests that the construction of a new, larger Waddell Dam will provide operational flood storage of 45,700 ac. ft. and joint flood-CAP storage of 77,100 ac.ft, so Agua Fria River flood flows may be less severe as a result. It can be expected that the river bottoms will be less dynamic, and that retention storage will not be as pronounced, due to a more channelized condition. The model therefore focused on computation of channel loss due to infiltration as the major unknown.

Channel infiltration was estimated using a USGS technique applicable to this type of watershed (USGS, 1970). The equation used was:

$$Q_1 = CL(Qs)^{0.8}$$

Where Q_1 - Infiltration rate for a channel reach in cfs.

Qs = Streamflow at the upstream end of the reach in cfs.

L = Length of the reach in miles.

C = Coefficient

Calibration of the model for historic flows resulted in C being 0.10 for the New River system, 0.16 for the Agua Fria upstream of the site, and 0.18 for the Agua Fria downstream of the site. This combination is consistent with the range of values expected and results in an average per-event runoff prediction error of 15 percent at the Avondale gage.

Impact of Floodwater Detention Dams--Measured flows at the New River and Skunk Creek gages were corrected for the recently constructed New River Dam (1985) and Adobe Dam (1982), respectively, using common storage routing techniques. Both dams are of earthfill construction, with uncontrolled concrete box outlet works and emergency spillways. The dams are designed to convey their Standard Project Floods without using sediment storage.

Consideration was given to modifying the New River Dam outlet works in order to utilize the sediment storage for better regulation of minor flood events. Costs for modifications would have to include periodic excavation of accumulated sediments. Table 5 gives elevation-capacity-outflow tables used in modeling the reservoirs.

Table 5

RESERVOIR CHARACTERISTICS

Structure	Elevation (ft. MSL)	Storage (ac. ft.) Sediment	Flood Control	Total	Outflow (cfs) Existing	Modified
New River Dam	1390	0	0	0	0	0
	1400	0	500	500	630	200
	1410	10	2000	2000	1300	630
	1420	1200	4800	6000	1690	1300
	1430	1700	10,000	11,700	2020	1690
	1440	2400	17,600	20,000	2280	2020
	1450	3700	29,300	33,000	2530	2280
	1460	4500	45,900	50,400	2720	2530
Adobe Dam	1340	0	0	0	0	
	1350	500	0	500	750	
	1360	1500	1800	3300	1300	
	1370	2300	7000	9300	1670	
	1380	2800	17,900	20,700	1950	

The modifications to New River Dam would cause the dam to release floodwaters more slowly, increasing downstream artificial recharge at the site by approximately 10-15 percent (from 4400 ac-ft/yr to 5000 ac-ft/yr for the New River). In addition, recharge in the natural channel would be increased by about 100 ac-ft/yr due to the longer duration of flows.

Assuming the planned construction of a new Waddell Dam by the USBR will include addition of 122,800 ac-ft of flood control and joint use storage and if the reservoir is operated to release floodwaters at levels favorable to the recharge site, approximately 5100 ac-ft/yr could be artificially recharged at the site from the Agua Fria River. This would require floodwater release durations of up to 25 days, not coincident with flows in the New River, and would require up to 85,000 ac-ft of storage. Such a release scenario would also increase natural channel recharge by as much as 12,600 ac-ft/yr.

Imported Floodwater--For this study it was assumed that flows from Cave Creek were discharged into the Arizona Canal and included in the discharge measurements by SRP for the Skunk Creek spillway. In the future, Cave Creek flows together with urban runoff will be conveyed to Skunk Creek via the Arizona Canal Diversion Channel (ACDC). However, for the purposes of this modeling effort it was assumed that flows into Skunk Creek would not change. It is anticipated that increased urban runoff collected by the ACDC will add to the amount of floodwater available for recharge at this site. Likewise, discharges from the Grand Canal into New River were assumed to remain unchanged. Refer to Figure 8 for locations of these features.

Recharge Facility Operations For Flood Flows--The facilities plan for the proposed recharge facility calls for four interconnected pond systems, A, B, C, and D (Figure 12). All four can be filled from flows in the New River. Ponds A and B can also utilize flows from Agua Fria River. Flows in the New River would first fill ponds D, then C, B, and A, in that order. Flows in the Agua Fria River would first fill A, then B.

All ponds are designed for an estimated steady-state infiltration rate of 1.5 cfs/ac and have an average water depth of 3 feet. During filling operations, a lower infiltration rate of 0.75 cfs/ac was estimated based on partially full conditions. The inlet canals and turnouts have been sized to allow filling within one day at 2.3 cfs/ac.

Estimates of Floodwater Recharge. Flood flows in the New River could be recharged at an average of 4400 ac-ft/yr, based on records from 1967-1981. If sediment storage in New

River Reservoir is utilized for regulation of flood flows, an additional 600 ac-ft/yr can be recharged at the recharge facility in addition to about 100 ac-ft/yr added channel recharge. A summary of the flood recharge potential for New River is shown on Table 6.

Flood flows in the Agua Fria River above the site are generally infrequent and intense under the present operation of Waddell Dam. Artificial recharge potential is negligible, in fact, high flows could be detrimental to the integrity of the facility. Planned construction of a new, larger Waddell Dam by the USBR as part of the Central Arizona Project will provide flood storage that, if operated favorably, could add up to 5100 ac-ft/yr recharge at the site. In addition, there is potential to add up to 12,600 ac-ft/yr of recharge in the natural channel upstream of the recharge facility by releasing flood flows more slowly. Releases would have to be limited to about 1700 cfs. All spills in the 14-year study period could be passed through Waddell Dam within 25 days at this rate, with the exception of the February 1980 flood, which was estimated to be a 50-year flood (USGS, June 1980). A summary of the flood recharge potential for Agua Fria River upstream from the site is is given in Table 7.

In summary, the recharge site could yield as estimated 4,400 ac-ft/yr on the average. Modifications to New River Dam could add 600 ac-ft/yr at the site and 100 ac-ft/yr in the natural channel. Favorable Waddell Dam operation could add up to 5,100 ac-ft/yr at the site and 12,600 ac-ft/yr in the natural channel. The most favorable conditions for both Agua Fria RIver and New River results in an estimated 10,100 ac-ft/yr of recharge at the site and 12,700 ac-ft/yr additional natural channel recharge.

Table 6
NEW RIVER FLOODWATER RECHARGE POTENTIAL
(all values are in ac-ft.)

	Existing New River Dam		Modified New River Dam		
Year	Site Recharge	Unused Flow	Site Recharge	Added Channel Recharge	Unused Flow
1967	7,300	8,100	8,800	200	6,400
1968	0	0	0	0	0
1969					
1970	3,800	2,700	4,500	200	1,900
1971	800	0	800	100	0
1972	1,600	0	1,600	0	0
1974					
1975					
1976	1,900	0	1,900	0	0
1977					
1978	22,000	26,300	25,300	600	22,500
1979	7,700	2,100	8,600	100	1,100
1980	16,600	16,700	18,600	300	14,400
1981					
Totals	61,700	55,900	70,100	1,500	46,300
Average Annually	4,400	4,000	5,000	100	3,300

Table 7

AGUA FRIA RIVER FLOODWATER RECHARGE POTENTIAL
FOR MODIFIED OPERATIONS AT NEW WADDELL DAM
(all values are in ac-ft.)

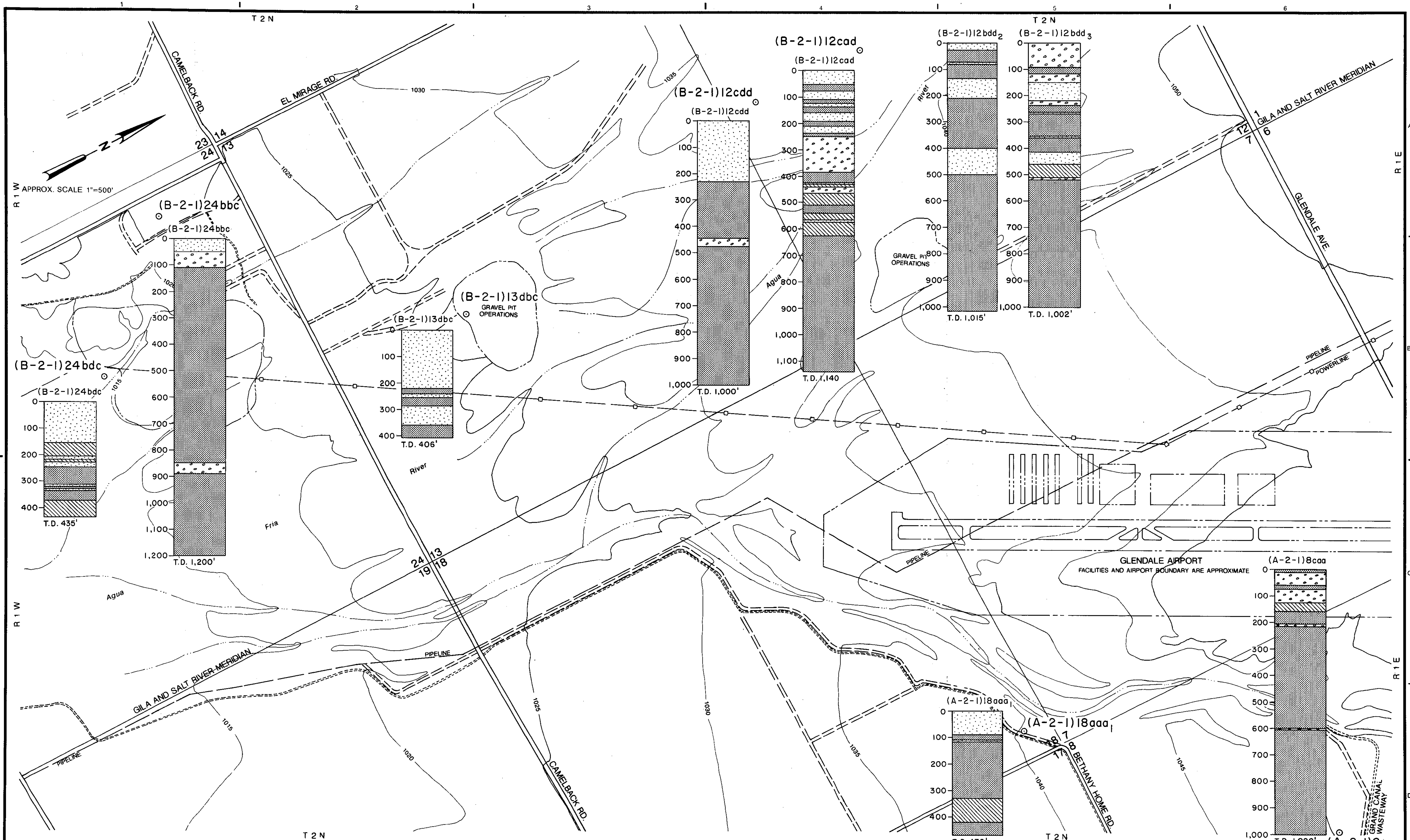
Year	Site Recharge	Added Channel Recharge	Unused FLow
1967	0	0	0
1968	1800	800	0
1969			
1970			
1971			
1972			
1974			
1975			
1976			
1977			
1978	21,300	34,200	0
1979	30,200	52,900	0
1980	18,100	89,000	98,700
Totals	71,400	176,900	98,700
Average Annually	5,100	12,600	7,100

SITE SUITABILITY

Hydrogeologic Conditions

The New River study area is shown on Figure 9. The New River vicinity is herein defined as the reach of New River from Skunk Creek to the Agua Fria River, including one mile of the Agua Fria River and about one mile on each side of New River. The New River vicinity includes the smaller New River study area.

Thickness of the Upper Alluvium unit in the New River vicinity ranges from 650 to 800 feet (U.S. Bureau of Reclamation, 1977). Depth to the basement complex in the New River vicinity is estimated to be more than 1,200 feet (Cooley,



CLAY, SANDY CLAY, CLAY WITH SAND, CLAY WITH GRAVEL, CLAY WITH CALICHE	SAND, CLAYEY SAND, SAND WITH GRAVEL, SANDSTONE
CALICHE, CEMENTED SAND, CEMENTED SAND AND GRAVEL, CEMENTED GRAVEL, CALICHE WITH CLAY	GRAVEL, GRAVEL WITH SAND, GRAVEL WITH BOULDERS, GRAVEL WITH CLAY, CONGLOMERATE

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FIGURE 9

AGUA FRIA/NEW RIVER RECHARGE SITE LITHOLOGIC DATA

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1973). Lithologic data for selected wells in the New River study area are summarized on Figure 9. Inspection of the lithologic data indicates that abundant fine-grained sediments including clay, sandy clay, and clay with gravel were penetrated during drilling operations.

Depth to groundwater level was measured in 1982 in 11 wells located in the New River vicinity and ranged from 117 to 278 feet below land surface (Reeter and Remick, 1986); average depth was about 170 feet. Of the 11 wells measured in the New River vicinity, five are located in the New River study area. Depth to groundwater level was measured in 1982 at these five wells and ranged from 117 to 156 feet below land surface (Reeter and Remick, 1986). Depth to groundwater level was measured in December 1984 and August 1985 at four wells in the New River study area and ranged from 115 and 291 feet below land surface (Arizona Department of Water Resources, 1987). Depth to groundwater level was measured in May and June 1987 at two wells in the New River study area and was 140 and 183 feet below land surface (Arizona Department of Water Resources, 1987).

Direction of groundwater in 1982 in the New River study area was from southeast to northwest. The Allied Landfill is a disposal site used for construction debris and is located at the intersection of Indian School Road and Agua Fria River, near the south boundary of the study area. Direction of groundwater movement is generally from the landfill to the northwest along the south boundary of the study area. Groundwater which is contaminated with volatile organic compounds has been detected in the West Maryvale area, located approximately one mile east of the study area. Groundwater movement is generally from the West Maryvale area toward the New River study area.

Reported pumping rates for wells located within the study area for years 1984 through 1987 range from about 1,419 to 2,693 gpm (Arizona Department of Water Resources, 1987). Transmissivity ranging from 20,000 to 60,000 gpd/ft has been assigned to the study area for electrical analog analysis of the Salt River Valley (Anderson, 1968). Transmissivity in the range from 5,000 to 110,000 gpd/ft and specific yield in the range from 10 to 12 percent was assigned for the Salt River Valley Cooperative Study Modeling Effort (Long, Niccoli, Hollander, and Watts, 1982).

Groundwater samples for laboratory chemical analyses were obtained in 1982 and 1983 from 10 wells located in the New River vicinity. Total dissolved solids for these samples was estimated from specific electrical conductance and ranged from about 260 to 1,030 mg/l (Reeter and Remick, 1986). Of the 10 wells sampled in the New River vicinity, four are located in the New River study area. Groundwater samples for laboratory chemical analyses were obtained in 1982 and 1983 from these four wells. Total dissolved solids for these samples was estimated from specific electrical conductance and ranged from about 380 to 900 mg/l (Reeter and Remick, 1986). Groundwater samples for laboratory chemical analyses were obtained in 1984 and 1987 from two wells located in the New River study area. Total dissolved solids for these samples was estimated from specific electrical conductance to be about 340 and 750 mg/l (Arizona Department of Water Resources, 1987).

Potential Groundwater Storage and Recovery Volumes

Comparison of altitude of groundwater level of 1952 and for 1984 indicates that average groundwater level decline for the New River study area is about 60 feet. Volumes of potential groundwater storage and potentially recoverable groundwater were computed using average specific yield of 10 percent, average specific retention of 25 percent, and average porosity of 35 percent for the sediments in the New River study area. Initial moisture content of 15 percent was assigned for the historic vadose zone. Initial moisture content equal to the specific retention of 25 percent was assigned to the 60 feet of the drained zone in the New River study area.

Total volume of potential groundwater storage in the drained zone and historic vadose zone is approximately 24 acre-feet of water per acre of surface area. For the 24 acre-feet of groundwater storage, 15 acre-feet would be recoverable groundwater and nine acre-feet would be "invested" groundwater required to bring the volumetric water content in the historic vadose zone from 15 percent to specific retention.

Assuming the long-term recharge rate at the site is limited only by surface infiltration rates, the estimated losses due to surface evaporation and "investment" in the vadose zone directly beneath the recharge basins would be about two percent for a project life of 20 years.

Soils

There are about 15 different soils classifications within the Agua Fria/New River study area. A majority of the soils are a sandy loam underlain by gravelly sand with variable sands and gravels in the active channel areas. A summary of SCS soils information classifications is shown on Table 8. A delineation of the different soils is contained on the soils classification map, Figure 10.

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FIGURE 10

AGUA FRIA/NEW RIVER RECHARGE SITE SOILS CLASSIFICATION MAP

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Table 8

AGUA FRIA/NEW RIVER RECHARGE SITE - SCS SOILS INFORMATION

MAP LEGEND	SOIL SERIES & MAP SYMBOLS	SCS DESCRIPTION OF INTAKE RATES	SOILS PROFILE: Depth from surface (inches)	SOILS PROFILE: Dominant USDA Texture	SCS Permeability Estimate (in/hr)
1a	Antho: AdB	Moderately rapid permeability	0-60	sandy loam or gravelly sandy loam	2.0-6.0
1b	Brios: Br, Bs	Rapid permeability	0-14 14-60	sandy loam sand & gravelly sand	2.0-6.0 6.0-20.0
1c	Carrizo: Cb	Rapid permeability	0-5 5-60	gravelly sandy loam very gravelly coarse sand	2.0-6.0 >20.0
1d	Coolidge: Cp	Moderately rapid permeability	0-24 24-60	sandy loam sandy loam	2.0-6.0 2.0-6.0
1e	Maripo: Ma	Moderately rapid permeability below a depth of 20 to 40 inches	0-34 34-60	sand loam gravelly sand	2.0-6.0 6.0-20.0
1f	Torripsamments: TD	Very rapid permeability		variable sands and gravels	
1g	Vint: Vg, Vk, Vh, Vr	Moderately rapid permeability	0-60	loamy fine sand	2.0-6.0
2a	Agault: Aa	Very rapid permeability below a depth of 20 to 40 inches	0-27 27-60	loam sand	0.6-2.0 >20.0
2b	Gilman: Ge, GgA	Moderate permeability	0-60	loam and very fine sandy loam	0.6-2.0
2c	Rillito: RpE	Moderate permeability	0-60	gravelly loam and sandy gravelly loam	0.6-2.0
3a	Avonda: An	Rapid permeability below a depth of 20 to 40 inches	0-13 13-27 27-60	clay loam loam loamy coarse sand	0.2-0.6 0.6-2.0 6.0-20
3b	Avondale: Ao	Moderate permeability	0-20 12-60	clay loam loam	0.2-0.6 0.6-2.0
3c	Cherioni: CO	Low permeability, less than 20 inches to bedrock	0-6 6-12	very gravelly loam silica-lime cemented hardpan bedrock	0.6-2.0
3d	Glenbar, Gt	Moderately slow permeability	0-60	clay loam and silty clay loam	0.2-0.6
CA	Calciorthids: CA	too variable to be estimated			

DATA SOURCE: SCS Soil Survey of Maricopa County, Arizona. September, 1977.

Land Ownership and Use

The land at this site is divided about one-third private ownership and the other two-thirds in public ownership. The private owners are anticipating that New Waddell Dam will reduce the chances of flooding and perhaps allow commercial development or expansion of sand and gravel operations. The public land is held by State Land, Bureau of Land Management, and City of Glendale. Presently the land is undeveloped consisting mostly of barren river channel deposits. Approximate property boundaries and ownerships are shown on the property ownership map, Figure 11.

CONCEPTUAL FACILITIES PLAN

Locating the recharge basins for this site plan was based primarily on using publicly owned lands, land with the best soils conditions, and the need to maintain close proximity to the active river channel for recharge of floodwaters. Major features of the Agua Fria/New River recharge site facilities plan are shown on Figure 12 and listed below:

Major Features

Inflatable Dam and Intake Structure (600 cfs)
Conveyance Channel (7600 ft.)
Interbasin & Drain Structures (9)
Diversion and Turnout Structures (3)
Monitor Wells (3)

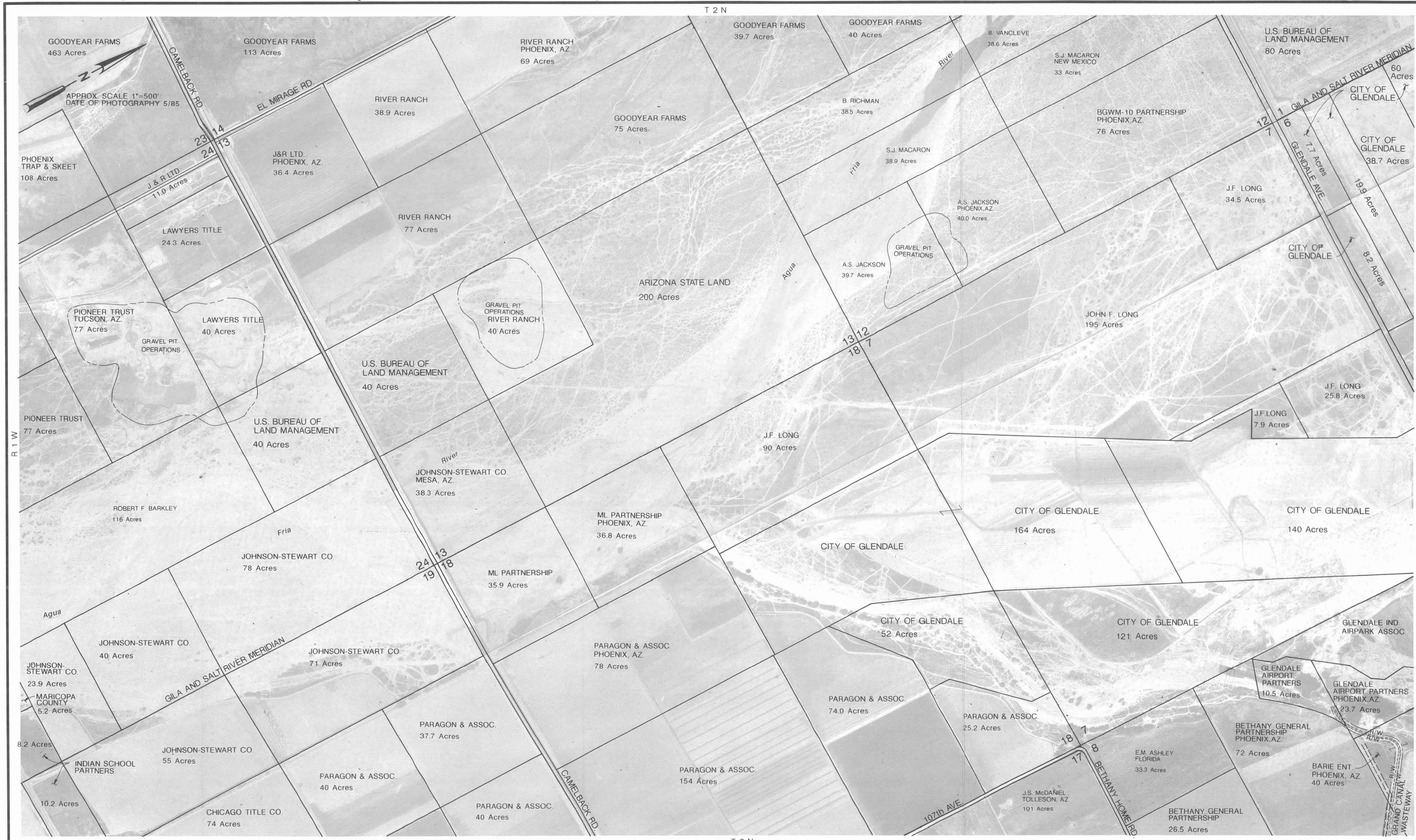

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FIGURE 11

AGUA FRIA/NEW RIVER RECHARGE SITE PROPERTY OWNERSHIP MAP

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Recharge Basins

Basin A -	163 acres,	2.0 fpd infiltration rate
Basin B -	73 acres,	2.0 fpd infiltration rate
Basin C -	31 acres,	2.0 fpd infiltration rate
Basin D -	52 acres,	2.0 fpd infiltration rate
TOTAL	318 acres,	2.0 fpd average rate

ESTIMATED ANNUAL RECHARGE RATE - 116,000 acre-feet/yr

An inflatable rubber dam used in New River is used to divert floodwaters and upstream releases of CAP water from the SRP Grand Canal. A conceptual drawing of the New River diversion dam and intake structure is shown on Figure 13. New River flows can be diverted to recharge basins in the Agua Fria River. New River has in-channel levees for recharge and the Agua Fria has both in-channel levees and off-channel basins. The off-channel basins would remain intact except during major floods. In-channel levees may need maintenance and repairs after moderate floods.

PROJECT COSTS

Estimated costs for capital improvements, land, and operations and maintenance are shown in Table 9. Costs for purchase of the recharge source water are not included.

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FIGURE 12

AGUA FRIA/NEW RIVER RECHARGE SITE CONCEPTUAL FACILITIES PLAN

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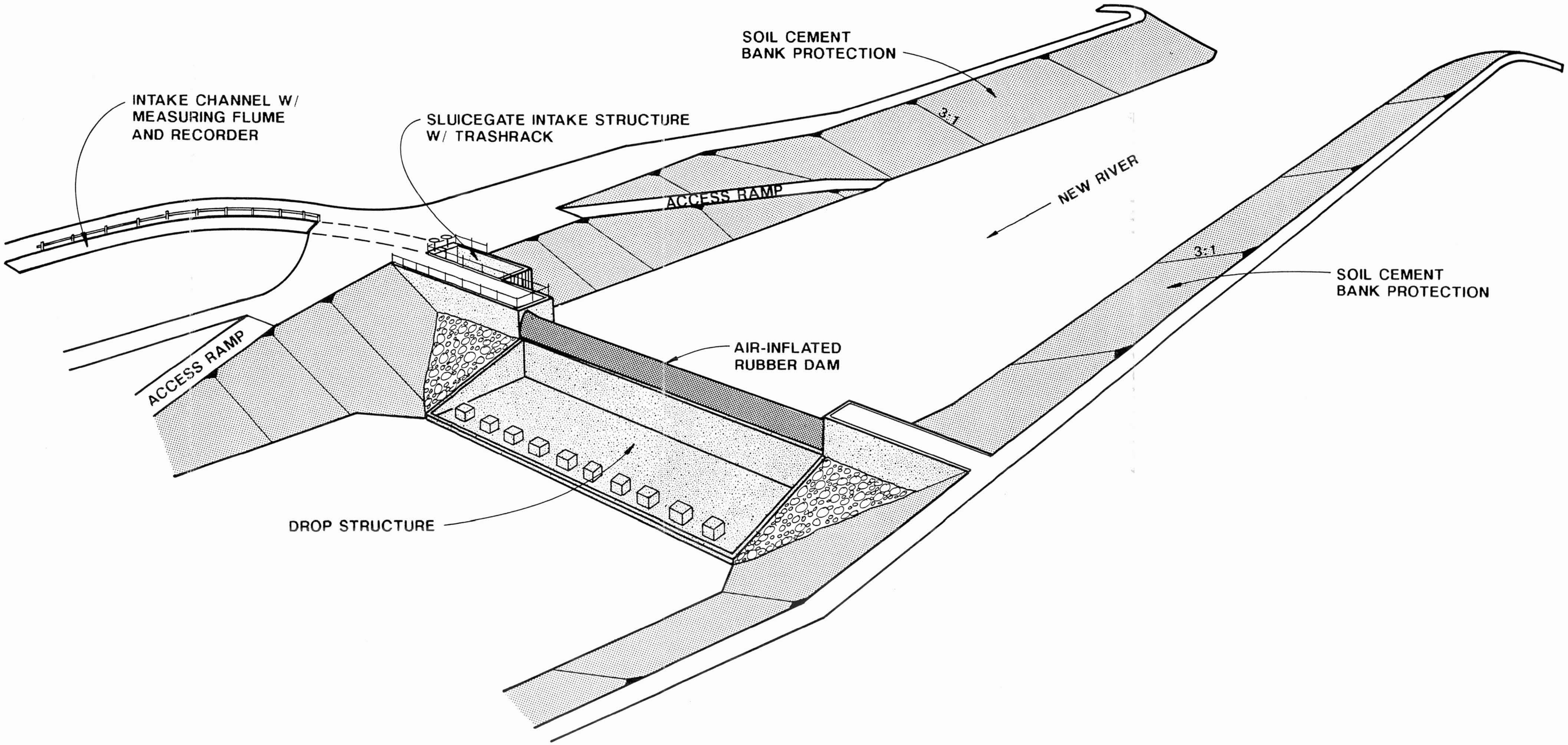

FIGURE 13
NEW RIVER
DIVERSION DAM
AND INTAKE STRUCTURE

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Table 9

PROJECT COSTS - AGUA FRIA/NEW RIVER RECHARGE PROJECT

ITEM	CONSTRUCTION COST
Earthwork for Levees & Channels	$336,000
Hydraulic Structures	$152,000
Pump Station	$998,000
Monitor Wells	$80,000
Subtotal	$1,566,000
Contingency (30%)	$470,000
Subtotal	$2,036,000
Engineering and Administration (15%)	$305,000
Construction Cost	$2,341,000
Land Purchase: 190 acres @ $15,000/ac.	$2,850,000
TOTAL PROJECT COST	$5,191,000
Annualized Project Cost (8% Revenue Bonds, 20 yr Maturity, 20% Initial Cost)	$634,000
Operation & Maintenance Cost (320 acres @ $1,000/ac.)	$320,000
Land Lease Cost: 400 acres @ $300/ac.	$120,000
Total Annual Cost	$1,074,000
Annual Cost Per Acre Foot, For 116,000 ac. ft./yr. Recharge	$9

QUEEN CREEK RECHARGE SITES

RECHARGE WATER SOURCES

The recharge water source for this site is CAP water. A turnout from the CAP aqueduct will deliver the water. The ability of the CAP aqueduct to carry the recharge flows is yet to be determined.

Floodwater availability at this site is low and has high potential for natural recharge. Gravel operations are extensive in the Queen Creek channel. For these reasons and economics, recharge of floodwaters is not a consideration for this site.

SITE SUITABILITY

Hydrogeologic Conditions

The Queen Creek study area is shown on Figure 14. The Queen Creek vicinity is herein defined as the reach of Queen Creek from Rittenhouse Road to the south boundary of Section 22, Township 2 South, Range 6 East, including about one mile on each side of Queen Creek. The Queen Creek vicinity also includes the smaller Queen Creek study area.

Thickness of the Upper Alluvium unit in the Queen Creek vicinity ranges from 200 to 300 feet and thickness of the Middle Alluvium unit ranges from 200 to 700 feet (Laney and Hahn, 1986). Depth to the basement complex in the Queen Creek vicinity is estimated to be more than 1,200 feet (Cooley, 1973). Lithologic data for selected wells in the Queen Creek study area are summarized on Figure 14. Inspection of the lithologic data indicates that isolated layers of sand and gravel and abundant fine-grained sediments were penetrated during drilling operations. Laney and Hahn (1986) estimated that in the Queen Creek vicinity, 80 percent or more of the Upper Alluvium unit, and 30 to 60 percent of the Middle Alluvium unit may consist of sand and gravel.

Depth to groundwater level was measured in 1982 at 16 wells located in the Queen Creek vicinity and ranged from 254 to 500 feet below land surface (Reeter and Remick, 1986); average depth was about 400 feet. Perched water in the west 1/4 of the Queen Creek vicinity is believed to be the cause for relatively shallow depth to water in this area. Of the 16 wells measured in the Queen Creek vicinity, seven are

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Legend

- CLAY, SANDY CLAY, CLAY WITH SAND, CLAY WITH GRAVEL, CLAY WITH CALICHE
- SAND, CLAYEY SAND, SAND WITH GRAVEL, SANDSTONE
- CALICHE, CEMENTED SAND, CEMENTED SAND AND GRAVEL, CEMENTED GRAVEL, CALICHE WITH CLAY
- GRAVEL, GRAVEL WITH SAND, GRAVEL WITH BOULDERS, GRAVEL WITH CLAY, CONGLOMERATE

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FIGURE 14

QUEEN CREEK RECHARGE SITE LITHOLOGIC DATA

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located in the Queen Creek study area. Depth to groundwater level was measured in 1982 at these seven wells and ranged from 436 to 500 feet below land surface (Reeter and Remick, 1986). Depth to groundwater level was measured in December 1984 at two wells in the Queen Creek study area and ranged from 433 and 450 feet below land surface (Arizona Department of Water Resources, 1987). Depth to groundwater level was measured in August 1987 at two wells in the Queen Creek study area and ranged from 485 and 590 feet below land surface (Arizona Department of Water Resources, 1987).

Direction of groundwater movement in 1982 in the Queen Creek study area was from northeast to southwest. Direction of groundwater flow is influenced by a cone of depression created by pumpage from wells along the northwest front of the Santan Mountains.

Reported pumping rates for wells located within the Queen Creek study area for years 1979 through 1987 range from about 985 to 2,130 gpm (Arizona Department of Water Resources, 1987). Transmissivity ranging from about 25,000 to 50,000 gpd/ft has been assigned to the Queen Creek study area for electrical analog analysis of the Salt River Valley (Anderson, 1968). Transmissivity in the range from 60,000 to 120,000 and specific yield in the range from eight to 12 percent were assigned to the Queen Creek study area for the Salt River Valley Cooperative Study Modeling Effort (Long, Niccoli, Hollander, and Watts, 1982).

Groundwater samples for laboratory chemical analyses were obtained in 1982 and 1983 from 13 wells located in the Queen Creek vicinity. Total dissolved solids from these samples was estimated from specific electrical conductance and ranged from about 370 to 2,080 mg/l (Reeter and Remick, 1986). Kister (1974) estimated total dissolved solids to range from 500 to 1,000 mg/l for groundwater samples in the

Queen Creek vicinity, and less than 500 mg/l for groundwater samples in the Queen Creek study area. Of the 13 wells samples in the Queen Creek vicinity, one is located in the Queen Creek study area. Groundwater samples for laboratory chemical analyses were obtained in 1982 from this well. Total dissolved solids for the sample was estimated from specific electrical conductance to be about 440 mg/l (Reeter and Remick, 1986). Groundwater samples for laboratory chemical analyses were obtained in 1985 and 1987 from six wells located in the Queen Creek study area. Total dissolved solids for these samples was estimated from specific electrical conductance and ranged from about 360 to 500 mg/l (Arizona Department of Water Resources, 1987).

Potential Groundwater Storage and Recovery Volumes

Review of existing water level data from 1947 to 1952 and for 1984 indicates that average groundwater level decline for the Queen Creek study area is about 250 feet. Volumes of potential groundwater storage and potentially recoverable groundwater were computed using average specific yield of 10 percent, average specific retention of 28 percent, and average porosity of 38 percent for the sediments in the Queen Creek study area. Initial moisture content of 10 percent was assigned for the historic vadose zone. Initial moisture content equal to the specific retention of 28 percent was assigned to the 200 feet of the drained zone in the Queen Creek study area.

Total volume of potential groundwater storage in the drained zone and historic vadose zone is approximately 90 acre-feet of water per acre of surface area. For the 90 acre-feet of groundwater storage, 45 acre-feet would be recoverable groundwater and 45 acre-feet would be "invested" groundwater required to bring the volumetric water content in the historic vadose zone from 10 percent to specific retention.

Table 10

QUEEN CREEK RECHARGE SITE - SCS SOILS INFORMATION

MAP LEGEND	SOIL SERIES & MAP SYMBOLS	SCS DESCRIPTION OF INTAKE RATES	SOILS PROFILE		SCS Permea-bility Estimate (in/hr)
			Depth from surface (inches)	Dominant USDA Texture	
1a	Alluvial land: Am	Moderate to very rapid permeability	0-60	variable	0.6-20.0
1b	Carrizo: Ca, Cb	Very rapid permeability	0-15 15-70	fine sandy loam (Cb) gravelly loamy sand (Ca) very gravelly sand	2.0-6.0 >20.0
1c	Vint: Vf	Moderately rapid permeability	0-60	loamy fine sand	2.0-6.0
2a	Agualt: Af	Very rapid permeability below depth of 20 to 40 inches	0-26 26-60	loam & very fine sandy loam sand	0.6-2.0 2.0-20.0
2b	Gilman: Gf, Gm	Moderate permeability	0-60	loam, fine sandy loam in places	0.6-2.0

DATA SOURCE: SCS Soil Survey of Eastern Maricopa and Northern Pima Counties Area, Arizona. November, 1974.

Assuming the long-term recharge rate at the site is limited only by surface infiltration rates, the estimated losses due to surface evaporation and "investment" in the vadose zone directly beneath the recharge basins would be about seven percent for a project life of 20 years.

Soils

There are 5 different soils classifications within the Queen Creek study area. A majority of the soils are deep loam and fine sandy loam with some areas underlain by a gravelly sand. A summary of SCS soils information together with a map legend for the different soils classifications is shown on Table 10. A delineation of the different soils is contained on the soils classification map, Figure 15.

Land Ownership and Use

Arizona State Land owns the lands within one-half mile of the CAP aqueduct on the west side. Lands further west are all privately owned. Lands within the Queen Creek channel are being actively mined for sand and gravel. Other lands are presently being farmed, but much of the land appears to be owned by investor groups for land speculations. Approximate property boundaries and ownerships are shown on the property ownership map, Figure 16.

CONCEPTUAL FACILITIES PLAN

Recharge basins were located in two principal areas. The largest area is State owned lands adjacent to the CAP aqueduct which are about half undeveloped land and half active farmland. The smaller area is a block of private land located off-channel about one mile downstream on the

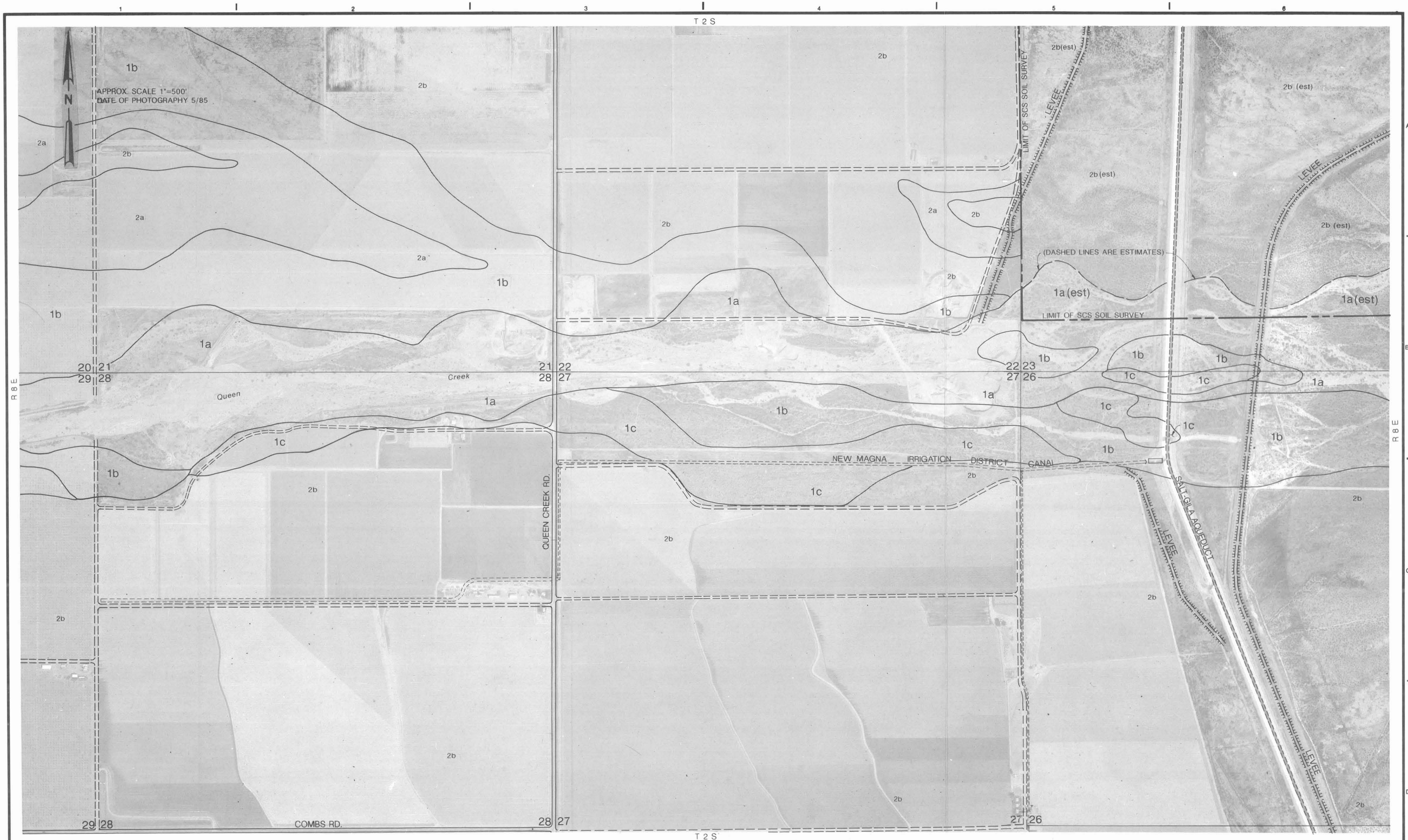

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FIGURE 15

QUEEN CREEK RECHARGE SITE SOILS CLASSIFICATION MAP

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FIGURE 16

QUEEN CREEK RECHARGE SITE PROPERTY OWNERSHIP MAP

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northside. This recharge basin site has the best soils conditions for off-channel lands in the study area.

Elevations of the lands adjacent to the aqueduct are about 10 feet above the water level in the CAP aqueduct, therefore pumping is required. The aqueduct turnout includes a pump station for the adjacent lands and a gravity turnout into the creek channel for conveyance to the downstream basins. The downstream basins are served by a diversion in the creek channel and a conveyance channel with check structures and turnouts to serve individual pairs of basins.

Major features of the Queen Creek recharge site facilities plan are shown on Figure 17 and listed below:

<u>Major Features</u>

- Canal turnout & Pump Station (250 cfs, 20 ft. lift)
- Conveyance Pipelines (600 ft., 60-inch dia.)
- Conveyance Channels (7,200 ft.lined, 5,800 ft. unlined)
- Interbasin & Drain Structures (19)
- Other Hydraulic Structures (9)
- Monitor Wells (6)

Recharge Basins

Basin A -	227 acres, 1.3 fpd infiltration rate
Basin B -	120 acres, 0.8 fpd infiltration rate
Basin C -	95 acres, 1.3 fpd infiltration rate
Basin D -	116 acres, 0.8 fpd infiltration rate
Basin E -	144 acres, 0.8 fpd infiltration rate
TOTAL	702 acres, 1.0 fpd average rate

ESTIMATED ANNUAL RECHARGE RATE - 128,000 acre-feet/yr

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FIGURE 17

QUEEN CREEK RECHARGE SITE CONCEPTUAL FACILITIES PLAN

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PROJECT COSTS

Estimated costs for capital improvements, land, power, and operations and maintenance are shown in Table 11. Costs for purchase of the recharge source water are not included in these costs.

Table 11

PROJECT COSTS - QUEEN CREEK RECHARGE PROJECT

ITEM	CONSTRUCTION COST
Earthwork for Levees and Channels	$1,015,000
Hydraulic Structures	$234,000
Pump Station	$1,437,000
Monitor Wells	$300,000
Subtotal	$2,986,000
Contingency (30%)	$896,000
Subtotal	$3,882,000
Engineering and Administration (15%)	$582,000
Construction Cost	$4,464,000
Land Purchase: 230 acres @ $15,000/ac.	$3,450,000
Total Project Cost	$7,914,000
Annualized Project Cost (8% Revenue Bonds, 20 yr Maturity, 20% Initial Cost)	$967,000
Operation & Maintenance Cost: 702 acres @ $500/ac.	$351,000
Pumping Cost (800 HP Maximum Demand, 4,125,000 kwhr/yr)	$221,000
Land Lease Cost: 600 acres @ $300/ac.	$180,000
Total Annual Cost	$1,719,000
Annual Cost Per Acre Foot, for 128,000 ac.ft/yr. Recharge	$13

ADDITIONAL DATA REQUIREMENTS

This section presents a rough outline of work tasks needed to fill data gaps or provide additional information to determine recharge project feasibility. The Conceptual facilities plans and cost estimates presented in this memorandum have been prepared using readily available data. In many instances data are sketchy or unavailable, therefore, certain assumptions or tentative criteria have been used which are critical items in project performance and overall feasibility. The data requirements described below are those needed to reduce uncertainties and provide the basis for a preliminary final design effort.

DATA NEEDS COMMON TO ALL SITES

Certain data requirements are common to all three sites. The general categories for these tasks include: Hydrogeology, Soils, and Infiltration Rates, and Land Ownership and Mapping.

Hydrogeology

Additional data required to assess the hydrogeological conditions of the project sites include a detailed well inventory, construction of monitor wells, analyses of lithology of the aquifer and vadose zone, estimation of aquifer parameters, and water quality testing for groundwater and recharge source water.

Well Inventory. An inventory of existing wells within three miles of the project site should be conducted. Information required for each well should include: state well number, ownership, date completed, depth drilled, casing diameter and depth, perforated interval, depth to water level, pumping rate, lithologic or drillers log, and use of water pumped from the well.

Monitor Well Construction. Monitor wells are needed to determine aquifer and vadose zone lithology, estimate aquifer parameters, measure groundwater levels, and to collect groundwater samples for laboratory chemical testing. These wells are typically 4- or 6-inches in diameter and are drilled 100 feet or more below the water table. Well construction, borehole geophysical logging, pumping test operations, and groundwater sampling should be supervised by a hydrogeologist onsite.

Lithology. Drill cuttings samples and borehole geophysical logs should be obtained during construction of monitor wells and analyzed for lithology. These samples and logs would be the basis for refined descriptions of the lithology of the aquifer and vadose zone, and for assessing the occurrence of poorly permeable layers which would impede downward flow of water. Such layers would not only impede free drainage in the vadose zone, but may also cause mounding. If perched groundwater mounds rise to land surface, the long-term infiltration rate will be diminished.

Drill cuttings should also be analyzed for the presence of potential pollutants in the vadose zone. Residual contaminants residing in the vadose zone could be leached into the groundwater during recharge. Potential contaminants could include nitrates, sulfates, and trace organic chemicals resulting from pesticide or herbicide applications.

Aquifer Parameters. Drill cores for selected intervals should be obtained during construction of the monitor wells. The cores should be submitted to testing laboratories for analysis for permeability and moisture content in order to more accurately determine long-term recharge rates and potential groundwater storage and recovery volumes.
Short-term single borehole pumping tests should be conducted at each newly constructed monitor well. The data collected from the pumping test should be analyzed to make estimates of aquifer parameters.

Groundwater Mounding Analysis. An important assumption made during this investigation that has far-reaching implications is that recharge rates are governed solely by surface infiltration rates. This may not be the case for long-term operations. Recharge from basins will result in a groundwater mound directly below the basins. The shape of this mound is a function of recharge rates and volumes, transmissivity, porosity, depth to groundwater, presence of impeding layers, etc. Reliable assessment of the "recharge mound" requires good hydrogeologic data obtained from onsite drilling and aquifer tests. Experience has shown that a three-dimensional groundwater model is the most reliable analytical tool for predicting groundwater level response to recharge activities. This is particularly true when the aquifer is anisotropic (differing horizontal and vertical permeabilities), as commonly occurs in alluvial aquifer materials similar to those found at the proposed recharge sites.

Evaluation of the recharge mound is important from an economic viewpoint. Groundwater modeling and recharge mounding analysis may reveal that recharge rates and volumes need to be reduced below the values estimated for this investigation. In other words subsurface conditions, not surface infiltration rates, are determined to be the controlling factor. As a result, cost per acre-foot recharged may increase and site storage potential will be reduced for a given period of recharge.

Water Quality Testing. Groundwater samples from existing wells near the project site, newly constructed monitor wells, and potential recharge source water should be obtained for laboratory chemical analyses. All samples should be tested for the routine constituents listed in Table 2 and selected samples analyzed for certain trace organic and inorganic constituents.

It is recommended that groundwater data be collected for at least one year prior to recharge to establish baseline conditions. To establish baseline water level and water quality conditions, groundwater samples should be obtained from the monitor wells and submitted for laboratory chemical analyses for routine constituents at three-month intervals prior to startup of recharge activities. Groundwater samples should be obtained and submitted for laboratory chemical analyses for trace constituents at one-year intervals. Water levels in the monitor wells should be measured at three-month intervals.

Soils and Infiltration Rates

Long-term infiltration rates are a critical item in determining recharge performance and project feasibility. Onsite soils work needed to characterize project site soils include test pits, soil borings, and infiltration testing.

Laboratory analyses of soil samples include textural analysis (including the clay fraction), chemical constituents testing, and fragmented hydraulic conductivity testing.

Test pits are excavated 8 to 10 feet deep with a backhoe for inspection of the soil profile. Soils borings are performed 4 to 6 feet deep with a hand auger or a truck-mounted auger. Onsite infiltration testing should be performed with double ring infiltrometers and/or small test pits (about 20 feet square). Long-term tests (5 days minimum) are required to assess infiltration rates for recharge purposes. The most reliable results are obtained if, the potential recharge source water is used during infiltration testing. The number of test pits, soil borings, and infiltration testing locations required to characterize soils conditions at the project site will vary depending on the areal extent of the recharge basins, the variability of site soils, and the quality of the recharge source water.

Another concern relative to soils are possible soils/aquifer materials and recharge water geochemical interactions that can inhibit infiltration rates over time. Specific geochemical analyses are not recommended at this stage of site investigations, but need to be considered following the completion of soil sampling and testing recommended above.

Under certain conditions, geochemical interactions that result in expansion of clays, formation of clays, or precipitation of minerals can significantly reduce infiltration rates.

Land Ownership and Previous Uses

Additional research of lands required for construction of recharge facilities needs to be performed. A title search to identify current owners, existing easements and rights-of-way, and any encumbrances or other conditions that would affect the proposed projects is required. In some cases owners should be contacted and the possibilities for lease or purchase of the needed properties explored. The need for new easements and rights-of-way also requires attention. The compatibility of the proposed projects with current zoning regulations and future planning goals needs to be determined.

Research of previous land use and cultural practices is needed to assess the potential of finding contaminants residing in the vadose zone. Waste disposal, chemical spills, and applications of herbicides or pesticides are potential sources of residual contaminants.

Site Mapping

The existing USGS topography used for this investigation is not adequate for additional planning or design efforts. New aerial photography and topographic mapping with 2 foot contours is required. Land surveys to set ground control is required for the aerial photography.

ADDITIONAL SITE SPECIFIC TASKS

In addition to the common tasks for additional data collection described above, each recharge project site has its own particular needs.

McMicken Dam Recharge Site

The capacity of the Beardsley Canal to carry CAP water to the project site needs to be evaluated. Available carrying capacity less irrigation deliveries needs to be determined on a monthly basis. The impacts of deliveries made to other potential recharge projects upstream also needs to be evaluated. The Maricopa Water District is conducting field surveys of the canal to determine the hydraulic capacity.

An alternative for delivering CAP water to the site is to release the recharge water into Trilby Wash which crosses the aqueduct about 9 miles to the northwest. The flows could be diverted out of the wash downstream and conveyed to a regulating reservoir constructed near the site. The flows could then be fed through a pipeline by gravity under the dam to the recharge site. An analysis using detailed topographic data, a study of the hydrologic impacts, and an evaluation of the impacts on the stability of McMicken Dam would be required.

Agua Fria/New River Recharge Site

An investigation of the potential for groundwater contamination from the Allied Landfill south of the sites needs to be investigated. An investigation of the contaminated groundwater in the West Maryvale area should be conducted to determine the source of the contamination and the potential for contaminating the recharge water. These investigations will require the collection and analysis of groundwater quality and water level data.

An investigation of the potential for lateral migration of recharge water from recharge basin A into the adjacent gravel pit located in the southeast quarter of Section 13, Township 2 North, Range 1 West should be conducted. This investigation should include 50- to 100-foot test borings at locations in recharge basin A and in the vicinity of the gravel pit.

Construction of the recharge facility within the floodplain of the Agua Fria River will have an impact on flood elevations upstream. Further studies are required to determine the magnitude of flood events (i.e., 50-year, 100-year) at the site, and the water surface profiles through the site, both before and after development. At that time the question of whether the flood benefits of the upstream reservoirs could be used to offset the impacts of the site should be resolved. Also of importance is the ability of the structures to withstand overtopping. It may be desirable to locate planned breach sections (fuse plugs) within some of the dikes to protect more valuable project components. The optimum design for levee configurations and sizing which result in the least impact on floodwater elevations should also be determined.

The existing Waddell Dam has about 152,000 acre-feet of storage space. A new Waddell Dam will be completed in 1995 by the United State Bureau of Reclamation (USBR) as part of the CAP. Preliminary plans indicate that the new dam will provide an additional 750,000 acre-feet of controllable storage which includes 45,700 acre-feet of operational flood storage and 77,100 acre-feet of joint use storage. The Army Corps of Engineers (COE) is conducting a comprehensive study of the hydrologic impacts of the dam enlargement which will be completed in late 1988. The COE study will examine the frequency of releases for the new dam and determine the flood control benefits. The fate of additional runoff water conserved by the new dam is uncertain. Maricopa Water District currently takes delivery of only a small portion of their 188,000 acre-feet/year water right from Agua Fria River. The potential for releasing waters behind Waddell Dam for recharge at the project site needs to be investigated. Of greatest concern are the potential impacts of these relases on low flow crossings and gravel pit operations upstream from the site.

Modifying the outlet structures on New River Dam and Adobe Dam to detain floodwaters within the sediment storage pool for enhancement of recharge operations downstream needs more investigation. There are uncertainties associated with the outlet modifications and the impacts on flood storage, sedimentation, and structural integrity of the dam.

Queen Creek Recharge Site

The ability of the CAP aqueduct to carry and deliver flows required for recharge at the project site at all times of the year needs investigation. Capacity of the aqueduct to carry future deliveries including recharge demands for each month needs to be evaluated.

The New Magma Irrigation District (NMID) has a CAP turnout and pump station adjacent to the location for the proposed turnout and pump station for recharge. The NMID pump station makes deliveries to irrigated farmland where recharge basins are proposed. The feasibility of using capacity in the NMID turnout, pump station, and conveyance system for recharge purposes needs to be investigated.

COSTS TO COLLECT ADDITIONAL DATA

Order of magnitude for collecting additional data have been prepared. Estimates for professional services and costs for construction/field work have been shown separated on Tables 12, 13, and 14.

Table 12
ESTIMATES OF COSTS TO COLLECT ADDITIONAL DATA FOR McMICKEN DAM RECHARGE SITE

RECOMMENDATION	WORK ITEM	COST ESTIMATE
Well Inventory	Professional Services	$6,000
Monitor Well Construction & Aquifer Testing (3 wells)	Well Construction	$125,000
	Professional Services	$18,000
Water Quality Testing & Monitoring	Laboratory Services	$8,000
	Professional Services	$15,000
Soils/Aquifer Geochemical Interactions Analysis	Laboratory & Professional Services	Unknown
Onsite Soils Investigation	Field Services	$4,000
	Laboratory Services	$3,000
	Professional Services	$11,000
Groundwater Model & Mounding Analysis	Professional Services	Unknown
Site Mapping	Survey & Aerial Mapping	$6,000
Land Ownership & Previous Uses	Professional Services	$3,000
Determine Capacity of Beardsley Canal to Carry Recharge Flows	Professional Services	$3,000
Evaluate Trilby Wash Alternative	Professional Services	$25,000

Table 13
ESTIMATES OF COSTS TO COLLECT ADDITIONAL DATA
FOR AGUA FRIA/NEW RIVER RECHARGE SITE

RECOMMENDATION	WORK ITEM	COST ESTIMATE
Well Inventory	Professional Services	$6,000
Monitor Well Construction & Aquifer Testing (3 wells)	Well Construction	$65,000
	Professional Services	$15,000
Water Quality Testing & Monitoring	Laboratory Services	$8,000
	Professional Services	$15,000
Groundwater Model & Mounding Analysis	Professional Services	Unknown
Onsite Soils Investigation	Field Services	$4,000
	Laboratory Services	$2,000
	Professional Services	$9,000
Soils/Aquifer Geochemical Interactions Analysis	Laboratory & Professional Services	Unknown
Site Mapping	Survey & Aerial Mapping	$13,000
Land Ownership & Previous Uses	Professional Services	$5,000
Initial Groundwater Contamination Investigation	Professional Services	$10,000
Floodplain Impacts Evaluation	Professional Services	Unknown
New Waddell Dam Impacts on Recharge	COE is conducting a hydrologic study regarding releases downstream.	Unknown
Investigate Modifications to Outlets on Upstream Dam	COE would need to be involved in a feasibility study.	Unknown

Table 14
ESTIMATES OF COSTS TO COLLECT ADDITIONAL DATA
FOR QUEEN CREEK RECHARGE SITE

RECOMMENDATION	WORK ITEM	COST ESTIMATE
Well Inventory	Professional Services	$6,000
Monitor Well Construction & Aquifer Testing (6 wells)	Well Construction	$270,000
	Professional Services	$30,000
Water Quality Testing & Monitoring	Laboratory Services	$8,000
	Professional Services	$15,000
Groundwater Model & Mounding Analysis	Professional Services	Unknown
Onsite Soils Investigation	Field Services	$4,000
	Laboratory Services	$3,000
	Professional Services	$14,000
Soils/Aquifer Geochemical Interactions Analysis	Laboratory & Professional Services	Unknown
Site Mapping	Survey & Aerial Mapping	$10,000
Land Ownership & Previous Uses	Professional Services	$8,000
Determine Capacity of CAP Aqueduct to Carry Recharge Flows	Professional Services	$3,000
Investigate Use of New Magma Irrigation District Facilities to Carry Recharge Flows	Professional Services	$5,000

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