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NUECES RIVER BASIN
REGIONAL WATER SUPPLY PLANNING STUDY
PHASE III - RECHARGE ENHANCEMENT

FINAL REPORT

Prepared for

Nueces River Authority
Edwards Underground Water District
City of Corpus Christi
South Texas Water Authority
Texas Water Development Board

by

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and
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for
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Regional Water Supply Planning Study
Phase III

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NUECES RIVER BASIN
REGIONAL WATER SUPPLY PLANNING STUDY
PHASE III- RECHARGE ENHANCEMENT

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1. Study Background and Objectives

The study area consists primarily of the Nueces River Basin, which covers an area of approximately 17,000 square miles in South Texas. Several entities interested in the potential effects and costs of developing additional recharge enhancement structures, along with the Texas Water Development Board (TWDB), have jointly participated in the performance of this study. These four entities are:

Nueces River Authority (Authority);
Edwards Underground Water District (EUWD);
City of Corpus Christi; and
South Texas Water Authority (STWA).

Over the past several decades, increasing water demands on the Edwards Aquifer have raised concerns about the ability of the aquifer to meet these demands without causing social, economic, and environmental problems. The headwaters of the Nueces River Basin contribute about 57% of the total volume of surface water recharged to the San Antonio portion of the Edwards Aquifer. Streams crossing the Edwards Aquifer recharge zone lose a significant portion of their flow through faults and solution cavities in the limestone formations. A large portion of the runoff from the headwater area, however, occurs during storms which exceed the natural recharge capability of the recharge zone. In this Phase III of the Nueces River Basin Regional Water Supply Planning Study, the 19 recharge enhancement reservoirs identified during Phase I have been evaluated with respect to cost and environmental concerns.

2. Description of Recharge Reservoirs

Two types of recharge reservoirs were analyzed based on hydrologic conditions for the 56-year period of record from 1934 through 1989. Type 1 reservoirs are catch-and-release structures and Type 2 are immediate recharge structures. Type 1 structures are located upstream of the recharge zone and are operated to release water at the maximum recharge rate of the downstream channel. Type 2 structures are located within the recharge zone. Water in the Type 2 structures recharges directly from the bottom of the reservoir and the entire volume is drained, usually within a period of less than one month. (The exception to this is the Indian Creek site located on the Nueces River, which may take from several months to more than a year to drain.) Figure 2.1-1 in Section 2 of this report illustrates the operation of both types of structures. The location of each of the recharge projects investigated is shown in Figure 2.1-2 in Section 2 of this report.

3. Basis for Recharge Volumes and Project Costs

In order to optimize the cost of a recharge program (i.e., get the most water for each dollar spent on the program), the 10%, 25%, 50%, and 100% (maximum) conservation capacities as determined in Phase I were analyzed for each site with respect to recharge amounts and costs. Conservation capacity is defined to be the volume of water which can be stored below the lowest uncontrolled reservoir outlet. Recharge volumes were calculated for each site using the Nueces River Basin Model developed during Phase I with some additional refinements to more accurately simulate the performance of smaller structures. Recharge enhancement volumes were calculated subject to average and drought conditions. Average conditions represent the average annual recharge rate for the entire 56-year period (1934-1989) analyzed. Drought conditions represent the average annual recharge rate for the 10-year period from 1947 through 1956 which is when the most severe drought of record occurred.

Cost estimates were prepared on the basis of 1991 construction, road relocation, land, and environmental mitigation costs, and estimated annual operation and maintenance costs. Construction cost estimates include 20% for contingencies. Engineering, legal, financial, and miscellaneous costs were assumed to total 20% of related capital costs. Annual debt service requirements were based on 25-year financing and a 7.5% interest rate. For projects impacting the water rights of the Choke Canyon/Lake Corpus Christi System (CC/LCC System), an estimated annual cost for purchase of these impacts was also included.

4. Summary of Recharge Enhancement Programs Investigated

A total of 19 recharge enhancement projects were investigated in this study including seven Type 1 projects, seven Type 2 projects on major rivers and streams, and five Type 2 projects on tributary streams. Optimal unit costs for each of the Type 2 Tributary projects proved to be substantially higher than unit costs for the Type 1 and Type 2 Mainstem projects. Collection and evaluation of daily precipitation and runoff data for the tributary subwatersheds, however, would result in improved estimates of recharge enhancement and potentially reduce the estimated unit costs for the Type 2 Tributary projects presented in this report.

Analyses of all recharge enhancement projects were performed for two different water rights scenarios. The first set of analyses was performed honoring all existing water rights (except for several small rights located downstream of Lake Corpus Christi) to the maximum extent possible within the analytical limitations of a monthly model. Under this scenario, inflows are released from the recharge reservoirs in months during which the reservoirs would have caused additional downstream shortages. Full mitigation of downstream shortages was not entirely possible within the model due, in part, to the monthly rather than daily simulation of recharge rates. A second set of analyses was performed in which, like the first scenario, additional water rights shortages were met by the release of water with one exception. This exception involved the water rights of the CC/LCC System in which case impacts were not mitigated by releases, but were assumed to be purchased.

In actual practice, under either water rights scenario, downstream water availability and operational flexibility for permittees having limited, or no storage rights will likely be improved by the implementation of recharge enhancement projects. This will occur as a result of water rights mitigation releases from the recharge projects being made at controlled rates over more extended periods than a natural storm hydrograph. In many instances, this will provide owners of irrigation rights the opportunity to divert water from the river for a period of days or even weeks after the storm flows would normally have passed.

Table ES-1 presents a ranking of all Type 1 and Type 2 Mainstem projects evaluated

TABLE ES-1
Recharge Enhancement Project Rankings

Honoring All Water Rights				Average Conditions	
Rank	**Project**	**Type**	**Optimal Percentage Capacity**	**Recharge Enhancement (acft/yr)**	**Annual Cost / Unit Recharge Enhancement**
1	Upper Sabinal	1	10	10,080	$163
2	Upper Verde	1	25	3,990	$210
3	Lower Sabinal	2	10	2,290	$211
4	Concan	1	10	8,190	$217
5	Upper Dry Frio	1	10	5,840	$221
6	Montell	1	10	26,370	$240
7	Upper Hondo	1	10	4,700	$248
8	Lower Frio	2	10	2,470	$271
9	Upper Seco	1	50	3,410	$335
10	Indian Creek	1/2	25	14,650	$357
11	Lower Verde	2	10	920	$410
12	Lower Hondo	2	10	1,280	$453
13	Lower Dry Frio	2	25	1,760	$498
14	Lower Seco	2	10	1,050	$567
With Purchase of Water Rights				**Average Conditions**	
Rank	**Project**	**Type**	**Optimal Percentage Capacity**	**Recharge Enhancement (acft/yr)**	**Annual Cost / Unit Recharge Enhancement**
1	Lower Sabinal	2	10	7,720	$66
2	Lower Frio	2	10	5,940	$114
3	Lower Verde	2	10	3,150	$134
4	Upper Sabinal	1	10	11,240	$146
5	Lower Hondo	2	10	3,930	$150
6	Upper Verde	1	25	4,540	$185
7	Concan	1	10	8,740	$204
8	Montell	1	10	32,090	$207
9	Indian Creek	1/2	25	26,500	$213
10	Lower Dry Frio	2	25	4,090	$216
11	Upper Dry Frio	1	10	5,840	$221
12	Lower Seco	2	10	2,520	$238
13	Upper Hondo	1	10	4,700	$248
14	Upper Seco	1	50	3,660	$313

in this study at optimal percentage capacity based on minimum annual cost per unit of recharge enhancement. Values in Table ES-1 are for average conditions subject to each of the two water rights scenarios. When honoring all water rights, Table ES-1 shows that a program of Type 1 projects would minimize the unit costs of developing the recharge enhancement potential of each subwatershed. The results of analyses of the Type 1 projects honoring all water rights are presented in Section 5 of this Executive Summary. The results of analyses of Type 1 projects with purchase of water rights in the CC/LCC System are not presented in this Executive Summary because the unit costs under this scenario are greater than for Type 2 projects.

Assuming the purchase of water rights in the CC/LCC System, Table ES-1 shows that a program of Type 2 projects with the marginal exception of the Montell Project would minimize the unit costs of developing the recharge enhancement potential of each subwatershed. The results of analyses of the Type 2 projects assuming the purchase of water rights in the CC/LCC System are presented in Section 6 of this Executive Summary. The results of analyses of Type 2 projects honoring all water rights are not presented in this Executive Summary because the unit costs under this scenario are greater than for Type 1 projects.

5. Summary of Type 1 Programs Honoring All Water Rights

Results of the analyses performed for the Type 1 projects for two sets of conservation capacities are presented in Table ES-2 and the following subsections. The two conservation capacities presented are the 100% capacity and the optimum capacity (with respect to minimum unit cost) selected from the four capacities analyzed at each site.

TABLE ES-2
Summary of Recharge Enhancement Programs-Type 1 Reservoirs

					Average Conditions		Drought Conditions			
Rank*	**Project**	**Percent Capacity**	**Capacity (acft)**	**Surface Area (ac)**	**Recharge Enhancement (acft/yr)**	**Cost/Unit Recharge Enhancement ($/acft/yr)**	**Recharge Enhancement (acft/yr)**	**Cost/Unit Recharge Enhancement ($/acft/yr)**	**Reduction in Median Estuarine Inflow (acft/yr)**	**Reduction in CC/LCC System Yield (acft/yr)**
100% Conservation Capacity										
1	Upper Dry Frio	100	60,000	1,800	9,420	$330	2,900	$1,072	0	0
2	Upper Verde	100	23,000	880	4,600	$339	1,390	$1,120	0	120
3	Upper Sabinal	100	93,300	3,110	14,670	$357	2,520	$2,078	0	30
4	Upper Hondo	100	47,000	2,000	8,360	$361	1,140	$2,647	0	0
5	Montell	100	252,300	6,190	34,200	$381	9,200	$1,415	2,460	440
6	Upper Seco	100	23,000	900	3,820	$398	290	$5,246	0	0
7	Concan	100	149,000	3,840	12,210	$486	3,085	$1,925	0	0
	Total		647,600	18,720	87,280		20,525		2,460	590
	Weighted Average					$383		$1,627		
Optimum Conservation Capacity										
1	Upper Sabinal	10	9,330	550	10,080	$163	2,520	$650	0	30
2	Upper Verde	25	5,750	350	3,990	$210	1,390	$603	0	120
3	Concan	10	14,900	710	8,190	$217	3,085	$577	0	0
4	Upper Dry Frio	10	6,000	440	5,840	$221	2,630	$491	0	0
5	Montell	10	25,230	1,460	26,370	$240	9,200	$688	2,460	440
6	Upper Hondo	10	4,700	350	4,700	$248	1,140	$1,024	0	0
7	Upper Seco	50	11,500	600	3,410	$335	290	$3,944	0	0
	Total		77,410	4,460	62,580		20,255		2,460	590
	Weighted Average					$227		$700		

*Rank is based on Cost/Unit Recharge Enhancement for Average Conditions.

100% Conservation Capacity

If all Type 1 projects are constructed at the maximum (100%) capacity, average annual recharge in the Nueces River Basin can be increased by 87,280 ac-ft per year (27%) and during the 10-year drought by 20,525 ac-ft per year (13%). These recharge volumes represent the maximum attainable recharge for the Type 1 structures. The unit cost of water under this program is $383 per ac-ft per year based on the average climatic conditions and $1,627 per ac-ft per year based on the 10-year drought period from 1947 to 1956. Total reservoir storage is 647,600 acre-feet and total capital costs for this program are in excess of $345,000,000. Under this program, the median inflow to the Nueces Estuary is reduced by 2,460 ac-ft per year (1%) and the yield of the CC/LCC System is reduced by 590 ac-ft per year (0.3%).

Optimum Conservation Capacity

If the Type 1 projects are downsized to provide the optimum unit cost of water at each site (based on the additional average annual recharge), average annual recharge in the Nueces River Basin is increased by 62,580 ac-ft per year (19%) and drought recharge is increased by 20,255 ac-ft per year (13%). The unit cost of water under this program is $227 per ac-ft per year based on average climatic conditions and $700 per ac-ft per year based on drought conditions. Although average annual recharge enhancement under this program decreases by 28% from the 100% Conservation Capacity Program, capital cost decreases by 60%. Under this program, total reservoir storage is 77,410 acre-feet and total capital costs are approximately $138,800,000. The median inflow to the Nueces Estuary is reduced by 2,460 ac-ft per year (1%) and the 1990 yield of the CC/LCC System is reduced by 590 ac-ft per year (0.3%).

6. Summary of Type 2 Programs with Purchase of Water Rights in CC/LCC System

Results of the analyses performed for the Type 2 projects for two sets of conservation capacities are presented in Table ES-3 and the following sub-sections. The two conservation capacities presented are the 100% capacity and the optimum capacity selected from the four capacities analyzed at each site.

100% Conservation Capacity

If all Type 2 projects are constructed at the maximum (100%) capacity, recharge in the Nueces River Basin can be enhanced by 96,210 ac-ft per year (30%) on the average and by 25,790 ac-ft per year (17%) during the 10-year drought. These recharge volumes represent the maximum recharge attainable with the Type 2 structures. The unit cost of water under this program is $260 per ac-ft per year based on average climatic conditions and $969 per ac-ft per year based on the 10-year drought period from 1947 to 1956. Total reservoir storage is 380,950 acre-feet and total capital costs for this program are approximately $247,600,000. The median inflow to the Nueces Estuary is reduced by 5,250 ac-ft per year (2.2%) and the 1990 yield of the CC/LCC System is reduced by 2,230 ac-ft per year (1%).

Optimum Conservation Capacity

If the Type 2 projects are downsized to provide the optimum unit cost of water at each site (based on the additional average annual recharge), average annual recharge in the

TABLE ES-3
Summary of Recharge Enhancement Programs-Type 2 Reservoirs

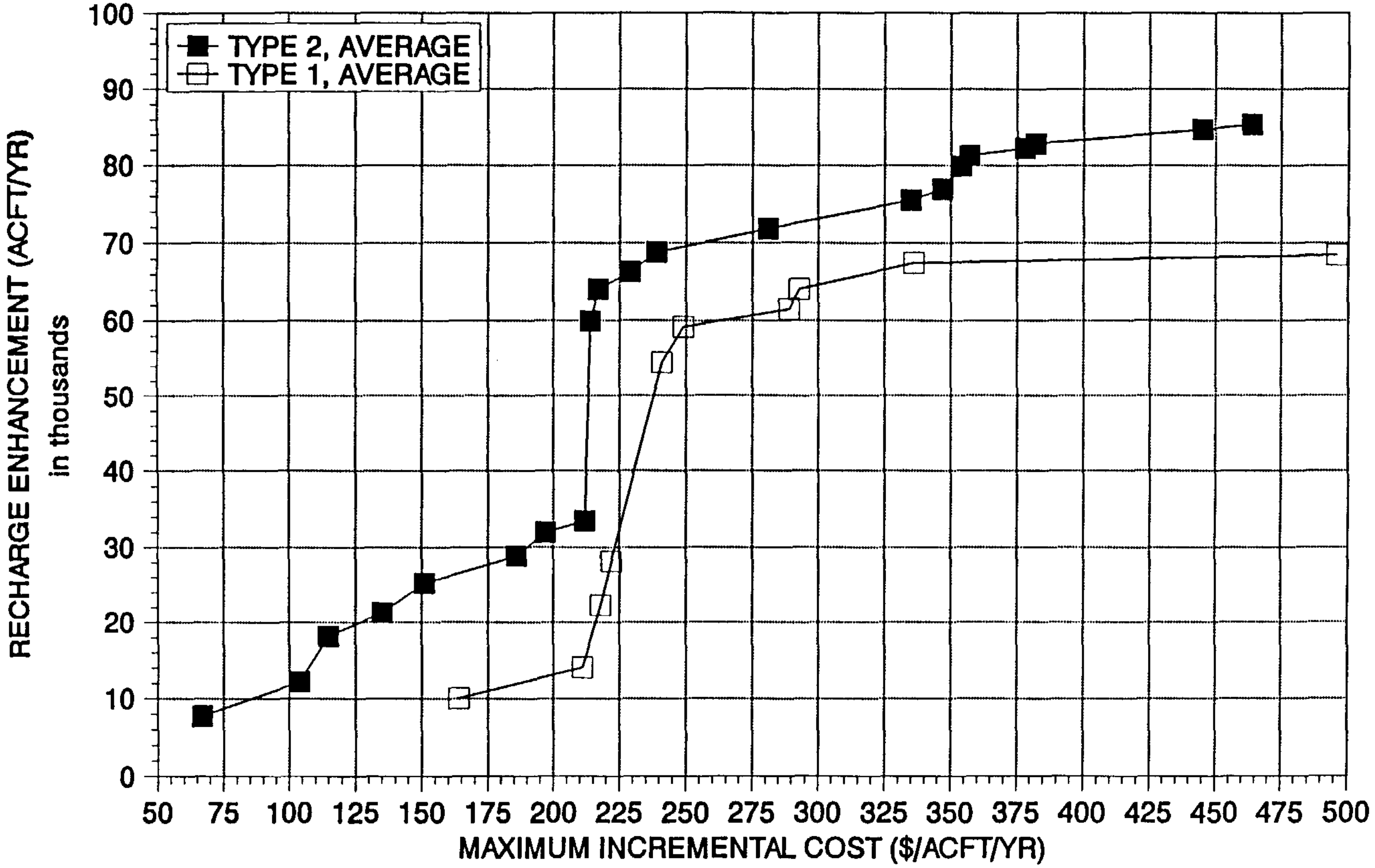
					Average Conditions		Drought Conditions			
Rank*	Project	Percent Capacity	Capacity (acft)	Surface Area (ac)	Recharge Enhancement (acft/yr)	Cost/Unit Recharge Enhancement ($/acft/yr)	Recharge Enhancement (acft/yr)	Cost/Unit Recharge Enhancement ($/acft/yr)	Reduction in Median Estuarine Inflow (acft/yr)	Reduction in CC/LCC System Yield (acft/yr)
100% Conservation Capacity										
1	Lower Sabinal	100	35,000	1,430	18,400	$145	2,770	$965	0	30
2	Lower Verde	100	24,000	1,730	6,220	$215	1,980	$676	0	120
3	Lower Hondo	100	28,000	1,260	9,420	$255	1,190	$2,021	0	0
4	Lower Frio	100	50,000	1,760	14,400	$267	3,180	$1,211	0	0
5	Indian Creek	100	165,000	7,650	34,500	$267	14,600	$630	5,250	2,080
6	Lower Dry Frio	100	30,000	1,190	6,170	$306	1,360	$1,387	0	0
7	Lower Seco	100	28,000	1,630	5,240	$422	290	$7,632	0	0
8	Elm Creek	100	6,940	370	670	$463	120	$2,584	0	0
9	Little Blanco	100	2,930	210	390	$662	100	$2,583	0	0
10	Quihi Creek	100	1,570	120	150	$811	30	$4,057	0	0
11	Leona River	100	2,930	220	280	$911	60	$4,253	0	0
12	Blanco	100	6,580	260	370	$1,318	110	$4,434	0	0
	Total		380,950	17,830	96,210		25,790		5,250	2,230
	Weighted Average					$260		$969		
Optimum Conservation Capacity										
1	Lower Sabinal	10	3,500	280	7,720	$66	2,300	$221	0	30
2	Lower Frio	10	5,000	340	5,940	$114	2,020	$337	0	0
3	Lower Verde	10	2,400	230	3,150	$134	1,380	$306	0	120
4	Lower Hondo	10	2,800	230	3,930	$150	1,190	$494	0	0
5	Indian Creek	25	41,250	2,770	26,500	$213	12,920	$437	4,970	1,500
6	Lower Dry Frio	25	7,500	420	4,090	$216	1,360	$650	0	0
7	Lower Seco	10	2,800	220	2,520	$238	290	$2,069	0	0
8	Elm Creek	100	6,940	370	670	$463	120	$2,584	0	0
9	Little Blanco	100	2,930	210	390	$662	100	$2,583	0	0
10	Quihi Creek	100	1,570	120	150	$811	30	$4,057	0	0
11	Leona River	100	2,930	220	280	$911	60	$4,253	0	0
12	Blanco	100	6,580	260	370	$1,318	110	$4,434	0	0
	Total		86,200	5,670	55,710		21,880		4,970	1,650
	Weighted Average					$193		$492		

*Rank is based on Cost/Unit Recharge Enhancement for Average Conditions.

Nueces River Basin is increased by 55,710 ac-ft per year (17%) and drought recharge is increased by 21,880 ac-ft per year (14%). The unit cost of water under this program is $193 per ac-ft per year based on average climatic conditions and $492 per ac-ft per year based on drought conditions. Although average annual recharge enhancement under this program decreases by 42% from the 100% Conservation Capacity Program, capital cost decreases by 61%. Under this program, total reservoir storage is 86,200 acre-feet and total capital costs are approximately $97,000,000. The median inflow to the Nueces Estuary is reduced by 4,970 ac-ft per year (2.1%) and the yield of the CC/LCC System is reduced by 1,650 ac-ft per year (0.8%).

7.0 Consideration of Type 1 and Type 2 Programs

The preceding two sections of the Executive Summary present Type 1 and Type 2 recharge enhancement programs with all sites evaluated at both 100% and the optimal percentage of maximum conservation capacity. In order to select the most appropriate program, the relative merits of various groups of projects need to be considered with respect to incremental annual unit cost of recharge enhancement under average conditions. Figure ES-1 presents potential recharge enhancement versus maximum incremental cost for a range of Type 1 and Type 2 programs subject to average and drought conditions. Each point in this figure represents a specific program comprised of individual projects at conservation capacities equal to or greater than the optimal capacity. The leftmost point of each curve in the figure represents the single project of a given type having the least unit cost at its optimal capacity subject to average climatic conditions. Each point, moving to the right along the curve, represents the addition of a project or upsizing of the same project to the



MAXIMUM INCREMENTAL COST BASED ON
AVERAGE CLIMATIC CONDITIONS.
SEE APPENDICES C AND D.

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INCREMENTAL COST SUMMARY OF RECHARGE ENHANCEMENT PROGRAMS

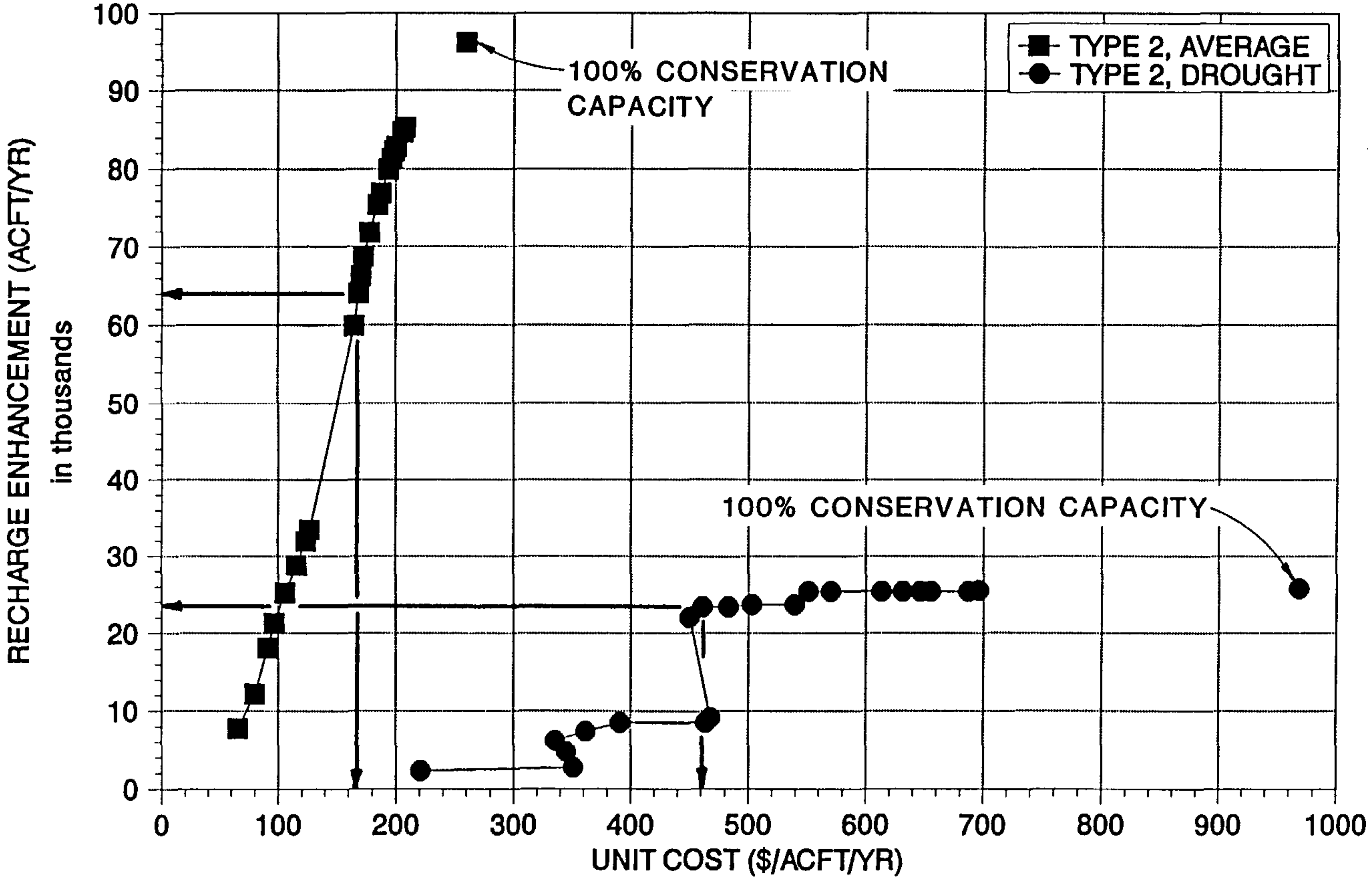
FIGURE ES-1

would be reduced by less than 1%, while the frequency of zero flows (which presently occur about 40% of the time) would be unaffected. Preliminary analyses show that implementation of either Type 1 or Type 2 Programs would reduce total recharge of the Carrizo-Wilcox Aquifer by less than 1% based on review of a Texas Water Development Board study of the Carrizo Aquifer in the Winter Garden Area (Ref. 15).

Review of the Type 2 Programs presented in Figure ES-1 and Appendix D reveals a significant breakpoint in recharge enhancement at a maximum incremental cost of approximately $217 per ac-ft per year. At this breakpoint, the program is comprised of all Type 2 Mainstem projects evaluated with the exception of the Lower Seco Project.

8.0 Example Type 2 Program

As an illustration of how the information developed in this study can be used to formulate a program for development of recharge enhancement projects, Figure ES-2 presents the same group of Type 2 programs shown in Figure ES-1 with respect to unit cost of recharge enhancement under both average and drought conditions, and Table ES-4 presents an Example Type 2 Program. This Example Program includes only the Type 2 reservoirs which provide additional recharge at an incremental unit cost of less than $217 per acre-foot per year. The six projects (and corresponding conservation capacities) which meet this criteria are (from west to east) Indian Creek (25%), Lower Dry Frio (25%), Lower Frio (25%), Lower Sabinal (50%), Lower Hondo (10%), and Lower Verde (25%). As indicated by the arrows in Figure ES-2, average annual recharge in the Nueces River Basin is increased by 64,030 ac-ft per year (20%) and drought recharge is increased by 23,390 ac-ft per year (15%) under this program. The unit cost of water under this Example



ARROWS INDICATE EXAMPLE TYPE 2 PROGRAM.
SEE APPENDIX D.

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UNIT COST SUMMARY OF TYPE 2 RECHARGE ENHANCEMENT PROGRAMS

FIGURE ES-2

TABLE ES-4
Example Type 2 Recharge Enhancement Program

					Average Conditions		Drought Conditions			
Rank*	**Project**	**Percent Capacity**	**Capacity (acft)**	**Surface Area (ac)**	**Recharge Enhancement (acft/yr)**	**Cost/Unit Recharge Enhancement ($/acft/yr)**	**Recharge Enhancement (acft/yr)**	**Cost/Unit Recharge Enhancement ($/acft/yr)**	**Reduction in Median Estuarine Inflow (acft/yr)**	**Reduction in CC/LCC System Yield (acft/yr)**
Example Type 2 Program**										
1	Lower Sabinal	50	17,500	960	15,350	$104	2,770	$575	0	30
2	Lower Frio	25	12,500	820	9,530	$141	3,180	$424	0	0
3	Lower Hondo	10	2,800	230	3,930	$150	1,190	$494	0	0
4	Lower Verde	25	6,000	500	4,630	$159	1,970	$373	0	120
5	Indian Creek	25	41,250	2,770	26,500	$213	12,920	$437	4,970	1500
6	Lower Dry Frio	25	7,500	420	4,090	$216	1,360	$650	0	0
	Total		87,550	5,700	64,030		23,390		4,970	1650
	Average					$169		$461		

*Rank is based on Cost/Unit Recharge Enhancement for Average Conditions.
**Program includes projects with a Cost/Unit Recharge Enhancement for Average Conditions less than $217/acft/yr ($0.67/1,000 gallons).

$169 per ac-ft per year based on the average annual increase in recharge and $461 per ac-ft per year based on drought conditions. It is apparent in Figure ES-2 that little additional recharge enhancement could be obtained under drought conditions by development of projects larger than those comprising the Example Program.

Although average annual recharge under the Example Program is 33% less than that for the 100% Conservation Capacity Program, capital cost decreases by 61%. Total reservoir storage is 87,550 acre-feet and total capital costs are approximately $97,100,000. The median inflow to the Nueces Estuary is reduced by 4,970 ac-ft per year (2.1%) and the 1990 yield of the CC/LCC System is reduced by 1,650 ac-ft per year (0.8%). It is estimated that the total storage capacity under the Example Type 2 Program would be reduced by about 8% after 50 years of sediment accumulation based on a study by the Texas Department of Water Resources (Ref. 13). Direct percolation rates from the projects will, over time, be reduced by sediment accumulation. However, analysis of this reduction at the existing Parker Creek recharge reservoir shows that, after 17 years of operation, the recharge rate is still more than adequate to drain the reservoir within a month.

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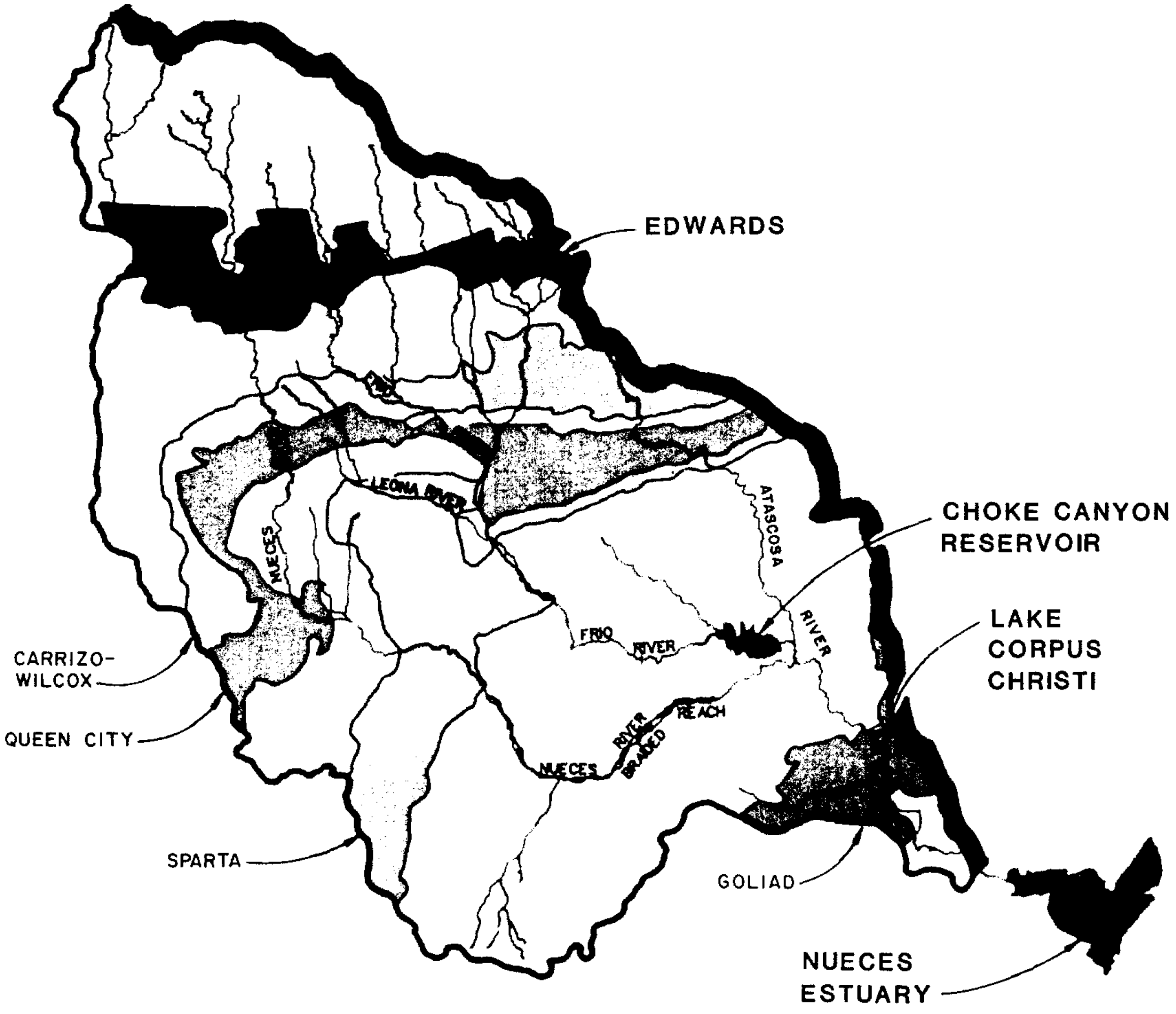
1.0 INTRODUCTION

The Nueces River Basin encompasses almost 17,000 square miles extending from the headwaters on the Edwards Plateau north of Uvalde through the Rio Grande Plains and Gulf Coast Prairies to the outlet at Nueces Bay near Corpus Christi. As is apparent in Figure 1.0-1, the Nueces River Basin is crossed by five major aquifer recharge zones including the Edwards, Carrizo-Wilcox, Queen City, Sparta, and Goliad. The most transmissive of these zones is the Edwards limestone aquifer recharge zone which lies at the base of the Balcones Escarpment in the headwaters of the Nueces and Frio Rivers. Approximately 20% of the Basin lies upstream of or atop the Edwards Aquifer recharge zone. The Edwards Aquifer is the sole source of water supply for the City of San Antonio as well as numerous agricultural interests throughout Uvalde and Medina Counties. The aquifer also feeds Leona, Comal, and San Marcos Springs, creating unique environments and recreational opportunities while providing base flow to the Leona, Guadalupe, and San Marcos Rivers.

The economic and ecologic dependence of the areas served by the Edwards Aquifer has prompted a series of studies with the objectives of evaluating the potential for artificial enhancement of aquifer recharge as well as the potential impacts of such enhancement to other interests in the Nueces River Basin. The Edwards Underground Water District, Nueces River Authority, Texas Water Development Board, City of Corpus Christi, and South Texas Water Authority have sponsored a multi-phase Regional Water Supply Planning



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RIVER BASIN MAP
WITH AQUIFER
RECHARGE ZONES

FIGURE 1.0-1

Study to accomplish these objectives. Phase I of the Study (Ref. 9) showed that potential exists for significantly enhancing recharge to the Edwards Aquifer through the development of medium to large size recharge dams. Phase I studies also quantified the maximum potential impacts of these dams on water availability to the City of Corpus Christi and the Nueces Estuary. Results of the Phase I studies were calculated without direct consideration of cost or environmental concerns. Phase II studies did not consider recharge enhancement projects, but addressed the reliability of the CC/LCC System subject to various operational and estuarine inflow constraints.

The primary objective of this phase (Phase III) of the Regional Water Supply Planning Study was to generally optimize the size of each previously identified recharge project on the basis of recharge enhancement, capital and annual costs, and potentially significant environmental impacts. The following sections of this report summarize the methodologies and site-specific considerations involved in accomplishing this objective. Section 2 details the methodologies applied in optimizing project development at the various sites including physical constraints, recharge enhancement honoring water rights, and project cost calculation. An evaluation of optimal development based on the unique characteristics of each individual recharge enhancement project is presented in Section 3. Environmental impacts and potential mitigation requirements are discussed in a report prepared by Paul Price Associates, Inc. included herein as Appendix A. Finally, Section 4 presents conclusions and recommendations concerning recharge enhancement and includes typical project development schedules for small and large projects.

2.0 RECHARGE PROJECT EVALUATION METHODOLOGY

A total of 19 potential recharge enhancement projects were identified in the first phase of the Regional Water Supply Planning Study of the Nueces River Basin. The maximum potential recharge enhancement and downstream impacts were evaluated in the Phase I studies by assuming a maximum reasonable storage or conservation capacity at each site without consideration of optimal site or basin development and environmental concerns. The project evaluation methodologies applied in this study were selected in an effort to maximize recharge enhancement while minimizing project costs and impacts on the environment and downstream water rights. Annual project cost per unit of recharge enhancement was computed in this study for four storage capacities at each site including 10%, 25%, 50%, and 100% of the maximum conservation capacity considered in Phase I.

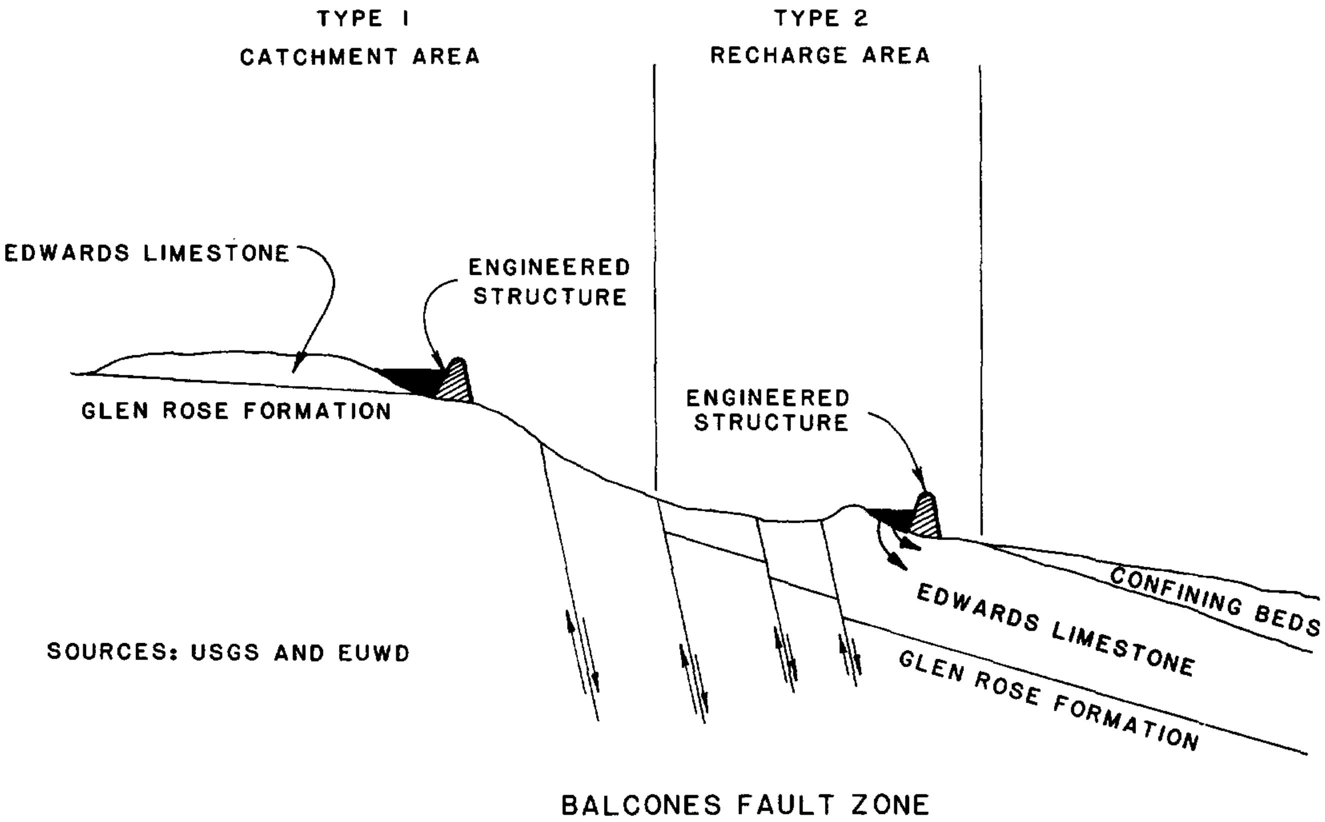
Optimum site development is defined to be the site capacity studied at which annual cost per unit recharge enhancement is minimized. Optimal basin development is defined to be the group of recharge enhancement projects by which basin-wide cost per unit recharge is minimized. In order to achieve optimal basin development, however, a specific project may be sized in excess of the "optimal" site capacity because the incremental unit cost of recharge at capacities in excess of the optimum for that project may be substantially less than the minimum unit cost for another project. The following sections summarize the physical considerations and the methodologies applied to estimate recharge enhancement potential and the related costs of dam, spillway, and outlet works construction, road relocations, land acquisition, water rights, environmental mitigation, permitting, and engineering.

2.1 Physical Considerations

2.1.1 Project Type

Recharge enhancement projects considered in this study are of two general types as indicated in Figure 2.1-1. Type 1 or "catch and release" projects are typically located immediately upstream of the recharge zone in order to maximize controlled drainage area. These structures impound both flood flows and base flows in excess of the estimated recharge capacity of the stream reach crossing the recharge zone. During months in which inflows are less than the downstream recharge capacity, releases equivalent to the downstream recharge capacity are made from storage. Hence, Type 1 recharge projects may maintain storage contents for periods of months and even years. For this reason, net evaporation losses from Type 1 reservoirs are accounted for in the calculation of recharge enhancement.

Type 2 or "direct percolation" recharge enhancement projects are typically located near the downstream boundary of the recharge zone in order to maximize both controlled drainage area and the opportunity for natural recharge as streamflows traverse the recharge zone. Continuous base flows across the recharge zone are virtually nonexistent; therefore, Type 2 structures typically impound only flood flows. Impounded flows percolate directly into the aquifer through the bottom of the reservoir at a rate accelerated by the driving head of reservoir storage. Detailed analyses of percolation rates observed at the existing project on Parker Creek indicate adequate capacity to recharge stored waters up to the assumed maximum site capacity, generally within one month. Evaporation losses were, therefore, assumed negligible for Type 2 projects and not accounted for in the calculation of recharge enhancement.



SOURCES: USGS AND EUWD

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TYPES OF RECHARGE ENHANCEMENT PROJECTS

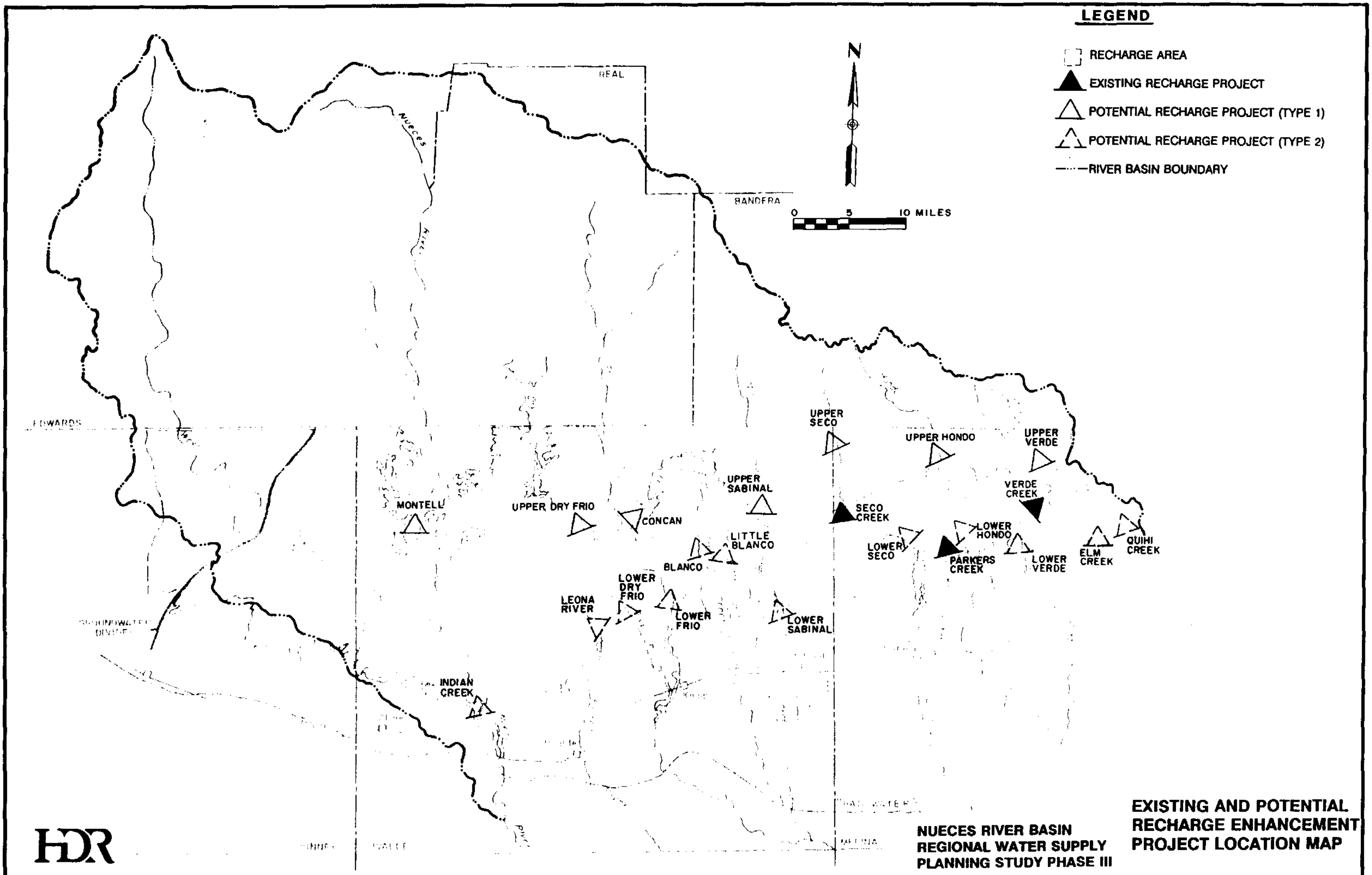
FIGURE 2.1-1

2.1.2 Site Selection

The locations of potential recharge enhancement projects evaluated in this study are presented in Figure 2.1-2 along with three existing recharge projects developed by the EUWD. The site selection criteria applied to Type 1 and Type 2 projects are summarized in the following paragraphs.

Of the seven Type 1 reservoir projects evaluated, six sites were identified during previous studies (Refs. 3 and 17). The Upper Verde Project was the only new Type 1 structure identified in Phase I of this study. Generally, the location of each of the Type 1 dams represents the first site upstream of the recharge zone which has suitable topography to impound a large volume of water and, to the extent possible, minimize relocations. For the purposes of this study, it was assumed that the geology of each site was suitable for construction of a large dam and reservoir. This assumption should be verified by field investigations and testing prior to any of these projects being considered for construction.

With the exception of the Indian Creek Project, each of the twelve Type 2 projects was identified during Phase I of this study. The Indian Creek Project was identified in a previous study performed for the Nueces River Authority (Ref. 6). Generally, the location of each Type 2 dam was selected to be as close as possible to the downstream limit of the recharge zone considering suitable topography for a large storage reservoir, minimization of relocations, and avoiding identified faults at the immediate dam site (Refs. 1 and 2). Site geology was assumed to be satisfactory for the construction of a dam and reservoir, although field investigations and testing will be required prior to any of these projects being considered for construction.



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EXISTING AND POTENTIAL RECHARGE ENHANCEMENT PROJECT LOCATION MAP

FIGURE 2.1-2

2.1.3 Basic Physical Data Development

Once site selection was accomplished for both the Type 1 and Type 2 projects, the basic physical data necessary to evaluate recharge enhancement potential and project cost was developed for each site. The relationship between water surface elevation, surface area, and storage capacity (E-A-C) was established using a polar planimeter to measure surface area from successive elevation contours on available topographic maps. These measurements were performed using 7.5-minute quadrangle topographic maps at a scale of 1 inch to 2,000 feet prepared by the U.S. Geological Survey. Storage volume calculations were generally performed using the average end area method. The E-A-C relationship was particularly important in establishing normal pool elevations for comparison with known sites of archaeological significance and in accurately estimating depletions of storage due to net evaporation at Type 1 sites. A centerline profile or valley cross section was also obtained from the topographic mapping in order to estimate dam construction quantities.

2.2 Recharge Enhancement Potential

2.2.1 Nueces River Basin Models

The recharge enhancement potential at each project site was calculated using the Nueces River Basin Model which was developed as a portion of Phase I of this Regional Water Supply Planning Study. Capabilities of the basin model include calculation of Edwards Aquifer recharge subject to the implementation of recharge projects operating under various upstream and downstream water rights constraints. The Lower Nueces Basin and Estuary Model (NUBEST) developed under separate contract with the Nueces River Authority and the City of Corpus Christi was used to quantify the impacts of recharge projects on the firm yield and storage of the Choke Canyon Reservoir / Lake Corpus Christi (CC/LCC) System and inflows to the Nueces Estuary.

The two models were used in tandem to determine the recharge enhancement under average and drought conditions, reductions in CC/LCC System yield and median storage, and reductions in average estuarine inflow resulting from the implementation of each potential project. Each of these parameters was computed assuming percentages of maximum conservation capacity for each recharge enhancement project of 10%, 25%, 50%, and 100%. Average conditions are based on the 56-year (1934 through 1989) historical period, while drought conditions are based on the 10-year (1947 through 1956) historical period. All simulations of CC/LCC System operations in this study are based on Phase IV of the City of Corpus Christi reservoir system operation plan and do not reflect as yet undetermined monthly estuarine inflow requirements and operational constraints being considered by the Texas Water Commission.

2.2.2 Water Rights Considerations

Potential recharge enhancement for each site at the four percentages of maximum storage or conservation capacity was computed subject to two water rights scenarios. Under both scenarios, all upstream and downstream water rights excluding those associated with the CC/LCC System were honored to the extent which they could have been without any additional recharge enhancement projects. Under the first scenario, inflows are passed through the recharge structures in order to fully honor the storage and diversion rights (up to the firm yield) associated with the CC/LCC system to the extent possible. In other words, no flows which would have reached the CC/LCC System under existing conditions were impounded by a recharge structure upstream of Choke Canyon Reservoir unless the CC/LCC System was full and spilling. (Note: Historically, there are many months when runoff over the recharge zone did not reach Choke Canyon Reservoir.) For recharge enhancement projects on the Nueces River, only the storage in Lake Corpus Christi, rather than the entire CC/LCC System, was considered in simulating operations. Under the second scenario, it was assumed that water rights could be purchased from the owners of the CC/LCC System by trading monetary compensation for the right to impound and recharge flows when the CC/LCC System is not spilling.

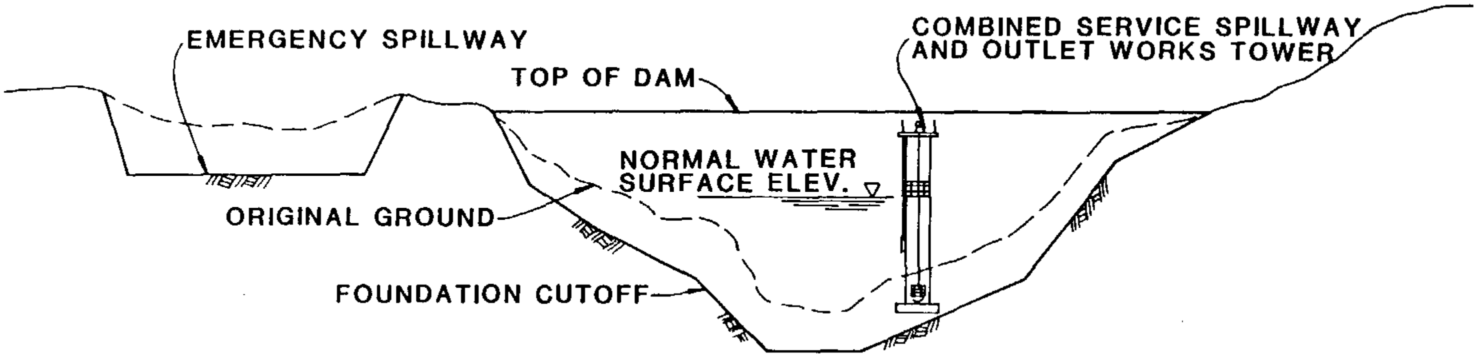
It is important to note that impacts to CC/LCC System storage rights and estuarine inflows cannot be completely avoided due to reservoir storage effects or hydrograph attenuation. Controlled release of all flood flows entering a Type 1 recharge project will result in Edwards Aquifer recharge rates in excess of those which would have occurred naturally, potentially causing reduced water availability downstream. Similarly, temporary impoundment of flood flows by a Type 2 recharge structure will result in percolation rates in excess of those which would have occurred naturally, potentially causing reduced water availability downstream. Once downstream of the Edwards Aquifer recharge zone, however, controlled releases could be subject to reduced channel loss rates due to the more continuous saturation of the streambed and reduced frequency of overbank flooding. Reduced channel losses will serve to mitigate, in part, the impacts of recharge projects on downstream water availability. Compensation for any remaining impacts could occur in the form of monetary compensation or mitigation by reservoir and water rights accounting procedures which could result in deferred compensation to affected water rights owners by releasing water in a month other than that in which the impact occurred.

2.3 Recharge Enhancement Costs

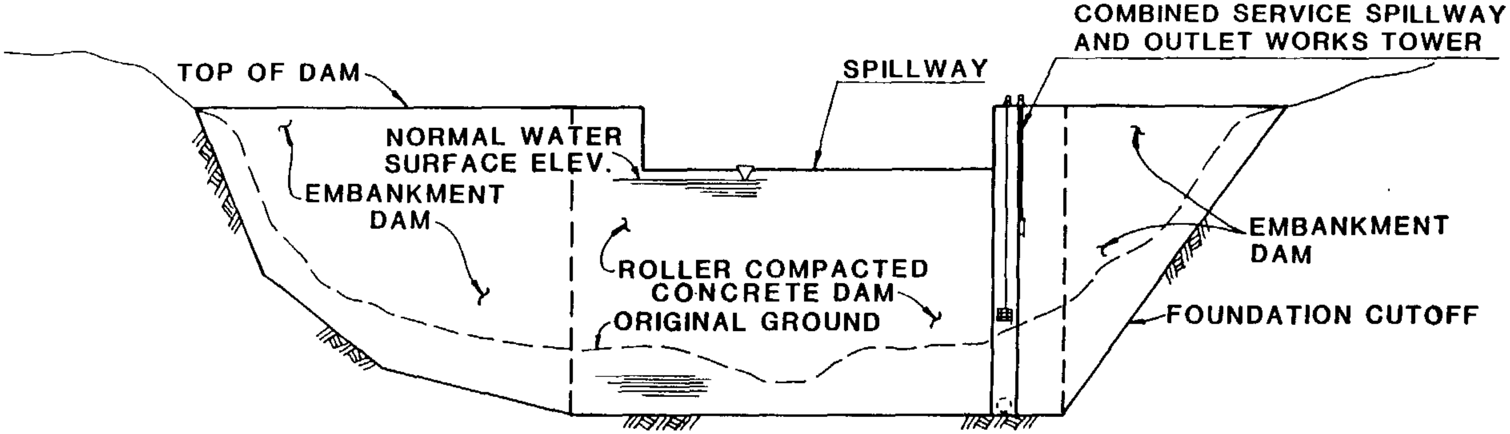
2.3.1 Conceptual Dam Designs

Based on knowledge gained through field visits to 14 of the proposed dam sites and a review of existing topographic and geologic information, two different dam types were considered appropriate for the recharge enhancement projects: 1) Embankment dams with a thin, central-clay core, rockfill shells, and an emergency spillway (Figures 2.3-1 and 2.3-2); and 2) Composite dams consisting of a roller compacted concrete (RCC) gravity overflow section connected to each abutment with embankment "wing" dams as previously described (Figures 2.3-1 and 2.3-3). The selection and conceptual design of each of these dam types was based on three observations/assumptions regarding the project sites: 1) Availability of clayey materials for use in a dam core is believed to be limited; 2) There is an abundance of natural sand, gravel, and cobble deposits for use in constructing dam shells and for producing roller compacted concrete; and 3) Foundation strengths are adequate to support an RCC gravity dam and/or the relatively steep slopes of a rockfill dam.

Review of the centerline profile and topographic features adjacent to the dam resulted in selection of the dam type best suited to each site. For the composite dam, the crest elevation of the RCC overflow spillway section was set at one foot above the normal water surface elevation. Properly designed RCC can withstand frequent overtopping flows without jeopardizing the structural integrity of the spillway and dam. For the embankment dams, the earth/rock cut emergency spillway was set at an elevation equal to the 25-year flood level in the reservoir. Depending on the integrity of the natural materials in which this type of spillway is excavated, it is typically desirable to minimize the frequency of flows through the spillway to reduce the potential for erosion damage. The criteria selected for



EMBANKMENT DAM WITH EMERGENCY SPILLWAY



COMPOSITE EMBANKMENT/ROLLER COMPACTED CONCRETE DAM WITH OVERFLOW SPILLWAYS

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CONCEPTUAL SITE DEVELOPMENT PROFILES

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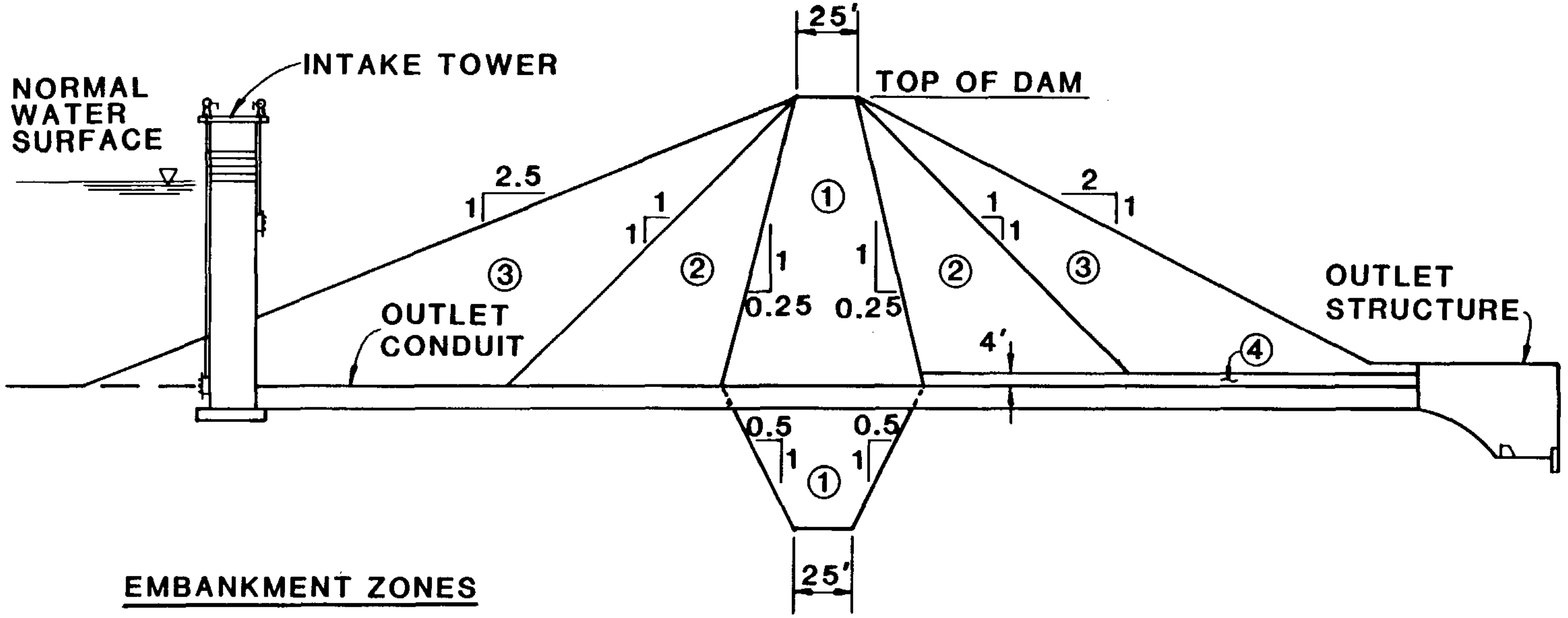
FIGURE 2.3-1



EMBANKMENT ZONES

① - IMPERVIOUS CORE
② - SAND & GRAVEL TRANSITION
③ - COBBLE & BOULDER ROCKFILL SHELLS
④ - PROCESSED FILTER/DRAIN

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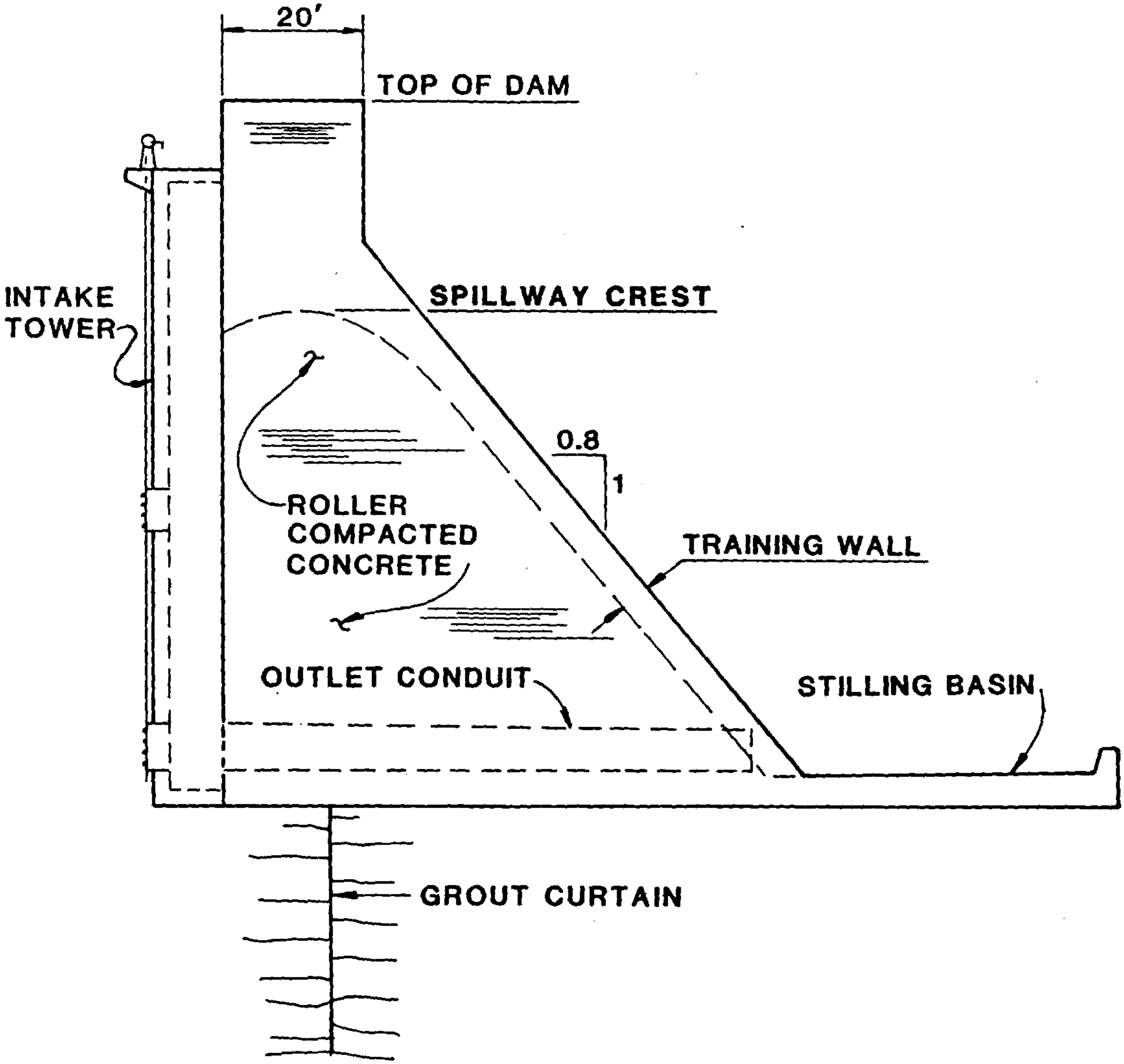
TYPICAL EMBANKMENT DAM SECTION

FIGURE 2.3-2



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TYPICAL ROLLER COMPACTED CONCRETE DAM SECTION

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FIGURE 2.3-3

establishing the emergency spillway crest elevation necessitates higher dam crest elevations for the embankment dam option than for the composite dam option in order to pass the Probable Maximum Flood (PMF) without overtopping.

At six of the mainstem sites, topographic and hydrologic constraints dictated the use of the composite dam design arrangement. For the other eight mainstem sites, both composite and embankment dam arrangements were considered. In general, composite dams proved more cost effective for smaller percentages (10%, 25%, and 50%) of maximum conservation capacity, while embankment dams proved more cost effective for maximum conservation capacity. At the smaller capacities, the composite dam option consisted of an RCC overflow section for virtually the entire dam length. At the larger capacities, the relatively higher cost of the RCC material compared to the earth and rock fill tended to inflate the total dam cost, making the embankment dam more economical. Embankment dams with excavated spillways similar to the existing Parker Creek project design were assumed for the five small Type 2 tributary projects.

Emergency spillway widths were selected to limit the depth of flow through the spillway to less than 25 feet during the PMF for the mainstem sites and 15 feet for the tributary sites. The potential for using other types and combinations of spillways to reduce dam height and cost should be investigated during the preliminary design phase of the selected projects.

A combined service spillway and low-flow outlet works was incorporated into each conceptual dam design. For the embankment dam alternatives, the outlet works would consist of a concrete intake tower near the upstream toe of the dam, a conduit passing through the base of the dam, and an energy dissipation structure at the downstream end of the conduit as shown in Figure 2.3-2. For the composite dams, the concrete intake tower would be cast into the vertical upstream face of the RCC section as indicated in Figure 2.3-3. Flow would discharge from the conduit directly onto the spillway stilling basin, eliminating the need for a separate energy dissipation structure. The intake tower in either case would include an uncontrolled overflow crest to maintain the reservoir at the normal pool elevation. Multiple gates would also be provided in the intake tower to selectively discharge flows through the dam. The top of the intake tower was assumed to be five feet above the emergency spillway elevation. Outlet conduits were sized to pass the maximum required water rights release within a one-month time period. Conduits through the RCC section were limited to eight feet in diameter in order to spread the discharge out along the downstream stilling basin. For embankment dams, a single conduit was selected to concentrate flow into the energy dissipation structure.

2.3.1.1 Flood Hydrology

Flood hydrology is the primary factor affecting the cost of many of the recharge enhancement projects as the results of hydrologic analyses determine dam height and spillway width. The Texas Water Commission (TWC) has promulgated dam design flood criteria specifying the applicable percentage of the PMF each structure must pass based on dam hazard potential and size classification. Table 2.3-1 summarizes the TWC hydrologic criteria for dams. The PMF was assumed to be the design flood event for the structures considered in this study due to size and hazard classification. In addition, the 25-year and 100-year flood elevations were used in determining emergency spillway elevations, land acquisition requirements, and major road relocations.

Table 2.3-1
Texas Water Commission
Hydrologic Criteria For Dams

Hazard Classification	Size Classification	Design Flood Event
Low Hazard	Small Intermediate Large	¼ PMF ¼ PMF to ½ PMF PMF
Significant Hazard	Small Intermediate Large	¼ PMF to ½ PMF ½ PMF to PMF PMF
High Hazard	Small Inermediate Large	PMF PMF PMF

Notes:

Hazard Classification:

- Low hazard dams are defined as those dams where failure may damage farm buildings, limited agricultural improvements, and county roads. For low hazard dams, no loss of human life would be expected.
- Significant hazard dams are defined as those dams where failure would not be expected to cause loss of human life, but may cause damage to isolated homes, secondary highways, minor railroads, or cause interruption of service or use of relatively important public utilities.
- High hazard dams are defined as those dams where failure would be expected to cause loss of human life, extensive damage to agricultural, industrial, or commercial facilities, important public utilities, main highways, or railroads.

Size Classification:

- Small size dams are classified as those dams which have a total height less than 40 feet and have a total reservoir storage at top of dam of less than 1,000 acre-feet.
- Intermediate size dams are classified as those dams which have a total height between 40 feet and 100 feet and a total reservoir storage at top of dam between 1,000 acre-feet and 50,000 acre-feet.
- Large dams are classified as those dams which have a total height in excess of 100 feet and have a total reservoir storage at top of dam greater than 50,000 acre-feet.

Estimates of the 25-year, 100-year, and the PMF hydrographs were developed using the HEC-1 Flood Hydrograph Package, a computer program developed by the U.S. Army Corps of Engineers (Ref. 16). HEC-1 computes runoff hydrographs, peak flows, and reservoir stages resulting from a particular rainfall event. Soil Conservation Service (SCS) methodology (Ref. 11) was selected as the most appropiate option to model each of the watersheds. Key input information required for application of the SCS methodology in HEC-1 includes watershed area, curve number, basin lag time, and precipitation depth. The watershed area and curve number applicable to each recharge enhancement project location were obtained from the Phase I report and project files. Average antecedent moisture conditions were assumed in modelling the 25-year and 100-year flood events. In compliance with TWC criteria, saturated antecedent moisture conditions and a full reservoir were assumed in modelling the PMF. Basin lag times were computed using the Kirpich formula (Ref. 4).

Precipitation depths for the 25-year and 100-year storm events were obtained from the National Weather Service (NWS) publications Hydro-35 (Ref. 5) and TP-40 (Ref. 19). These two storm events were distributed according to "balanced storm" criteria and were assumed to occur over the entire watershed. Areal rainfall reduction factors recommended by the NWS, which convert the point rainfall amounts to an average depth of rainfall for large watersheds, were applied for these storm events. Precipitation depths for the probable maximum storm were obtained from NWS Hydrometeorological Report No. 51 (Ref. 10). These rainfall amounts were distributed according to a 24 hour, SCS Type II Rainfall Distribution in order to obtain an estimate of the magnitude of the peak runoff rate for the PMF.

A comprehensive summary of the flood hydrology on which recharge enhancement project costs were based as well as a comparison with historical flood peaks near several project locations is provided in Table 2.3-2.

TABLE 2.3-2
FLOOD HYDROLOGY SUMMARY TABLE

	Watershed Data			25-Yr Flood		100-Yr Flood		PMF		Historical Records		
Recharge Enhancement Project	Watershed Area (sq.mi)	Basin Lag Time (hours)	Average Travel Velocity (fps)	24-hr Rainfall (inches)	Peak Flow (cfs)	24-hr Rainfall (inches)	Peak Flow (cfs)	24-hr Rainfall (inches)	Peak Flow (cfs)	Maximum Peak Flow (cfs)	Year	Period of Record (years)
Upper Verde	55	1.9	5.0	7.5	39,100	9.7	52,200	38.2	277,500	N/A	N/A	N/A
Lower Verde	105	3.8	5.1	7.5	44,300	9.5	58,800	36.4	307,000	N/A	N/A	N/A
Upper Hondo	96	2.1	5.6	7.5	60,200	9.5	81,000	36.4	428,500	69,800	1958	37
Lower Hondo	149	3.7	5.4	7.5	62,400	9.5	83,000	35.5	432,700	51,800	1987	29
Upper Seco	45	1.5	5.5	7.4	37,600	9.4	51,300	38.7	269,800	38,500	1973	29
Lower Seco	168	4.1	5.1	7.3	63,300	9.2	84,900	32.5	414,300	35,800	1987	29
Upper Sabinal	206	4.8	5.1	7.4	72,000	9.3	94,800	34.0	474,000	55,800	1987	47
Lower Sabinal	241	6.6	5.2	7.4	66,400	9.4	88,600	33.7	433,300	73,300	1958	37
Upper Dry Frio	126	6.5	4.6	7.3	34,100	9.2	46,000	33.5	228,200	123,000	1966	37
Lower Dry Frio	184	6.7	5.0	7.3	48,500	9.3	64,900	30.0	290,200	N/A	N/A	N/A
Concan	389	7.0	4.9	7.3	106,600	9.3	140,200	31.1	618,000	162,000	1932	67
Lower Frio	447	8.6	5.0	7.3	97,200	9.3	130,000	30.0	585,300	N/A	N/A	N/A
Montell	737	8.0	4.8	7.1	173,700	9.0	231,300	28.6	971,900	307,000	1955	67
Indian Creek	1861	19.9	4.5	7.1	208,300	9.1	281,700	23.8	978,000	616,000	1935	62
Blanco	25.5	1.9	5.3	7.3	20,200	9.3	26,000	39.3	132,500	N/A	N/A	N/A
Little Blanco	11.4	0.9	5.5	7.3	15,000	9.3	19,600	38.9	102,100	N/A	N/A	N/A
Quihi	6.1	1.1	3.9	7.5	7,600	9.7	9,800	38.9	45,500	N/A	N/A	N/A
Elm	26.9	2.0	4.5	7.5	21,200	9.7	27,700	38.9	132,800	N/A	N/A	N/A
Leona	11.4	1.1	5.0	7.3	12,000	9.3	16,200	38.9	84,800	N/A	N/A	N/A

2.3.1.2 Quantity and Cost Calculations

Computer spreadsheets were developed for each dam type to facilitate calculation of material quantities and construction costs. The average end area method was used to calculate quantities based on the dam centerline profile and top of dam elevation determined from the PMF analyses for each reservoir size. Unit cost data were selected by reviewing bid tabulations for similar earth, rockfill, and RCC dam projects constructed in Texas. The unit costs used for various materials are presented in Table 2.3-3.

TABLE 2.3-3
Unit Cost Data for Projects

Item	Cost/Cubic Yard ($)
Impervious Clay Core	3.00
Sand & Gravel Transitions	2.00
Rockfill Shells	4.00
Processed Filter/Drain	12.00
Foundation Excavation	2.50
Reinforced Concrete-Walls	400.00
Reinforced Concrete-Slabs	120.00
Roller Compacted Concrete	40.00

2.3.2 Road Relocations

Road relocations necessitated by the development of each recharge enhancement project were determined using 7.5-minute topographic maps prepared by the USGS. State and U.S. Highways were relocated above the 100-year flood level to assure unrestricted travel in times of emergency. Private gravel and paved roads providing access to houses or other structural improvements were relocated above the normal pool level. Road relocation cost estimates were developed for 10% and 100% of the maximum conservation capacity at each site. In general, relocation costs associated with the 25% and 50% conservation capacities were calculated by linear interpolation from the costs at the 10% and 100% capacities.

Relocated highway alignments were selected to minimize cost by avoiding mountainous terrain and stream crossings whenever possible. Both highway and private road relocation costs were calculated using unit prices per linear foot based on consultation with the local offices of the State Department of Highways and Public Transportation in Uvalde and Medina Counties and on recent bid tabulations for comparable work. Highway relocation costs were calculated by classifying segments of the revised alignment according to terrain. Terrain classifications and associated unit costs in dollars per linear foot ($/lf) were flat, rolling, and mountainous at $125/lf, $175/lf, and $225/lf, respectively. Highway bridge costs were based on $1,260/lf of bridge deck. Private road relocation costs were calculated for paved and gravel roads at $50/lf and $25/lf, respectively.

2.3.3 Land Acquisition

A significant component of capital cost for many of the recharge enhancement projects evaluated in this study was the cost of land acquisition. For the purposes of this study, it was assumed that all periodically inundated land up to the 25-year flood level would be purchased outright and that a flood easement would be obtained for land between the 25-year and 100-year flood levels. Review of rural land prices (Refs. 7 and 8) for Uvalde and Medina Counties resulted in the selection of estimated purchase and easement costs of $800 per acre and $500 per acre, respectively. An additional cost of $50,000 per unit was included for purchase of structural improvements noted on the topographic maps as being within the 25-year flood pool. For projects located on stream segments having a significant base flow and existing or potential recreational opportunities, the land acquisition cost included a 1,000-foot wide "premium acreage" strip along the stream up to the 25-year flood level. The purchase cost of this strip was assumed to be $10,000 per acre.

2.3.4 Environmental Mitigation

Estimated environmental mitigation costs were developed by Paul Price Associates, Inc. (PPA) for the maximum (100%) conservation capacity for each recharge enhancement project. These costs include environmental studies and reports, archaeological work, and, if necessary, costs for habitat evaluations and acquisition and management of mitigation lands. Environmental mitigation costs for the 10%, 25%, and 50% conservation capacities at each site were estimated by reduction of the projected cost at the 100% capacity based on the ratios of normal pool acreage at the lesser capacities to that at the 100% capacity. For a detailed summary of pertinent environmental considerations and a more thorough explanation of environmental mitigation costs, please refer to Appendix A.

2.3.5 Water Rights Mitigation

For the various recharge enhancement projects which impacted the water rights of the CC/LCC System, costs for water rights mitigation were included in the cost estimates. Costs were calculated on the basis of two components. The first component included payment of replacement cost for the reduced yield of the CC/LCC System. For the purposes of this study, a cost of $321.00 per acre-foot per year was used as compensation for any reduction in the system yield. This amount is equivalent to about $0.99 per 1,000 gallons and is based on the approximate cost for the City of Corpus Christi to develop a comparable source of water to replace the reduced firm yield. The second cost component addresses the long-term average impacts on reservoir inflows, lake levels, and inflows to the Nueces Estuary. It was assumed that all of these impacts are reflected in the change in average annual inflows to the Nueces Estuary. For each recharge project evaluated, the resulting average annual reduction in estuarine inflow was multiplied by a unit cost of $16 per acre-feet per year. This unit cost is approximately 5% of the unit cost of firm-yield water which is consistent with the concept of "interruptible" supply as implemented by the Lower Colorado River Authority, City of Austin, and Texas Water Commission. Although the selection of these cost values for mitigation of water rights impacts is arbitrary, it represents what is believed to be reasonable compensation. A mutually acceptable cost for mitigation of water rights impacts would ultimately need to be negotiated by the parties involved.

2.3.6 Miscellaneous Project Costs

Based on comparable reservoir projects, the miscellaneous engineering, permitting, legal, and other costs associated with recharge enhancement project development were assumed to be approximately 20% of related capital costs. Project capital costs were annualized based on a 25-year finance period and an annual interest rate of 7.5 percent. Annual operations and maintenance (O&M) costs were assumed to be approximately 0.4 percent of the total capital cost of each project and annual management costs for mitigation lands were assumed to be $10 per acre per year.

3.0 RECHARGE ENHANCEMENT PROJECT EVALUATIONS

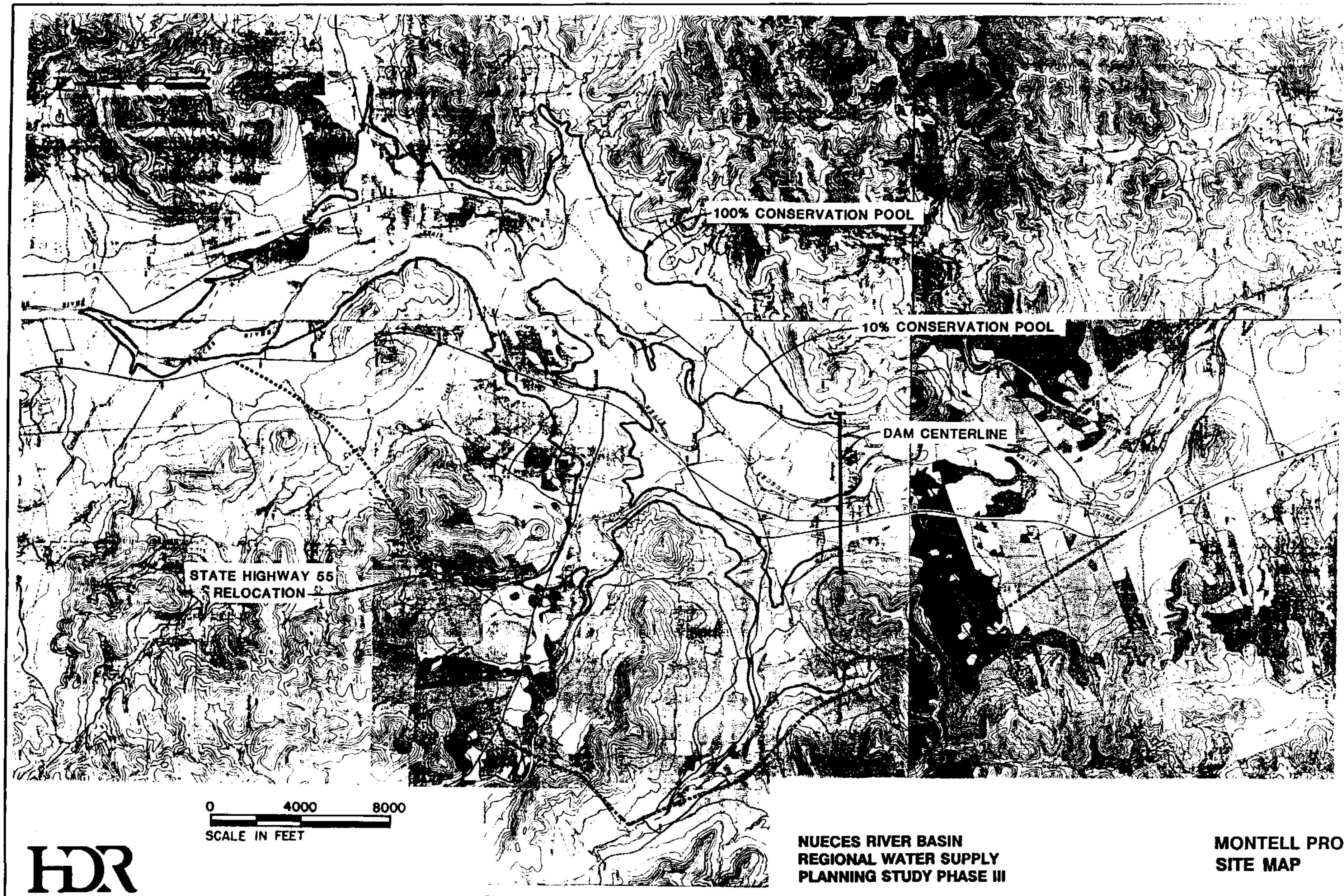
An evaluation of each of the potential recharge enhancement projects considered in this study is presented in this section. The evaluations provide a brief description of any items of interest or concern noted during the field reconnaissance conducted in May, 1991 and present any conclusions regarding the feasibility of project development at the site. A site map, project cost and data summary tables subject to the two water rights scenarios, and a graphical project evaluation summary assuming purchase of water rights are included in each section.

3.1 Type 1 Recharge Enhancement Projects

3.1.1 Montell Project

The Montell Project is located on the Nueces River at the community of Montell near the upstream edge of the Edwards Aquifer recharge zone. The project site was identified in a previous study (Ref. 17) and has the largest maximum conservation capacity (252,000 ac-ft) of any of the projects considered in this study. As indicated in Figure 3.1-1, development of this project would necessitate the relocation of State Highway 55 and the acquisition of substantial improved riverfront property and numerous dwellings. Environmental considerations at this site include the possibility of threatened or endangered species and the proximity of identified sites of archaeologic or historical significance, including the Nuestra Señora de la Candelaria del Cañon Mission and aqueduct. Purchase and management of wooded mitigation lands would be required.

The composite embankment / roller compacted concrete dam type was selected for this site due to the flood potential associated with the relatively large upstream drainage



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MONTELL PROJECT
SITE MAP

FIGURE 3.1-1

area, topographic constraints, and the availability of construction materials. Steep, massive rock abutments beyond the floodplain and extensive gravel to cobble deposits were noted near the dam site.

Recharge enhancement was calculated assuming both the release of flows across the recharge zone downstream of the dam site and the diversion of up to 2,000 ac-ft of water per month to the Dry Frio River for subsequent natural recharge. Cost estimates for the Montell Project included the capital costs of a small diversion dam, pump station, and raw water pipeline to the Dry Frio River, as well as annual power costs for operation of the pump station. Calculated recharge enhancement was greater for this project than any other project evaluated.

Project cost and data summaries subject to the two water rights scenarios are included as Tables 3.1-1a and 3.1-1b, and Figure 3.1-2 graphically summarizes project evaluation. As indicated in the tables and figures, optimal site development is at about 10% of the maximum conservation capacity at a minimum cost per unit recharge enhancement of $207 per ac-ft per year assuming limited purchase of water rights from the owners of the CC/LCC System.

3.1.2 Concan Project

The Concan Project is located on the Frio River at the community of Concan near the upstream edge of the Edwards Aquifer recharge zone. The project site was identified in a previous study by the U.S. Army Corps of Engineers (Ref. 17). At a maximum conservation capacity of 149,000 ac-ft, Concan is the second largest of the Type 1 projects and the third largest of all projects evaluated in this study. Development of this project

TABLE 3.1-1a
Montell Project Cost and Data Summary

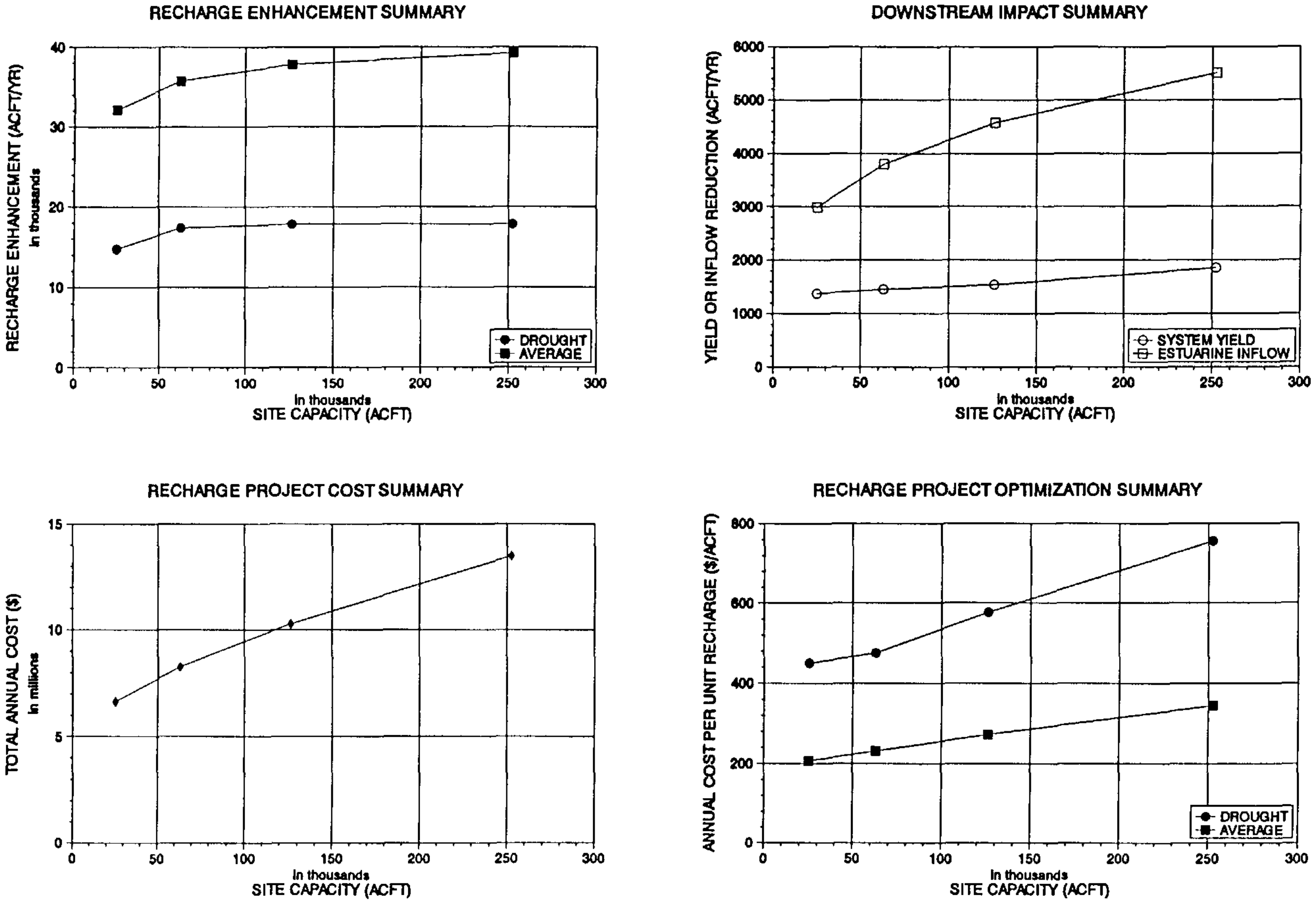
Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	**25%**	**50%**	**100%**
Dam Type	RCC Composite	RCC Composite	RCC Composite	RCC Composite
Conservation Pool:				
Elevation (ft-msl)	1272.7	1291.1	1310.2	1334.9
Surface Area (ac)	1,460	2,640	4,010	6,190
Capacity (acft)	25,230	63,075	126,150	252,300
25-Year Flood Pool:				
Elevation (ft-msl)	1282.9	1301.0	1319.7	1343.6
Surface Area (ac)	2,140	3,310	4,910	6,960
100-Year Flood Pool:				
Elevation (ft-msl)	1285.0	1303.3	1321.8	1345.6
Surface Area (ac)	2,260	3,460	5,090	7,180
Top of Dam Elevation (ft-msl)	1302.4	1320.8	1339.9	1364.6
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	9,200	9,200	9,200	9,200
Average Conditions	26,370	29,140	31,710	34,200
CC/LCC System Yield Reduction (acft/yr)	440	440	440	440
Median CC/LCC System Storage Reduction (%)	0.1	0.1	0.1	0.1
Estuarine Inflow Reduction (acft/yr)	2,460	3,060	3,720	4,510
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$30,481,690	$40,022,580	$52,230,850	$71,654,770
Road Relocations	$5,915,000	$7,316,667	$8,718,333	$10,120,000
Land Acquisition	$7,946,000	$10,093,100	$12,994,300	$17,773,900
Environmental Mitigation	$1,421,389	$2,570,183	$3,903,952	$6,026,300
Engineering, Legal, Financial, and Misc.	$9,152,816	$12,000,506	$15,569,487	$21,114,994
Total Capital Cost	$54,916,895	$72,003,035	$93,416,922	$126,689,964
Capital Cost / Unit Capacity	$2,177	$1,142	$741	$502
Annual Capital Cost	$4,926,045	$6,458,672	$8,379,498	$11,364,090
Operations and Maintenance	$1,226,527	$1,276,490	$1,339,023	$1,438,519
Water Rights Mitigation	$180,600	$190,200	$200,760	$213,400
Total Annual Cost	$6,333,172	$7,925,363	$9,919,281	$13,016,009
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$688	$861	$1,078	$1,415
Average Conditions	$240	$272	$313	$381

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.1-1b
Montell Project Cost and Data Summary With Purchase of Water Rights

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	RCC Composite	RCC Composite	RCC Composite	RCC Composite
Conservation Pool:				
Elevation (ft-msl)	1272.7	1291.1	1310.2	1334.9
Surface Area (ac)	1,460	2,640	4,010	6,190
Capacity (acft)	25,230	63,075	126,150	252,300
25-Year Flood Pool:				
Elevation (ft-msl)	1282.9	1301.0	1319.7	1343.6
Surface Area (ac)	2,140	3,310	4,910	6,960
100-Year Flood Pool:				
Elevation (ft-msl)	1285.0	1303.3	1321.8	1345.6
Surface Area (ac)	2,260	3,460	5,090	7,180
Top of Dam Elevation (ft-msl)	1302.4	1320.8	1339.9	1364.6
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	14,750	17,390	17,850	17,850
Average Conditions	32,090	35,750	37,810	39,220
CC/LCC System Yield Reduction (acft/yr)	1,380	1,450	1,540	1,860
Median CC/LCC System Storage Reduction (%)	-0.2	-0.2	-0.2	-0.2
Estuarine Inflow Reduction (acft/yr)	2,990	3,800	4,570	5,510
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$30,481,690	$40,022,580	$52,230,850	$71,654,770
Road Relocations	$5,915,000	$7,316,667	$8,718,333	$10,120,000
Land Acquisition	$7,946,000	$10,093,100	$12,994,300	$17,773,900
Environmental Mitigation	$1,421,389	$2,570,183	$3,903,952	$6,026,300
Engineering, Legal, Financial, and Misc.	$9,152,816	$12,000,506	$15,569,487	$21,114,994
Total Capital Cost	$54,916,895	$72,003,035	$93,416,922	$126,689,964
Capital Cost / Unit Capacity	$2,177	$1,142	$741	$502
Annual Capital Cost	$4,926,045	$6,458,672	$8,379,498	$11,364,090
Operations and Maintenance	$1,226,527	$1,276,490	$1,339,023	$1,438,519
Water Rights Mitigation	$490,820	$526,250	$567,460	$685,220
Total Annual Cost	$6,643,392	$8,261,413	$10,285,981	$13,487,829
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$450	$475	$576	$756
Average Conditions	$207	$231	$272	$344

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.



NOTE: FIGURES ASSUME PURCHASE OF WATER RIGHTS.

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MONTELL PROJECT
EVALUATION SUMMARY

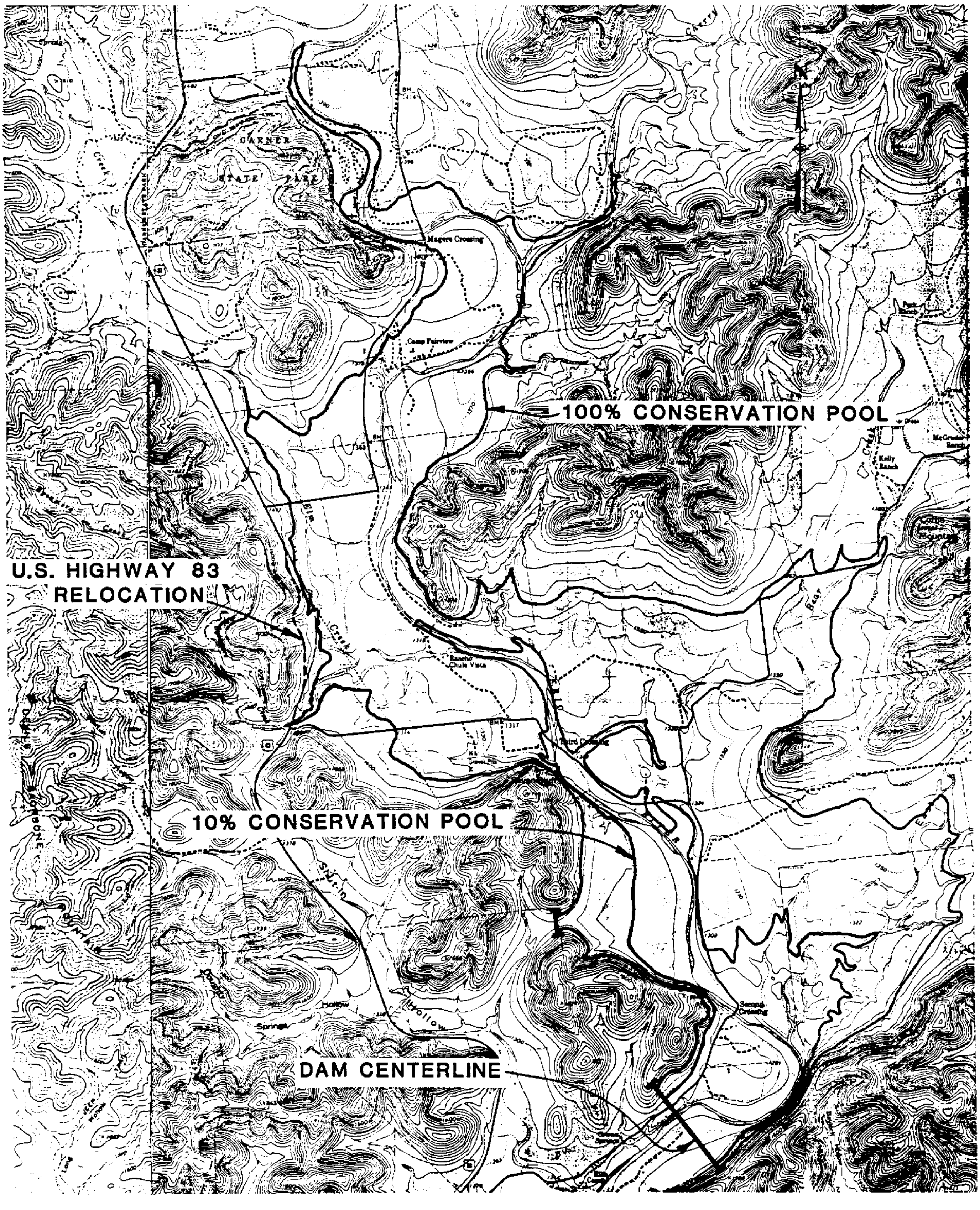
FIGURE 3.1-2

would necessitate the acquisition of extensive riverfront property and numerous dwellings and could necessitate a relatively minor relocation of U.S. Highway 83 on the west side of the reservoir as indicated in Figure 3.1-3.

Environmental considerations at this site are numerous and include potential presence of threatened or endangered species and several sites of archaeological or historical significance. A portion of Garner State Park would be affected by the headwaters of the Concan Project if developed at maximum conservation capacity. Purchase and management of wooded mitigation lands would be required.

The composite embankment / roller compacted concrete dam type was selected for this site due to the flood potential associated with the relatively large upstream drainage area, topographic constraints, and the availability of construction materials. The dam site is located in a broad, flat valley with very steep massive rock abutments. Extensive sands and gravels were noted in the river channel and it appears that the valley consists of sand and gravel terrace deposits.

Project cost and data summaries subject to the two water rights scenarios are included as Tables 3.1-2a and 3.1-2b and Figure 3.1-4 graphically summarizes project evaluation. Due to the high recharge capacity of the Frio River bed, the Concan Project would have no significant impact on the yield of the CC/LCC System because waters originating above Concan would not have arrived at Choke Canyon Reservoir during the critical drought under natural conditions. The Concan Project would, however, reduce inflows to the CC/LCC System during years outside of the critical drought period. As indicated in the tables and figures, optimal site development is at about 10% of the



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CONCAN PROJECT
SITE MAP

FIGURE 3.1-3

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TABLE 3.1-2a
Concan Project Cost and Data Summary

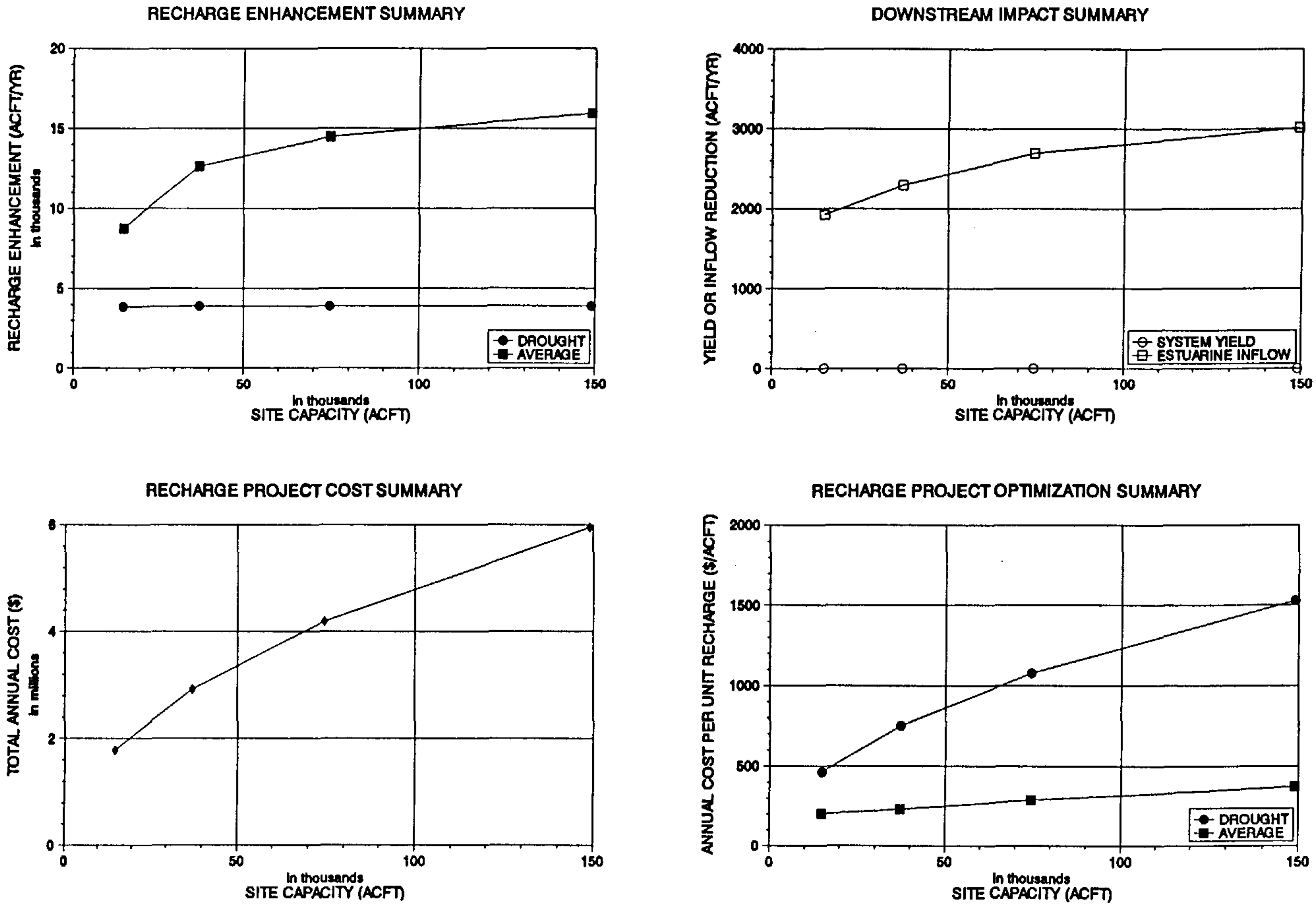
Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	RCC Composite	RCC Composite	RCC Composite	RCC Composite
Conservation Pool:				
Elevation (ft-msl)	1300.5	1321.8	1341.2	1365.3
Surface Area (ac)	710	1,450	2,400	3,840
Capacity (acft)	14,900	37,250	74,500	14,9000
25-Year Flood Pool:				
Elevation (ft-msl)	1312.0	1332.7	1351.4	1374.2
Surface Area (ac)	1,030	1,990	2,900	4,450
100-Year Flood Pool:				
Elevation (ft-msl)	1314.3	1335.1	1353.7	1376.5
Surface Area (ac)	1,130	2,110	3,060	4,610
Top of Dam Elevation (ft-msl)	1326.9	1354.5	1373.9	1398.0
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	3,085	3,085	3,085	3,085
Average Conditions	8,190	9,860	11,300	12,210
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.4	0.4	0.4	0.4
Estuarine Inflow Reduction (acft/yr)	1,610	1,800	2,110	2,310
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$10,082,790	$16,547,920	$23,207,380	$33,182,180
Road Relocations	$80,000	$391,667	$703,333	$1,015,000
Land Acquisition	$4,988,800	$7,659,600	$11,100,400	$15,212,400
Environmental Mitigation	$705,396	$1,440,598	$2,384,438	$3,815,100
Engineering, Legal, Financial, and Misc.	$3,171,397	$5,207,957	$7,479,110	$10,644,936
Total Capital Cost	$19,028,383	$31,247,741	$44,874,661	$63,869,616
Capital Cost / Unit Capacity	$1,277	$839	$602	$429
Annual Capital Cost	$1,706,846	$2,802,922	$4,025,257	$5,729,105
Operations and Maintenance	$47,431	$80,692	$116,830	$171,129
Water Rights Mitigation	$25,760	$28,800	$33,760	$36,960
Total Annual Cost	$1,780,037	$2,912,414	$4,175,847	$5,937,193
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$577	$944	$1,354	$1,925
Average Conditions	$217	$295	$370	$486

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.1-2b
Concan Project Cost and Data Summary With Purchase of Water Rights

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	RCC Composite	RCC Composite	RCC Composite	RCC Composite
Conservation Pool:				
Elevation (ft-msl)	1300.5	1321.8	1341.2	1365.3
Surface Area (ac)	710	1,450	2,400	3,840
Capacity (acft)	14,900	37,250	74,500	149,000
25-Year Flood Pool:				
Elevation (ft-msl)	1312.0	1332.7	1351.4	1374.2
Surface Area (ac)	1,030	1,990	2,900	4,450
100-Year Flood Pool:				
Elevation (ft-msl)	1314.3	1335.1	1353.7	1376.5
Surface Area (ac)	1,130	2,110	3,060	4,610
Top of Dam Elevation (ft-msl)	1326.9	1354.5	1373.9	1398.0
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	3,850	3,890	3,890	3,890
Average Conditions	8,740	12,640	14,490	15,950
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.4	0.4	0.4	0.4
Estuarine Inflow Reduction (acft/yr)	1,920	2,300	2,700	3,020
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$10,082,790	$16,547,920	$23,207,380	$33,182,180
Road Relocations	$80,000	$391,667	$703,333	$1,015,000
Land Acquisition	$4,988,800	$7,659,600	$11,100,400	$15,212,400
Environmental Mitigation	$705,396	$1,440,598	$2,384,438	$3,815,100
Engineering, Legal, Financial, and Misc.	$3,171,397	$5,207,957	$7,479,110	$10,644,936
Total Capital Cost	$19,028,383	$31,247,741	$44,874,661	$63,869,616
Capital Cost / Unit Capacity	$1,277	$839	$602	$429
Annual Capital Cost	$1,706,846	$2,802,922	$4,025,257	$5,729,105
Operations and Maintenance	$47,431	$80,692	$116,830	$171,129
Water Rights Mitigation	$30,720	$36,800	$43,200	$48,320
Total Annual Cost	$1,784,997	$2,920,414	$4,185,287	$5,948,553
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$464	$751	$1,076	$1,529
Average Conditions	$204	$231	$289	$373

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.



RECHARGE ENHANCEMENT SUMMARY

DOWNSTREAM IMPACT SUMMARY

RECHARGE PROJECT COST SUMMARY

RECHARGE PROJECT OPTIMIZATION SUMMARY

NOTE: FIGURES ASSUME PURCHASE OF WATER RIGHTS.

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CONCAN PROJECT EVALUATION SUMMARY

FIGURE 3.1-4

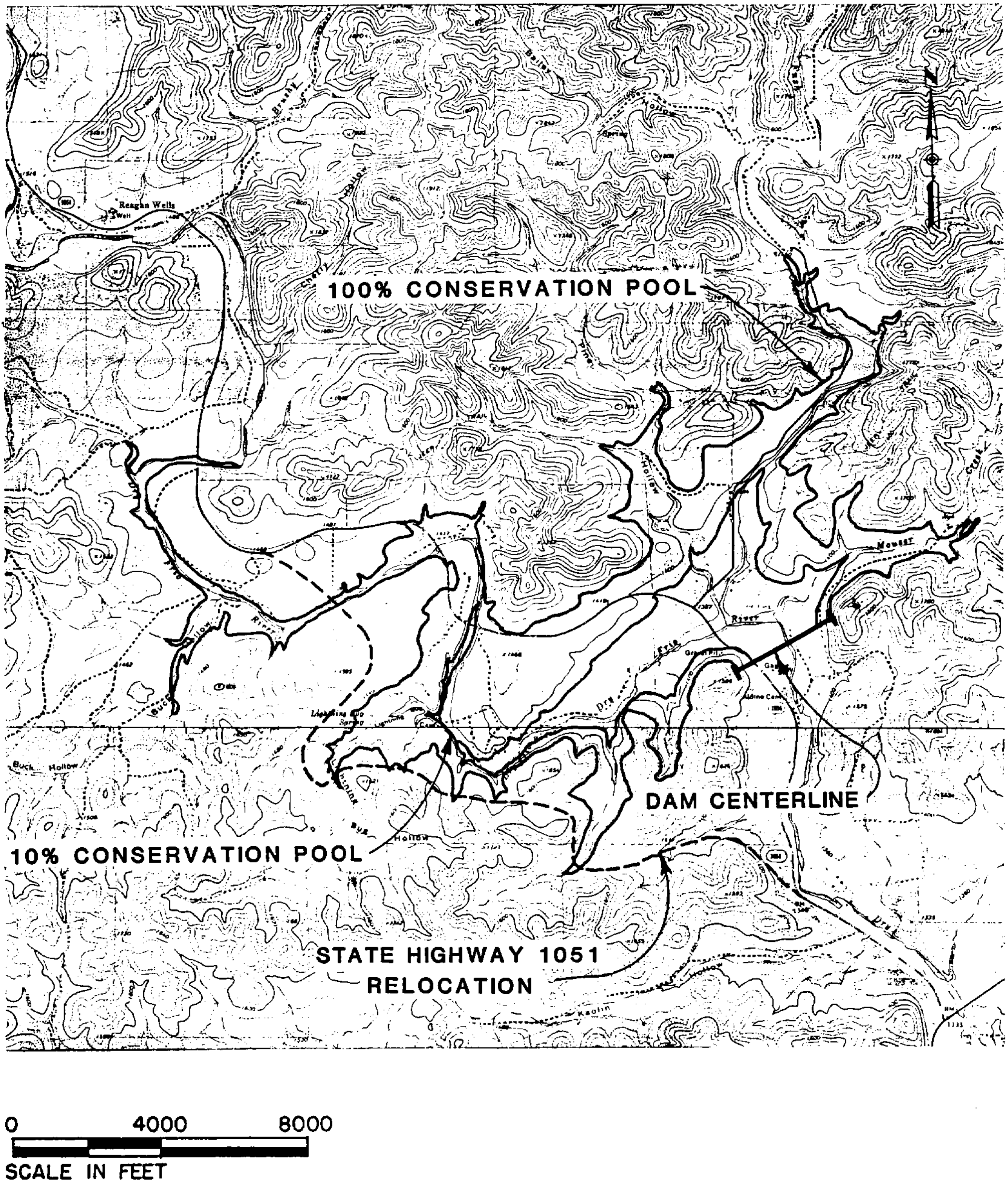
maximum conservation capacity at a minimum cost per unit recharge enhancement of $204 per ac-ft per year assuming limited purchase of water rights.

3.1.3 Upper Dry Frio Project

The Upper Dry Frio Project is located on the Dry Frio River about 5 miles southeast of Reagan Wells near the upstream edge of the Edwards Aquifer recharge zone. The project site was identified in a previous study (Ref. 3) and has a maximum conservation capacity of 60,000 ac-ft and a maximum normal water surface area of 1,800 acres. As indicated in Figure 3.1-5, development of this project would necessitate relocation of several miles of State Highway 1051. Environmental considerations at this site include the purchase and management of wooded mitigation lands, however, there are no recorded sites of archaelogical significance in the project area.

Both the embankment dam and the composite embankment / roller compacted concrete dam types were evaluated for this site with the composite dam proving more economical at the 10% and 25% capacities and the embankment dam being more economical at the 50% and 100% capacities. Field reconnaissance indicated the presence of sufficient construction materials for either dam type.

Project cost and data summaries subject to the two water rights scenarios are included as Tables 3.1-3a and 3.1-3b and Figure 3.1-6 graphically summarizes project evaluation. Due to the extremely high recharge capacity of the Dry Frio River bed, the Upper Dry Frio Project would have no significant impact on the yield of the CC/LCC System because waters originating above the site would not have arrived at Choke Canyon Reservoir during the critical drought under natural conditions. The Upper Dry Frio Project



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UPPER DRY FRIO PROJECT
SITE MAP

FIGURE 3.1-5

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TABLE 3.1-3a
Upper Dry Frio Project Cost and Data Summary

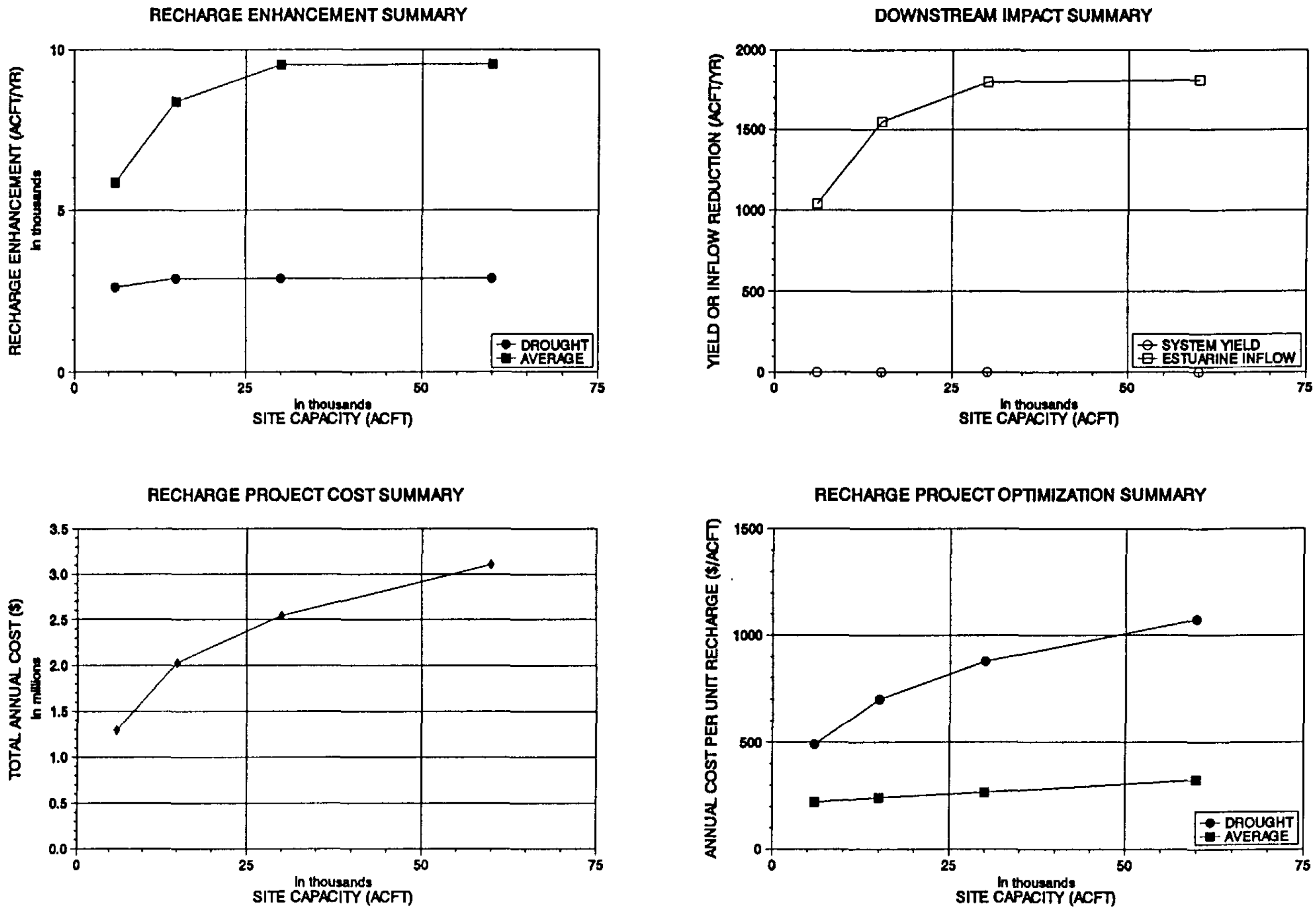
Physical Data	**Percentage of Maximum Project Conservation Capacity**			
	10%	**25%**	**50%**	**100%**
Dam Type	RCC Composite	RCC Composite	Embankment	Embankment
Conservation Pool:				
Elevation (ft-msl)	1387.2	1402.1	1417.4	1438.0
Surface Area (ac)	440	780	1,160	1,800
Capacity (acft)	6,000	15,000	30,000	60,000
25-Year Flood Pool:				
Elevation (ft-msl)	1393.1	1407.8	1436.5	1451.0
Surface Area (ac)	570	910	1,740	2,360
100-Year Flood Pool:				
Elevation (ft-msl)	1394.5	1409.1	1439.2	1453.2
Surface Area (ac)	600	950	1,840	2,460
Top of Dam Elevation (ft-msl)	1405.6	1420.5	1453.6	1468.1
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	2,630	2,900	2,900	2,900
Average Conditions	5,840	8,360	9,400	9,420
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.2	0.2	0.2	0.2
Estuarine Inflow Reduction (acft/yr)	1,040	1,550	1,780	1,780
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$4,272,720	$6,892,390	$8,947,060	$11,786,830
Road Relocations	$3,795,000	$4,927,000	$6,115,667	$7,191,000
Land Acquisition	$3,121,830	$5,649,650	$6,656,560	$7,149,960
Environmental Mitigation	$457,844	$811,633	$1,207,044	$1,873,000
Engineering, Legal, Financial, and Misc.	$2,329,479	$3,656,135	$4,585,266	$5,600,158
Total Capital Cost	$13,976,873	$21,936,808	$27,511,598	$33,600,948
Capital Cost / Unit Capacity	$2,329	$1,462	$917	$560
Annual Capital Cost	$1,253,726	$1,967,732	$2,467,790	$3,014,005
Operations and Maintenance	$21,491	$35,370	$47,388	$65,147
Water Rights Mitigation	$16,640	$24,800	$28,480	$28,480
Total Annual Cost	$1,291,856	$2,027,901	$2,543,659	$3,107,632
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$491	$699	$877	$1,072
Average Conditions	$221	$243	$271	$330

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.1-3b
Upper Dry Frio Project Cost and Data Summary With Purchase of Water Rights

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	RCC Composite	RCC Composite	Embankment	Embankment
Conservation Pool:				
Elevation (ft-msl)	1387.2	1402.1	1417.4	1438.0
Surface Area (ac)	440	780	1,160	1,800
Capacity (acft)	6,000	15,000	30,000	60,000
25-Year Flood Pool:				
Elevation (ft-msl)	1393.1	1407.8	1436.5	1451.0
Surface Area (ac)	570	910	1,740	2,360
100-Year Flood Pool:				
Elevation (ft-msl)	1394.5	1409.1	1439.2	1453.2
Surface Area (ac)	600	950	1,840	2,460
Top of Dam Elevation (ft-msl)	1405.6	1420.5	1453.6	1468.1
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	2,630	2,900	2,900	2,900
Average Conditions	5,840	8,360	9,520	9,540
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.2	0.2	0.2	0.2
Estuarine Inflow Reduction (acft/yr)	1,040	1,550	1,800	1,810
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$4,272,720	$6,892,390	$8,947,060	$11,786,830
Road Relocations	$3,795,000	$4,927,000	$6,115,667	$7,191,000
Land Acquisition	$3,121,830	$5,649,650	$6,656,560	$7,149,960
Environmental Mitigation	$457,844	$811,633	$1,207,044	$1,873,000
Engineering, Legal, Financial, and Misc.	$2,329,479	$3,656,135	$4,585,266	$5,600,158
Total Capital Cost	$13,976,873	$21,936,808	$27,511,598	$33,600,948
Capital Cost / Unit Capacity	$2,329	$1,462	$917	$560
Annual Capital Cost	$1,253,726	$1,967,732	$2,467,790	$3,014,005
Operations and Maintenance	$21,491	$35,370	$47,388	$65,147
Water Rights Mitigation	$16,640	$24,800	$28,800	$28,960
Total Annual Cost	$1,291,856	$2,027,901	$2,543,979	$3,108,112
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$491	$699	$877	$1,072
Average Conditions	$221	$243	$267	$326

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.



NOTE: FIGURES ASSUME PURCHASE OF WATER RIGHTS.

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UPPER DRY FRIO PROJECT EVALUATION SUMMARY

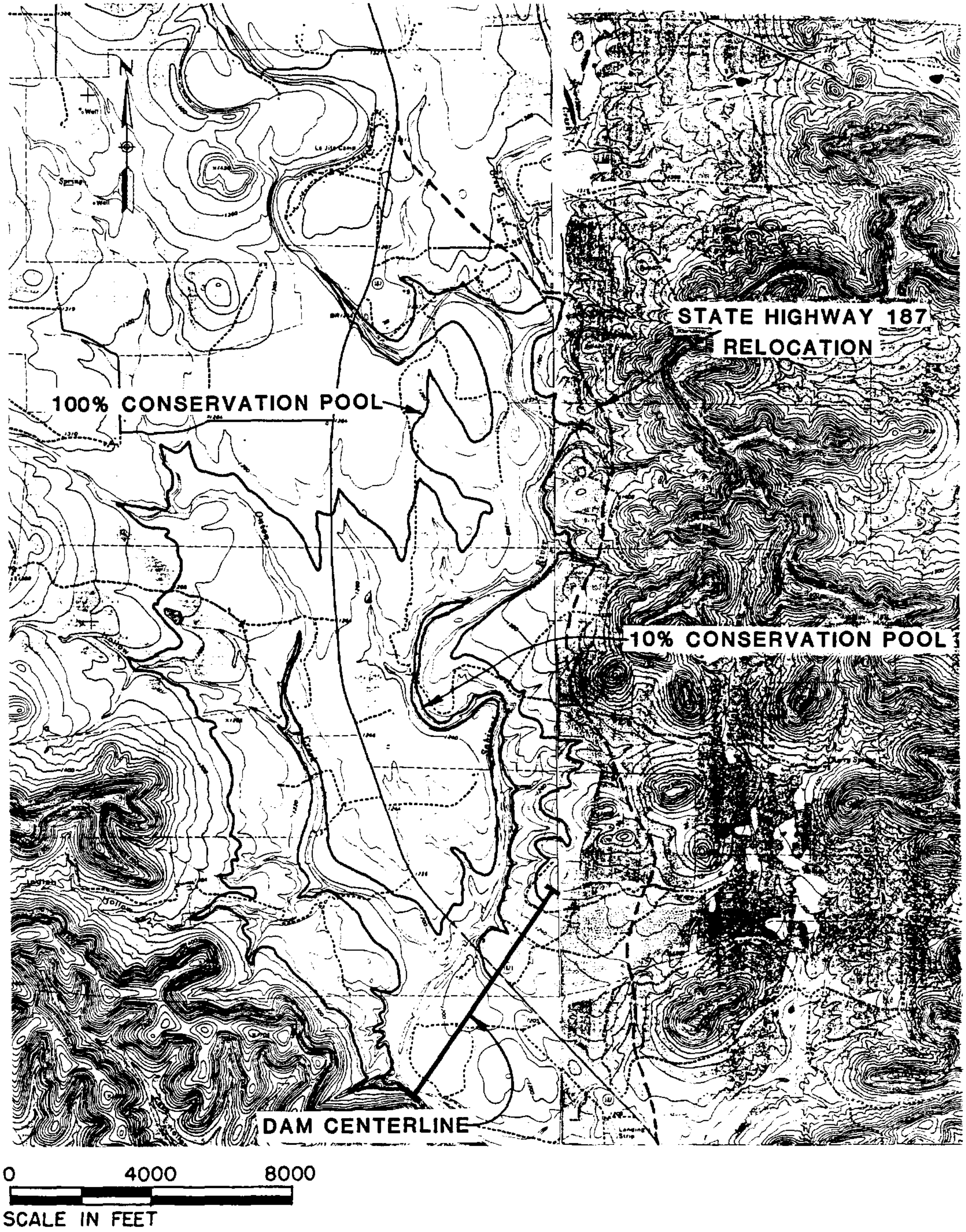
FIGURE 3.1-6

would, however, reduce inflows to the CC/LCC System during years outside of the critical drought period. As indicated in the tables and figures, optimal site development is at about 10% of the maximum conservation capacity at a minimum cost per unit recharge enhancement of $221 per ac-ft per year under either water rights scenario.

3.1.4 Upper Sabinal Project

The Upper Sabinal Project is located on the Sabinal River near the upstream edge of the Edwards Aquifer recharge zone. The project site was identified in a previous study (Ref. 17) and has a maximum conservation capacity of 93,300 ac-ft. Development of this project would necessitate the relocation of several miles of State Highway 187 as indicated in Figure 3.1-7. Environmental considerations at this site include the possible presence of threatened or endangered species, instream flow studies, and purchase and management of wooded mitigation lands. No sites of archaeological significance have been recorded within the maximum conservation pool of the reservoir.

Project cost and data summaries subject to the two water rights scenarios are included as Tables 3.1-4a and 3.1-4b and Figure 3.1-8 graphically summarizes project evaluation. Both the embankment dam and the composite embankment / roller compacted concrete dam types were evaluated for this site with the composite dam proving more economical at the 10%, 25%, and 50% capacities and the embankment dam being more economical at the 100% capacity. As indicated in the tables and figures, optimal site development is at about 10% of the maximum conservation capacity at a minimum cost per unit recharge enhancement of $146 per ac-ft per year assuming purchase of water rights from the owners of the CC/LCC System. When honoring all water rights to extent possible



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UPPER SABINAL PROJECT
SITE MAP

FIGURE 3.1-7

TABLE 3.1-4a
Upper Sabinal Project Cost and Data Summary

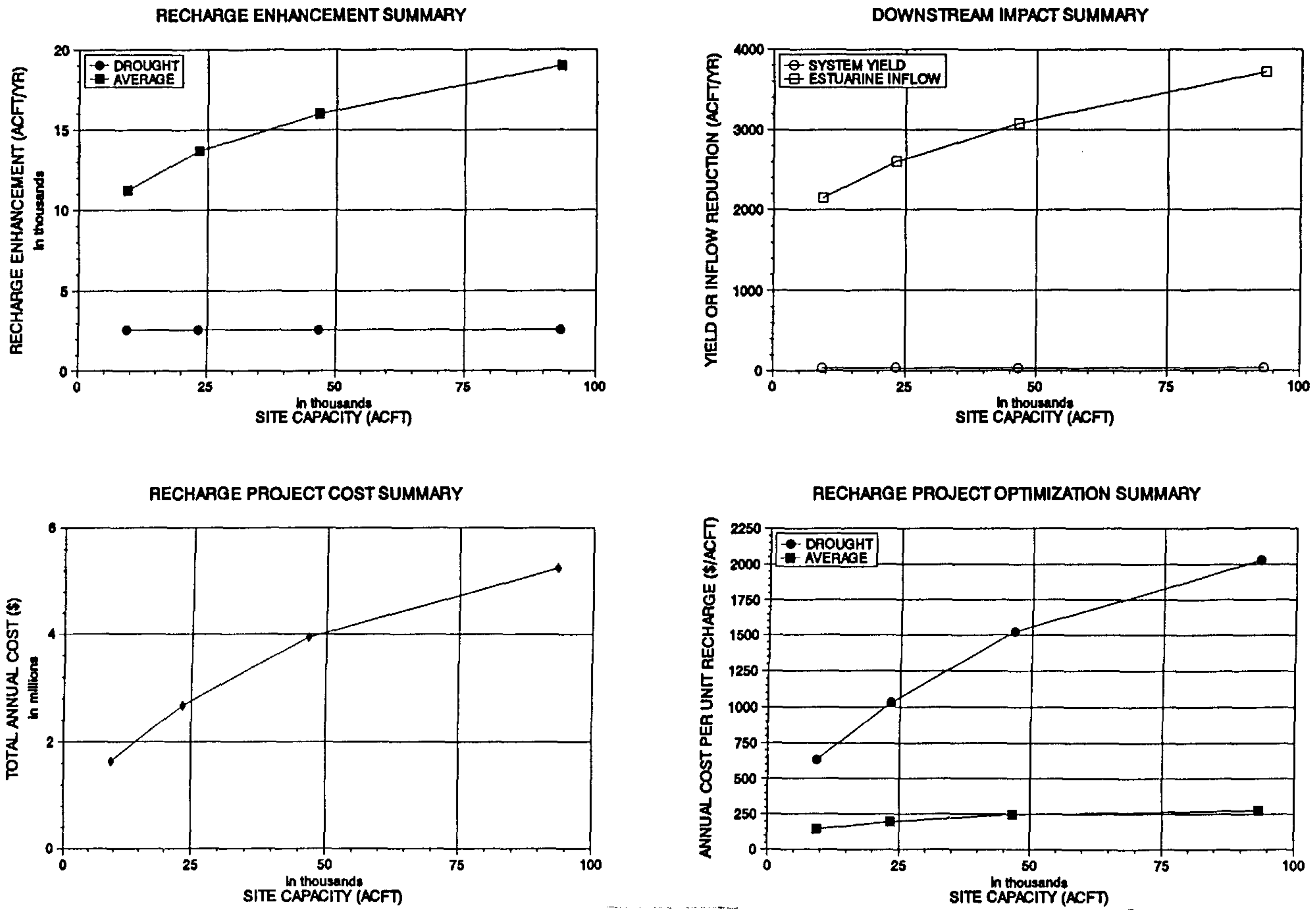
Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	RCC Composite	RCC Composite	RCC Composite	Embankment
Conservation Pool:				
Elevation (ft-msl)	1213.4	1231.1	1247.3	1266.4
Surface Area (ac)	550	1,070	1,850	3,110
Capacity (acft)	9,330	23,325	46,650	93,300
25-Year Flood Pool:				
Elevation (ft-msl)	1222.6	1239.7	1255.1	1279.2
Surface Area (ac)	790	1,420	2,310	4,200
100-Year Flood Pool:				
Elevation (ft-msl)	1224.3	1241.5	1256.9	1281.4
Surface Area (ac)	850	1,520	2,420	4,390
Top of Dam Elevation (ft-msl)	1239.5	1257.2	1273.4	1296.2
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	2,520	2,520	2,520	2,520
Average Conditions	10,080	11,230	12,890	14,670
CC/LCC System Yield Reduction (acft/yr)	30	30	30	30
Median CC/LCC System Storage Reduction (%)	0.4	0.4	0.4	0.4
Estuarine Inflow Reduction (acft/yr)	1,950	2,170	2,510	2,900
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$7,445,380	$13,129,120	$19,890,600	$26,654,510
Road Relocations	$3,587,000	$4,339,500	$5,092,000	$5,470,000
Land Acquisition	$2,943,200	$5,239,200	$8,360,600	$11,660,290
Environmental Mitigation	$542,413	$1,055,240	$1,824,481	$3,067,100
Engineering, Legal, Financial, and Misc.	$2,903,599	$4,752,612	$7,033,536	$9,370,380
Total Capital Cost	$17,421,592	$28,515,672	$42,201,217	$56,222,280
Capital Cost / Unit Capacity	$1,867	$1,223	$905	$603
Annual Capital Cost	$1,562,717	$2,557,856	$3,785,449	$5,043,139
Operations and Maintenance	$35,282	$63,216	$98,062	$137,718
Water Rights Mitigation	$40,830	$44,350	$49,790	$56,030
Total Annual Cost	$1,638,828	$2,665,422	$3,933,302	$5,236,887
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$650	$1,058	$1,561	$2,078
Average Conditions	$163	$237	$305	$357

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

Table 3.1-4b
Upper Sabinal Project Cost and Data Summary With Purchase of Water Rights

	Percentage of Maximum Project Conservation Capacity			
Physical Data	**10%**	**25%**	**50%**	**100%**
Dam Type	RCC Composite	RCC Composite	RCC Composite	Embankment
Conservation Pool:				
Elevation (ft-msl)	1213.4	1231.1	1247.3	1266.4
Surface Area (ac)	550	1,070	1,850	3,110
Capacity (acft)	9,330	23,325	46,650	93,300
25-Year Flood Pool:				
Elevation (ft-msl)	1222.6	1239.7	1255.1	1279.2
Surface Area (ac)	790	1,420	2,310	4,200
100-Year Flood Pool:				
Elevation (ft-msl)	1224.3	1241.5	1256.9	1281.4
Surface Area (ac)	850	1,520	2,420	4,390
Top of Dam Elevation (ft-msl)	1239.5	1257.2	1273.4	1296.2
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	2,590	2,590	2,590	2,590
Average Conditions	11,240	13,690	16,010	19,000
CC/LCC System Yield Reduction (acft/yr)	30	30	30	30
Median CC/LCC System Storage Reduction (%)	0.6	0.6	0.6	0.6
Estuarine Inflow Reduction (acft/yr)	2,150	2,600	3,080	3,720
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$7,445,380	$13,129,120	$19,890,600	$26,654,510
Road Relocations	$3,587,000	$4,339,500	$5,092,000	$5,470,000
Land Acquisition	$2,943,200	$5,239,200	$8,360,600	$11,660,290
Environmental Mitigation	$542,413	$1,055,240	$1,824,481	$3,067,100
Engineering, Legal, Financial, and Misc.	$2,903,599	$4,752,612	$7,033,536	$9,370,380
Total Capital Cost	$17,421,592	$28,515,672	$42,201,217	$56,222,280
Capital Cost / Unit Capacity	$1,867	$1,223	$905	$603
Annual Capital Cost	$1,562,717	$2,557,856	$3,785,449	$5,043,139
Operations and Maintenance	$35,282	$63,216	$98,062	$137,718
Water Rights Mitigation	$44,030	$51,230	$58,910	$69,150
Total Annual Cost	$1,642,028	$2,672,302	$3,942,422	$5,250,007
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$634	$1,032	$1,522	$2,027
Average Conditions	$146	$195	$246	$276

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.



NOTE: FIGURES ASSUME PURCHASE OF WATER RIGHTS.

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UPPER SABINAL PROJECT EVALUATION SUMMARY

FIGURE 3.1-8

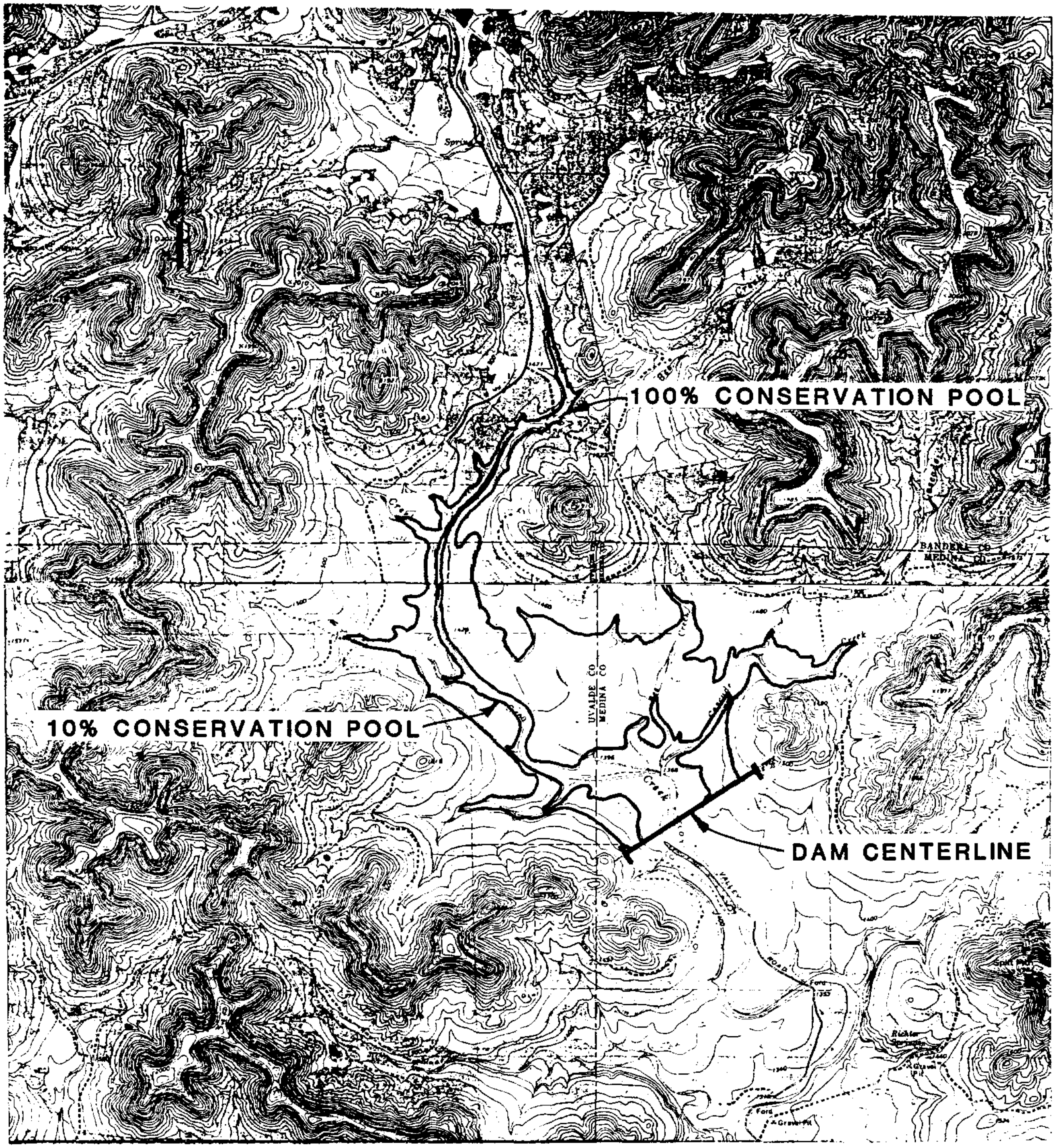
(first water rights scenario), the unit cost of recharge enhancement at the 10% capacity becomes $163 per ac-ft per year making the Upper Sabinal Project the most economical of all Type 1 projects evaluated.

3.1.5 Upper Seco Project

The Upper Seco Project is located on Seco Creek about 1.5 miles south of the intersection of the Uvalde, Medina, and Bandera County lines. The project site was identified in a previous study (Ref. 17) and has a maximum conservation capacity of 23,000 ac-ft. As indicated in Figure 3.1-9, the project is located in a somewhat remote area necessitating only minimal relocation of private roads. Environmental considerations at this site include the possible presence of threatened or endangered species, instream flow studies, and purchase and management of wooded mitigation lands. No sites of archaeological significance have been recorded within the maximum conservation pool of the reservoir.

Both the embankment dam and the composite embankment / roller compacted concrete dam types were evaluated for this site with the composite dam proving more economical at the 10% and 25% capacities and the embankment dam being more economical at the 50% and 100% capacities. Field reconnaissance indicated the presence of sufficient construction materials for either dam type including extensive sand and gravel terrace deposits along the left bank and cobbles and boulders in the streambed.

Project cost and data summaries subject to the two water rights scenarios are included as Tables 3.1-5a and 3.1-5b and Figure 3.1-10 graphically summarizes project evaluation. Due to limited runoff from the watershed upstream and the existing Seco Creek



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**UPPER SECO PROJECT
SITE MAP**

FIGURE 3.1-9

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TABLE 3.1-5a
Upper Seco Project Cost and Data Summary

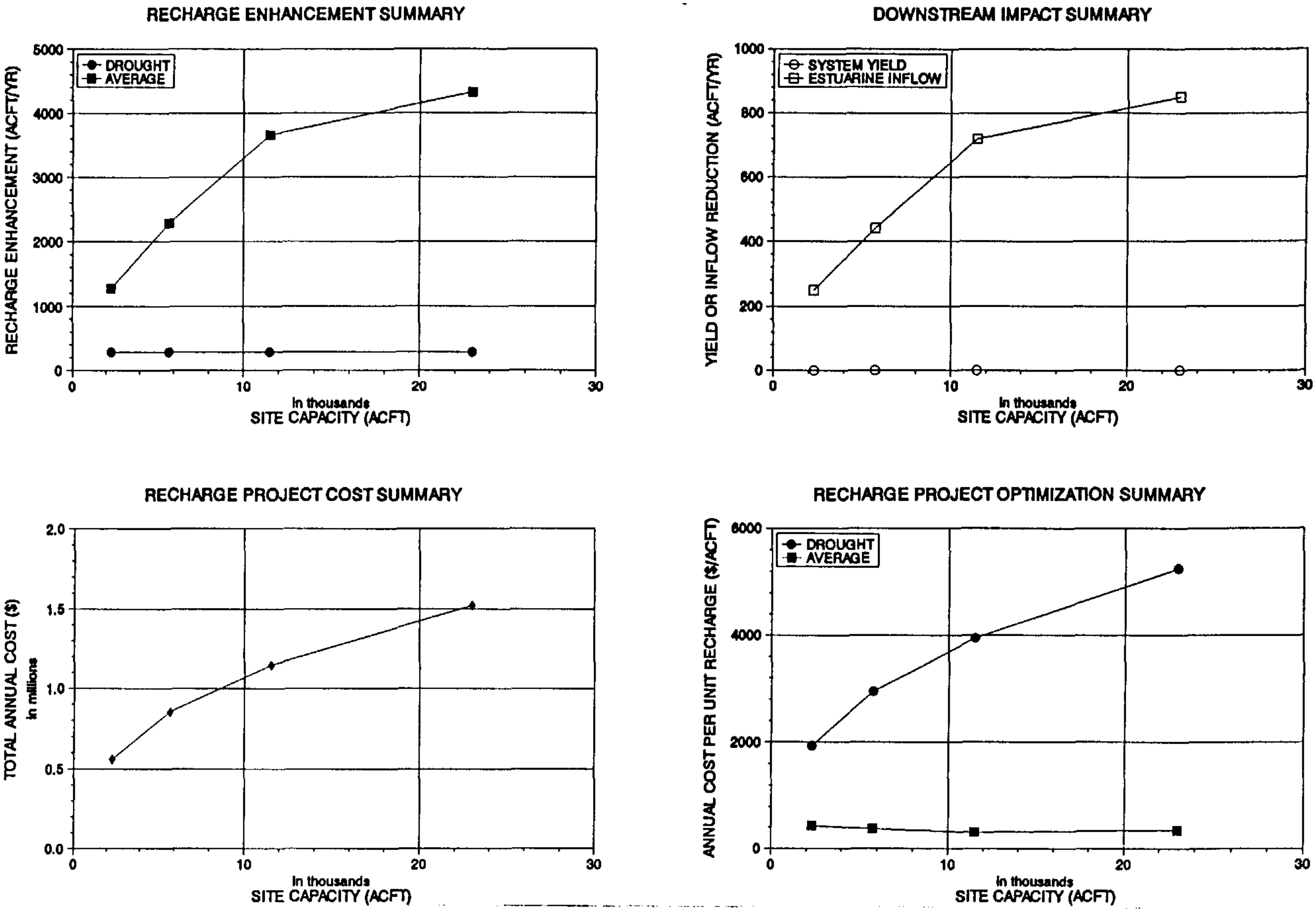
	Percentage of Maximum Project Conservation Capacity			
Physical Data	**10%**	**25%**	**50%**	**100%**
Dam Type	RCC Composite	RCC Composite	Embankment	Embankment
Conservation Pool:				
Elevation (ft-msl)	1401.9	1412.7	1425.0	1441.1
Surface Area (ac)	190	380	600	900
Capacity (acft)	2,300	5,750	11,500	23,000
25-Year Flood Pool:				
Elevation (ft-msl)	1407.9	1418.7	1437.9	1448.6
Surface Area (ac)	300	490	840	1,080
100-Year Flood Pool:				
Elevation (ft-msl)	1409.3	1420.1	1440.9	1450.4
Surface Area (ac)	320	510	900	1,130
Top of Dam Elevation (ft-msl)	1420.8	1436.1	1455.2	1465.9
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	290	290	290	290
Average Conditions	1,280	2,280	3,410	3,820
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.1	0.1	0.1	0.1
Estuarine Inflow Reduction (acft/yr)	250	440	690	780
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$3,511,590	$5,329,740	$6,515,860	$8,534,190
Road Relocations	$0	$25,000	$50,000	$75,000
Land Acquisition	$1,307,520	$1,880,420	$3,024,430	$4,055,140
Environmental Mitigation	$201,041	$402,082	$634,867	$952,300
Engineering, Legal, Financial, and Misc.	$1,004,030	$1,527,448	$2,045,031	$2,723,326
Total Capital Cost	$6,024,181	$9,164,691	$12,270,188	$16,339,956
Capital Cost / Unit Capacity	$2,619	$1,594	$1,067	$710
Annual Capital Cost	$540,369	$822,073	$1,100,636	$1,465,694
Operations and Maintenance	$15,946	$25,119	$32,063	$43,137
Water Rights Mitigation	$4,000	$7,040	$11,040	$12,480
Total Annual Cost	$560,315	$854,232	$1,143,739	$1,521,311
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$1,932	$2,946	$3,944	$5,246
Average Conditions	$438	$375	$335	$398

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.1-5b
Upper Seco Project Cost and Data Summary With Purchase of Water Rights

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	RCC Composite	RCC Composite	Embankment	Embankment
Conservation Pool:				
Elevation (ft-msl)	1401.9	1412.7	1425.0	1441.1
Surface Area (ac)	190	380	600	900
Capacity (acft)	2,300	5,750	11,500	23,000
25-Year Flood Pool:				
Elevation (ft-msl)	1407.9	1418.7	1437.9	1448.6
Surface Area (ac)	300	490	840	1,080
100-Year Flood Pool:				
Elevation (ft-msl)	1409.3	1420.1	1440.9	1450.4
Surface Area (ac)	320	510	900	1,130
Top of Dam Elevation (ft-msl)	1420.8	1436.1	1455.2	1465.9
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	290	290	290	290
Average Conditions	1,280	2,280	3,660	4,330
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.1	0.1	0.1	0.1
Estuarine Inflow Reduction (acft/yr)	250	440	720	850
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$3,511,590	$5,329,740	$6,515,860	$8,534,190
Road Relocations	$0	$25,000	$50,000	$75,000
Land Acquisition	$1,307,520	$1,880,420	$3,024,430	$4,055,140
Environmental Mitigation	$201,041	$402,082	$634,867	$952,300
Engineering, Legal, Financial, and Misc.	$1,004,030	$1,527,448	$2,045,031	$2,723,326
Total Capital Cost	$6,024,181	$9,164,691	$12,270,188	$16,339,956
Capital Cost / Unit Capacity	$2,619	$1,594	$1,067	$710
Annual Capital Cost	$540,369	$822,073	$1,100,636	$1,465,694
Operations and Maintenance	$15,946	$25,119	$32,063	$43,137
Water Rights Mitigation	$4,000	$7,040	$11,520	$13,600
Total Annual Cost	$560,315	$854,232	$1,144,219	$1,522,431
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$1,932	$2,946	$3,946	$5,250
Average Conditions	$438	$375	$313	$352

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.



NOTE: FIGURES ASSUME PURCHASE OF WATER RIGHTS.

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**UPPER SECO PROJECT
EVALUATION SUMMARY**

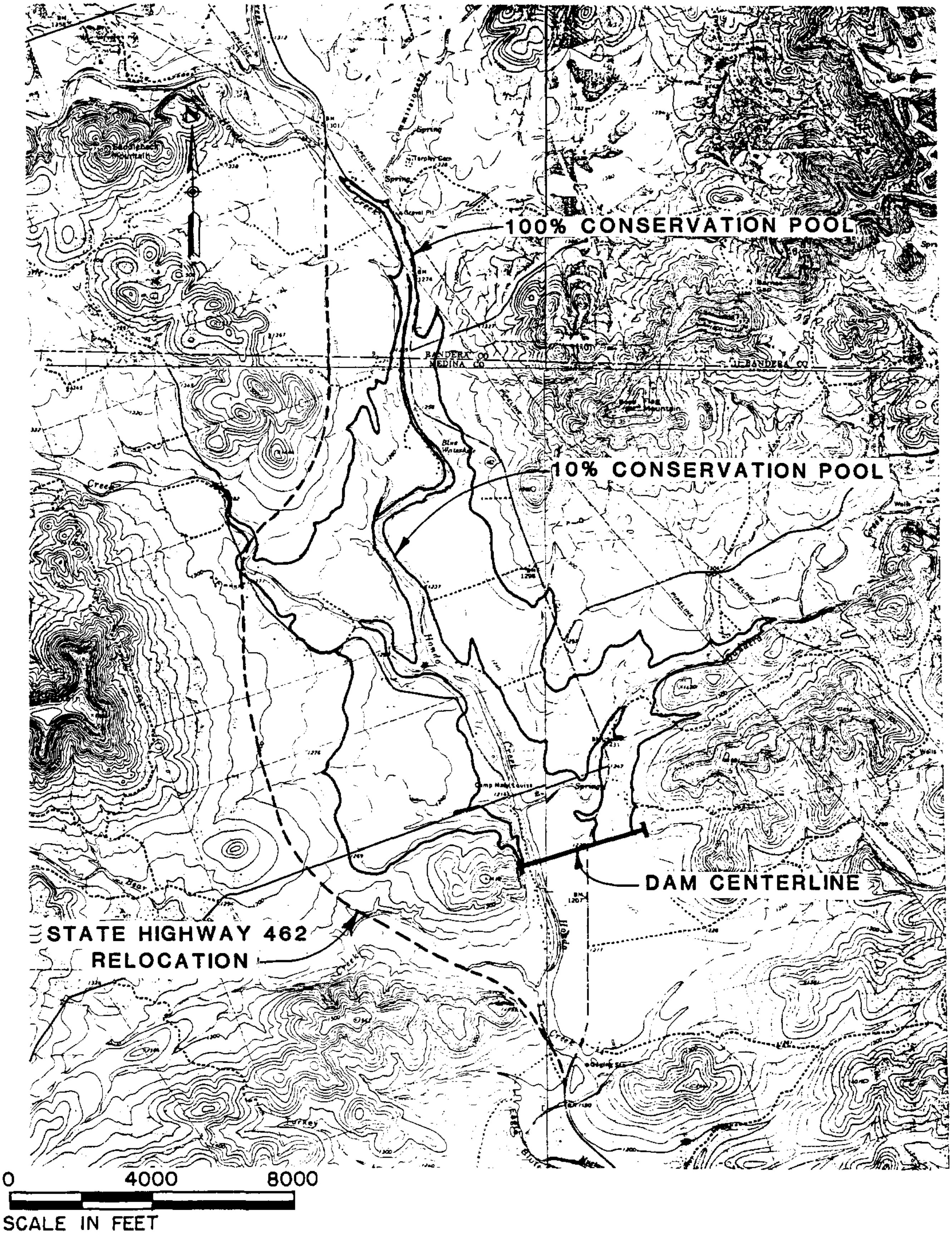
FIGURE 3.1-10

recharge project located downstream of the site, recharge enhancement due to this project would be the least of any Type 1 project evaluated. As indicated in the tables and figures, optimal site development based on average conditions is at about 50% of the maximum conservation capacity at a minimum cost per unit recharge enhancement of $313 per ac-ft per year assuming purchase of water rights from the owners of the CC/LCC System. When honoring all water rights to extent possible (first water rights scenario), the unit cost of recharge enhancement at the 50% capacity becomes $335 per ac-ft per year making the Upper Seco Project the least economical of all Type 1 projects evaluated.

3.1.6 Upper Hondo Project

The Upper Hondo Project is located on Hondo Creek in Medina County about 3 miles south of the Bandera County line near Camp Mary Louise. It is a Type 1 project identified in a previous study by the U.S. Army Corps of Engineers (Ref. 17) and has a maximum conservation capacity of 47,000 ac-ft. As indicated in Figure 3.1-11, development of this project would necessitate the relocation of several miles of State Highway 462 and the acquisition of improved streamfront property including Camp Mary Louise. Environmental considerations at this site include the possible presence of threatened or endangered species, instream flow studies, purchase and management of wooded mitigation lands, and the existance of dinosaur tracks in Hondo Creek downstream of the project. No sites of archaeological significance have been recorded within the maximum conservation pool of the reservoir.

Project cost and data summaries subject to the two water rights scenarios are included as Tables 3.1-6a and 3.1-6b and Figure 3.1-12 graphically summarizes project



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UPPER HONDO PROJECT
SITE MAP

FIGURE 3.1-11

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TABLE 3.1-6a
Upper Hondo Project Cost and Data Summary

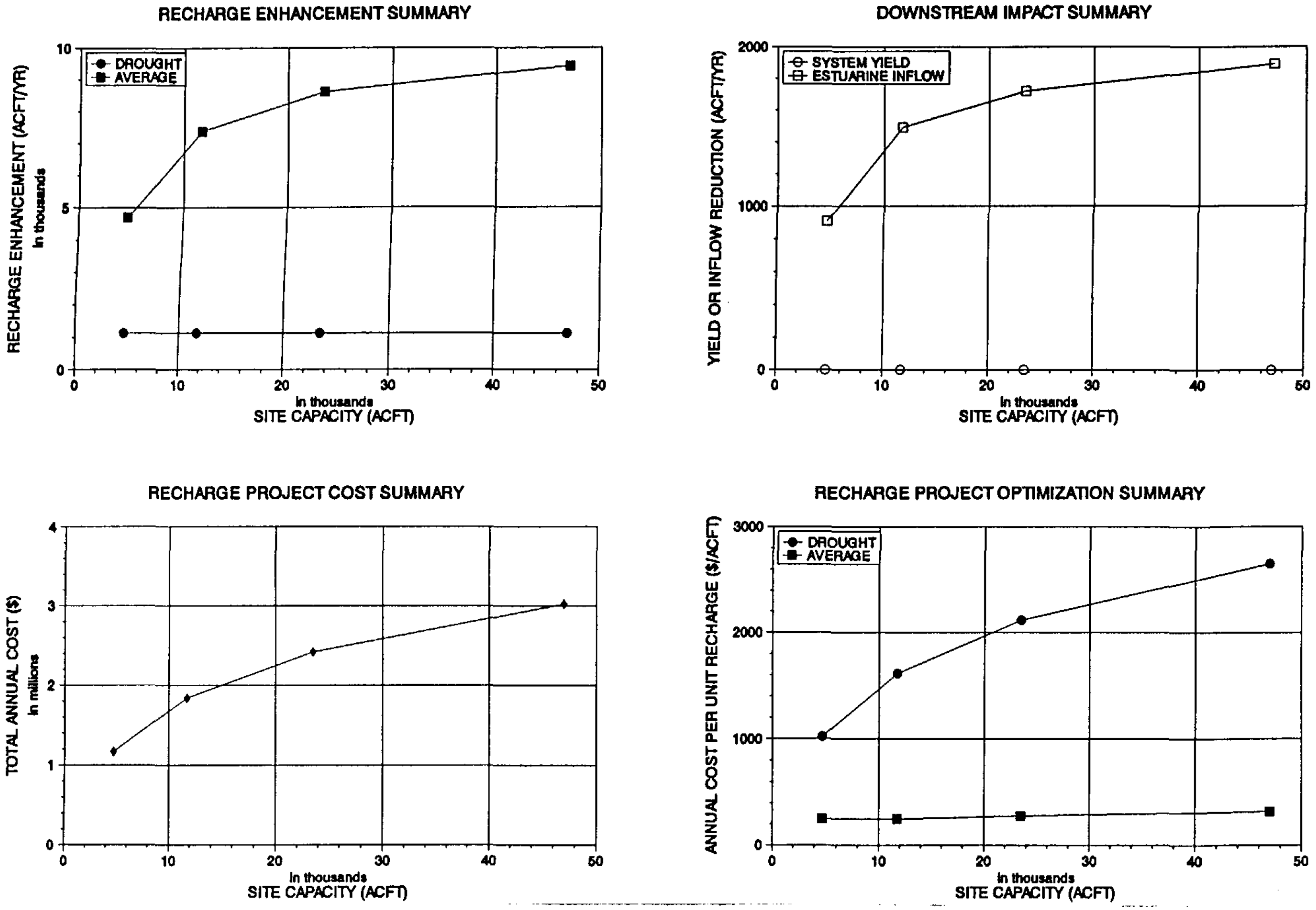
Physical Data	**Percentage of Maximum Project Conservation Capacity**			
	10%	**25%**	**50%**	**100%**
Dam Type	RCC Composite	RCC Composite	RCC Composite	Embankment
Conservation Pool:				
Elevation (ft-msl)	1226.3	1241.1	1251.1	1266.6
Surface Area (ac)	350	770	1,260	2,000
Capacity (acft)	4,700	11,750	23,500	47,000
25-Year Flood Pool:				
Elevation (ft-msl)	1234.5	1247.7	1257.6	1275.1
Surface Area (ac)	570	1,100	1,580	2,480
100-Year Flood Pool:				
Elevation (ft-msl)	1236.1	1249.4	1259.4	1276.8
Surface Area (ac)	610	1,180	1,660	2,570
Top of Dam Elevation (ft-msl)	1247.9	1262.7	1272.7	1290.2
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	1,140	1,140	1,140	1,140
Average Conditions	4,700	7,030	7,680	8,360
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.1	0.1	0.1	0.1
Estuarine Inflow Reduction (acft/yr)	910	1,400	1,550	1,700
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$4,014,600	$6,752,700	$9,212,480	$10,652,840
Road Relocations	$3,380,000	$4,717,667	$6,055,333	$7,393,000
Land Acquisition	$2,776,830	$4,304,440	$5,160,840	$7,138,460
Environmental Mitigation	$352,695	$775,929	$1,269,702	$2,015,400
Engineering, Legal, Financial, and Misc.	$2,104,825	$3,310,147	$4,339,671	$5,439,940
Total Capital Cost	$12,628,950	$19,860,883	$26,038,026	$32,639,640
Capital Cost / Unit Capacity	$2,687	$1,690	$1,108	$694
Annual Capital Cost	$1,132,817	$1,781,521	$2,335,611	$2,927,776
Operations and Maintenance	$19,558	$34,711	$49,450	$62,611
Water Rights Mitigation	$14,560	$22,400	$24,800	$27,200
Total Annual Cost	$1,166,935	$1,838,632	$2,409,861	$3,017,587
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$1,024	$1,613	$2,114	$2,647
Average Conditions	$248	$262	$314	$361

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.1-6b
Upper Hondo Project Cost and Data Summary With Purchase of Water Rights

Physical Data	**Percentage of Maximum Project Conservation Capacity**			
	10%	**25%**	**50%**	**100%**
Dam Type	RCC Composite	RCC Composite	RCC Composite	Embankment
Conservation Pool:				
Elevation (ft-msl)	1226.3	1241.1	1251.1	1266.6
Surface Area (ac)	350	770	1,260	2,000
Capacity (acft)	4,700	11,750	23,500	47,000
25-Year Flood Pool:				
Elevation (ft-msl)	1234.5	1247.7	1257.6	1275.1
Surface Area (ac)	570	1,100	1,580	2,480
100-Year Flood Pool:				
Elevation (ft-msl)	1236.1	1249.4	1259.4	1276.8
Surface Area (ac)	610	1,180	1,660	2,570
Top of Dam Elevation (ft-msl)	1247.9	1262.7	1272.7	1290.2
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	1,140	1,140	1,140	1,140
Average Conditions	4,700	7,370	8,610	9,420
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.1	0.2	0.2	0.2
Estuarine Inflow Reduction (acft/yr)	910	1,490	1,720	1,890
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$4,014,600	$6,752,700	$9,212,480	$10,652,840
Road Relocations	$3,380,000	$4,717,667	$6,055,333	$7,393,000
Land Acquisition	$2,776,830	$4,304,440	$5,160,840	$7,138,460
Environmental Mitigation	$352,695	$775,929	$1,269,702	$2,015,400
Engineering, Legal, Financial, and Misc.	$2,104,825	$3,310,147	$4,339,671	$5,439,940
Total Capital Cost	$12,628,950	$19,860,883	$26,038,026	$32,639,640
Capital Cost / Unit Capacity	$2,687	$1,690	$1,108	$694
Annual Capital Cost	$1,132,817	$1,781,521	$2,335,611	$2,927,776
Operations and Maintenance	$19,558	$34,711	$49,450	$62,611
Water Rights Mitigation	$14,560	$23,840	$27,520	$30,240
Total Annual Cost	$1,166,935	$1,840,072	$2,412,581	$3,020,627
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$1,024	$1,614	$2,116	$2,650
Average Conditions	$248	$250	$280	$321

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.



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UPPER HONDO PROJECT EVALUATION SUMMARY

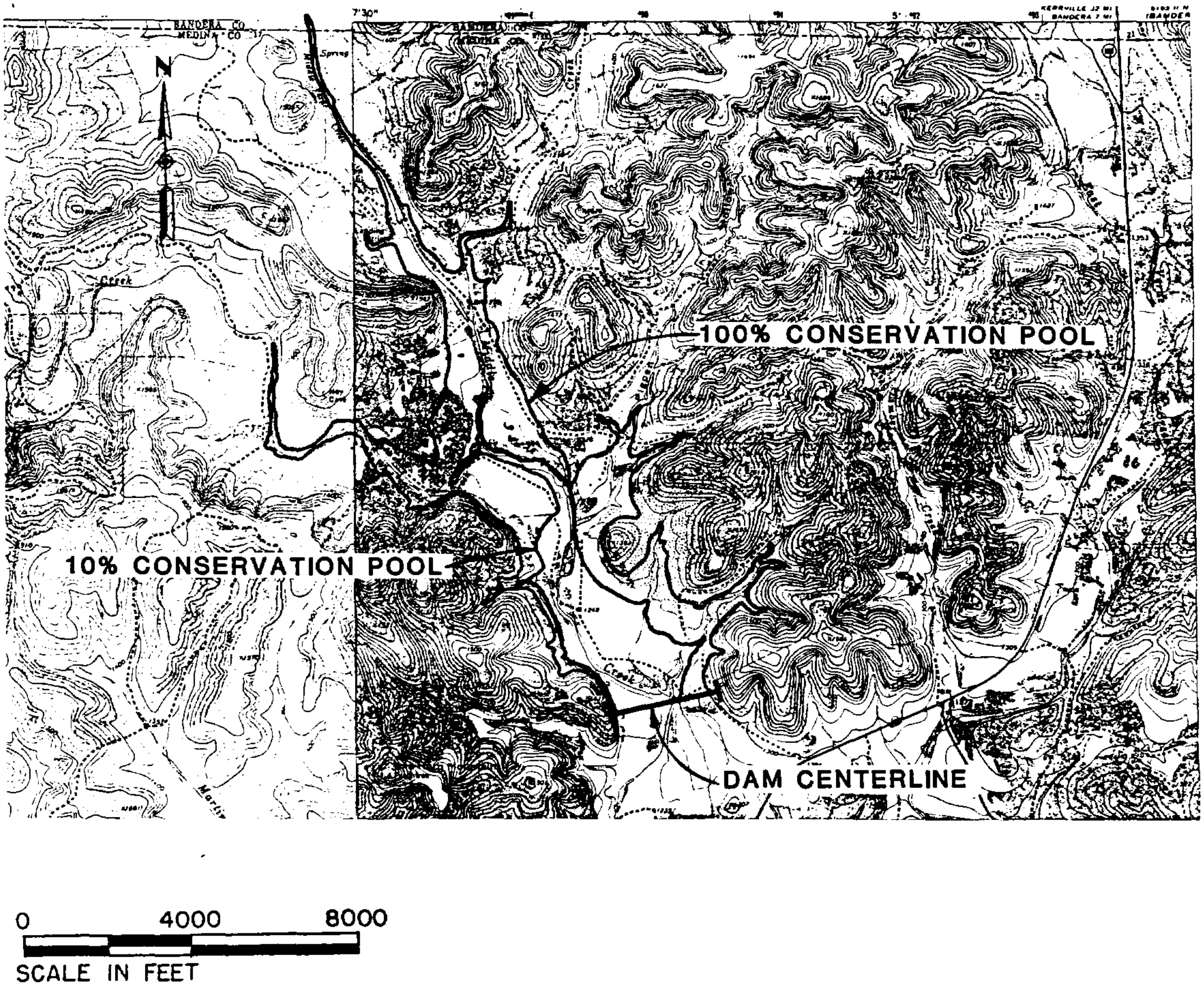
FIGURE 3.1-12

evaluation. Both the embankment dam and the composite embankment / roller compacted concrete dam types were evaluated for this site with the composite dam proving more economical at the 10%, 25%, and 50% capacities and the embankment dam being more economical at the 100% capacity. As indicated in the tables and figures, optimal site development is at about 10% of the maximum conservation capacity at a minimum cost per unit recharge enhancement of $248 per ac-ft per year subject to either of the water rights scenarios considered.

3.1.7 Upper Verde Project

The Upper Verde Project is located on Middle Verde Creek near the upstream edge of the Edwards Aquifer recharge zone. Maximum conservation storage capacity and surface area are 23,000 ac-ft and 880 acres, respectively. As indicated in Figure 3.1-13, no major highway relocations would be necessitated by the project, however, some relocation of private roads would be required. Environmental considerations at this site include the possible presence of threatened or endangered species, instream flow studies, and purchase and management of wooded mitigation lands. No sites of archaeological significance have been recorded within the maximum conservation pool of the reservoir.

Both the embankment dam and the composite embankment / roller compacted concrete dam types were evaluated for this site with the composite dam proving more economical at the 10%, 25%, and 50% capacities and the embankment dam being more economical at the 100% capacity. Although minor flooding was in progress when the site was visited, extensive gravel deposits are likely as gravel has apparently been mined recently immediately upstream of the dam site.



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UPPER VERDE PROJECT
SITE MAP

FIGURE 3.1-13

Project cost and data summaries subject to the two water rights scenarios are included as Tables 3.1-7a and 3.1-7b and Figure 3.1-14 graphically summarizes project evaluation. As indicated in the tables and figures, optimal site development is at about 25% of the maximum conservation capacity at a minimum cost per unit recharge enhancement of $185 per ac-ft per year assuming purchase of water rights from the owners of the CC/LCC System. When honoring all water rights to extent possible (first water rights scenario), the unit cost of recharge enhancement at the 25% capacity becomes $210 per ac-ft per year making the Upper Verde Project the second most economical of all Type 1 projects evaluated.

3.2 Type 2 Mainstem Recharge Enhancement Projects

3.2.1 Indian Creek Project

The Indian Creek Project is located on the Nueces River approximately two miles downstream of the West Nueces River confluence and immediately downstream of the Indian Creek confluence. The project site was identified in a previous study (Ref. 6) and has the second largest maximum conservation capacity (165,000 ac-ft) and largest surface area (7,650 ac) of any of the projects considered in this study. As indicated in Figure 3.2-1, development of this project at 100% capacity would necessitate a minor relocation of State Highway 55.

Although the Indian Creek Project is located near the downstream edge of the Edwards Aquifer recharge zone as is typical of Type 2 projects, it also bears certain similarity to the Type 1 projects as flows may be stored in the reservoir for extended periods due to the relatively low direct percolation rate. Recharge enhancement was calculated

TABLE 3.1-7a
Upper Verde Project Cost and Data Summary

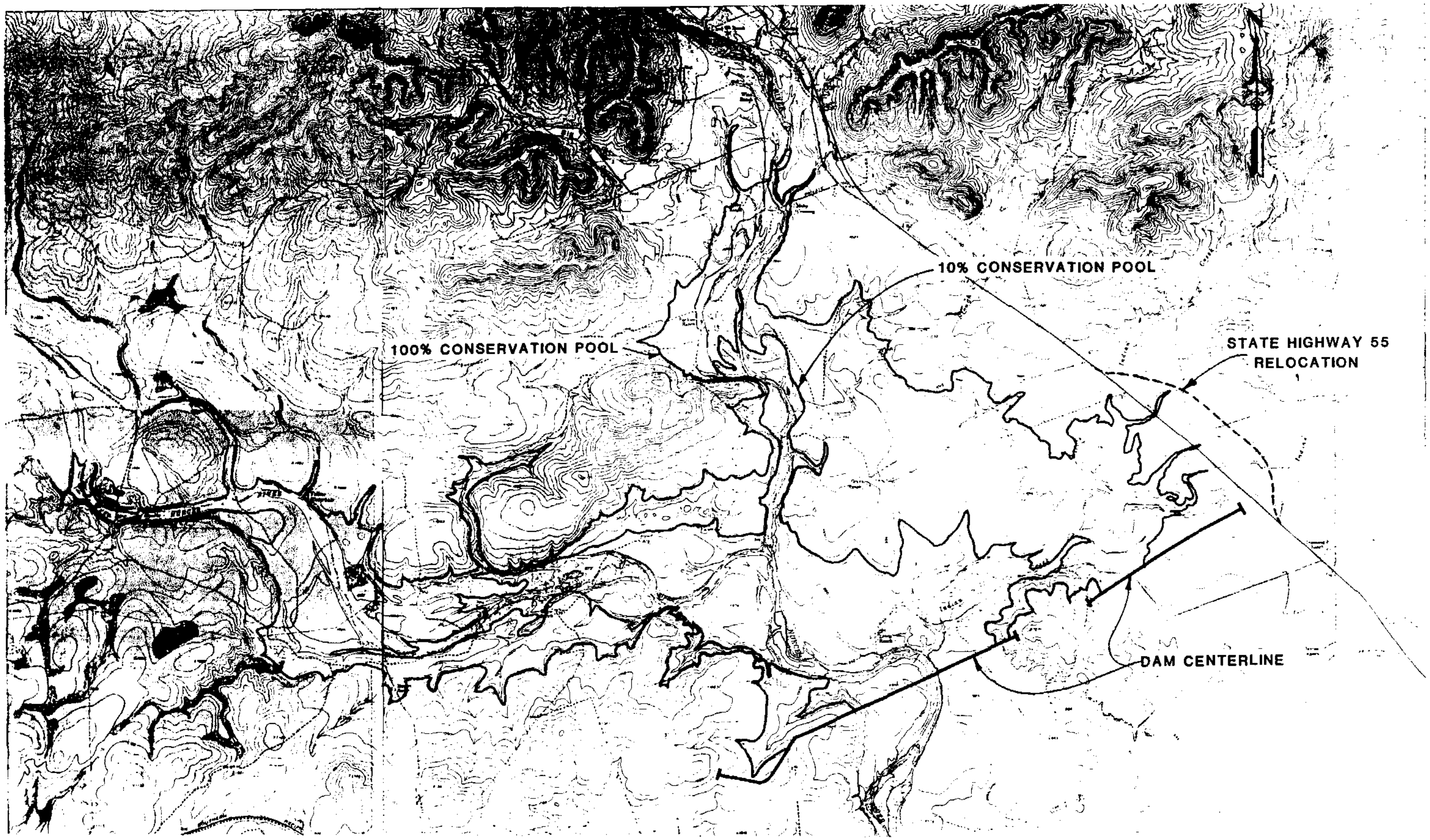
Physical Data	Percentage of Maximum Project conservation Capacity			
	10%	20%	50%	100%
Dam Type	RCC Composite	RCC Composite	RCC Composite	Embankment
Conservation Pool:				
Elevation (ft-msl)	1260.4	1270.6	1283.9	1300.9
Surface Area (ac)	230	350	540	880
Capacity (acft)	2,300	5,750	11,500	23,000
25-Year Flood Pool:				
Elevation (ft-msl)	1266.7	1277.0	1289.7	1312.9
Surface Area (ac)	310	430	660	1,170
100-Year Flood Pool:				
Elevation (ft-msl)	1268.1	1278.3	1291.0	1315.0
Surface Area (ac)	320	450	680	1,220
Top of Dam Elevation (ft-msl)	1280.4	1290.6	1303.9	1331.3
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	1,210	1,390	1,390	1,390
Average Conditions	2,950	3,990	4,280	4,600
CC/LCC System Yield Reduction (acft/yr)	120	120	120	120
Median CC/LCC System Storage Reduction (%)	0.1	0.1	0.1	0.1
Estuarine Inflow Reduction (acft/yr)	490	730	800	880
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$2,928,450	$4,367,670	$6,698,280	$7,546,180
Road Relocations	$125,000	$145,833	$166,667	$85,000
Land Acquisition	$1,931,420	$2,243,620	$3,211,230	$5,048,750
Environmental Mitigation	$244,767	$372,472	$574,670	$936,500
Engineering, Legal, Financial, and Misc.	$1,045,927	$1,425,919	$2,130,169	$2,723,286
Total Capital Cost	$6,275,564	$8,555,514	$12,781,017	$16,339,716
Capital Cost / Unit Capacity	$2,729	$1,488	$1,111	$710
Annual Capital Cost	$562,918	$767,430	$1,146,457	$1,465,673
Operations and Maintenance	$14,014	$20,971	$32,193	$38,985
Water Rights Mitigation	$46,360	$50,200	$51,320	$52,600
Total Annual Cost	$623,292	$838,600	$1,229,970	$1,557,257
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$515	$603	$885	$1,120
Average Conditions	$211	$210	$287	$339

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.1-7b
Upper Verde Project Cost and Data Summary With Purchase of Water Rights

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	RCC Composite	RCC Composite	RCC Composite	Embankment
Conservation Pool:				
Elevation (ft-msl)	1260.4	1270.6	1283.9	1300.9
Surface Area (ac)	230	350	540	880
Capacity (acft)	2,300	5,750	11,500	23,000
25-Year Flood Pool:				
Elevation (ft-msl)	1266.7	1277.0	1289.7	1312.9
Surface Area (ac)	310	430	660	1,170
100-Year Flood Pool:				
Elevation (ft-msl)	1268.1	1278.3	1291.0	1315.0
Surface Area (ac)	320	450	680	1,220
Top of Dam Elevation (ft-msl)	1280.4	1290.6	1303.9	1331.3
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	1,210	1,910	1,910	1,910
Average Conditions	2,950	4,540	4,980	5,580
CC/LCC System Yield Reduction (acft/yr)	120	120	120	120
Median CC/LCC System Storage Reduction (%)	0.1	0.1	0.1	0.1
Estuarine Inflow Reduction (acft/yr)	490	840	940	1,080
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$2,928,450	$4,367,670	$6,698,280	$7,546,180
Road Relocations	$125,000	$145,833	$166,667	$85,000
Land Acquisition	$1,931,420	$2,243,620	$3,211,230	$5,048,750
Environmental Mitigation	$244,767	$372,472	$574,670	$936,500
Engineering, Legal, Financial, and Misc.	$1,045,927	$1,425,919	$2,130,169	$2,723,286
Total Capital Cost	$6,275,564	$8,555,514	$12,781,017	$16,339,716
Capital Cost / Unit Capacity	$2,729	$1,488	$1,111	$710
Annual Capital Cost	$562,918	$767,430	$1,146,457	$1,465,673
Operations and Maintenance	$14,014	$20,971	$32,193	$38,985
Water Rights Mitigation	$46,360	$51,960	$53,560	$55,800
Total Annual Cost	$623,292	$840,360	$1,232,210	$1,560,457
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$515	$440	$645	$817
Average Conditions	$211	$185	$247	$280

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.



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INDIAN CREEK PROJECT
SITE MAP

FIGURE 3.2-1

assuming a direct percolation capacity of 2,000 ac-ft per month and the diversion of up to 2,000 ac-ft per month to the Dry Frio River for subsequent natural recharge. Calculated recharge enhancement for this project was greater than that for any other Type 2 project evaluated. Cost estimates for the Indian Creek Project include the capital costs of a small diversion dam, pump station, and raw water pipeline to the Dry Frio River as well as annual power costs for operation of the pump station.

Environmental considerations at this site include the possibility of threatened or endangered species and the proximity of identified sites of archaeological significance. As the reservoir area will be subject to inundation for extended periods, purchase and management of wooded mitigation lands would be required.

The composite embankment / roller compacted concrete dam type was selected for this site due to the flood potential associated with the large upstream drainage area and the availability of construction materials. A peak flood flow near this site of 616,000 cubic feet per second (63% of the Probable Maximum Flood) was observed in 1935. Abundant gravel to cobble deposits were noted in the river bed during the field reconnaissance.

Project cost and data summaries subject to the two water rights scenarios are included as Tables 3.2-1a and 3.2-1b and Figure 3.2-2 graphically summarizes project evaluation. As indicated in the tables and figures, optimal site development is at about 25% of the maximum conservation capacity at a minimum cost per unit recharge enhancement of $213 per ac-ft per year assuming purchase of water rights from the owners of the CC/LCC System. Preliminary analyses indicate that implementation of the Indian Creek Project will have no significant adverse impact on the braided reach of the Nueces River. Studies conducted by the U.S. Geological Survey (Ref. 18) and frequency analysis of

TABLE 3.2-1a
Indian Creek Project Cost and Data Summary

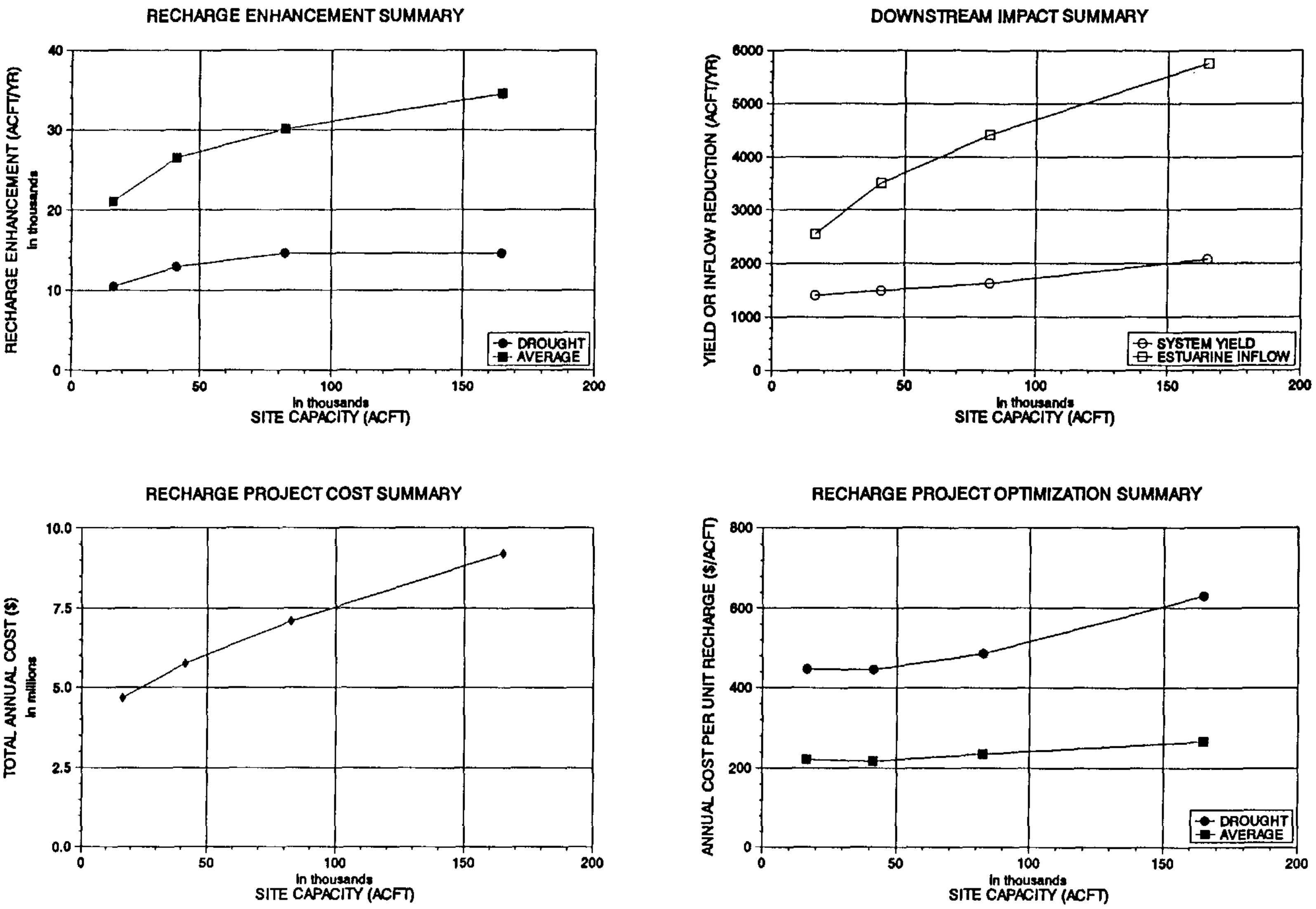
Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	RCC Composite	RCC Composite	RCC Composite	RCC Composite
Conservation Pool:				
Elevation (ft-msl)	975.1	987.9	999.0	1012.5
Surface Area (ac)	1,260	2,770	4,760	7,650
Capacity (acft)	16,500	41,250	82,500	165,000
25-Year Flood Pool:				
Elevation (ft-msl)	984.3	996.9	1007.9	1021.2
Surface Area (ac)	2,190	4,340	6,610	9,620
100-Year Flood Pool:				
Elevation (ft-msl)	986.1	998.8	1009.9	1023.1
Surface Area (ac)	2,460	4,710	7,060	10,100
Top of Dam Elevation (ft-msl)	999.1	1011.9	1023.0	1036.5
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	3,850	3,840	3,840	3,830
Average Conditions	10,680	14,650	18,040	22,180
CC/LCC System Yield Reduction (acft/yr)	10	10	10	10
Median CC/LCC System Storage Reduction (%)	0.0	0.0	0.0	0.0
Estuarine Inflow Reduction (acft/yr)	1,630	2,330	3,030	4,120
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$24,813,930	$31,039,830	$38,486,000	$50,837,120
Road Relocations	$0	$0	$0	$3,148,000
Land Acquisition	$2,488,700	$4,256,100	$6,660,900	$9,985,500
Environmental Mitigation	$701,105	$1,541,319	$2,648,620	$4,256,710
Engineering, Legal, Financial, and Misc.	$5,600,747	$7,367,450	$9,559,104	$13,645,466
Total Capital Cost	$33,604,482	$44,204,698	$57,354,623	$81,872,796
Capital Cost / Unit Capacity	$2,037	$1,072	$695	$496
Annual Capital Cost	$3,014,322	$3,965,161	$5,144,710	$7,343,990
Operations and Maintenance	$1,192,550	$1,221,401	$1,256,388	$1,313,348
Water Rights Mitigation	$29,290	$40,490	$51,690	$69,130
Total Annual Cost	$4,236,162	$5,227,053	$6,452,788	$8,726,468
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$1,100	$1,361	$1,680	$2,278
Average Conditions	$397	$357	$358	$393

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.2-1b
Indian Creek Project Cost and Data Summary With Purchase of Water Rights

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	RCC Composite	RCC Composite	RCC Composite	RCC Composite
Conservation Pool:				
Elevation (ft-msl)	975.1	987.9	999.0	1012.5
Surface Area (ac)	1,260	2,770	4,760	7,650
Capacity (acft)	16,500	41,250	82,500	165,000
25-Year Flood Pool:				
Elevation (ft-msl)	984.3	996.9	1007.9	1021.2
Surface Area (ac)	2,190	4,340	6,610	9,620
100-Year Flood Pool:				
Elevation (ft-msl)	986.1	998.8	1009.9	1023.1
Surface Area (ac)	2,460	4,710	7,060	10,100
Top of Dam Elevation (ft-msl)	999.1	1011.9	1023.0	1036.5
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	10,460	12,920	14,600	14,600
Average Conditions	21,050	26,500	30,130	34,500
CC/LCC System Yield Reduction (acft/yr)	1,410	1,500	1,630	2,080
Median CC/LCC System Storage Reduction (%)	-0.2	-0.1	-0.2	-0.3
Estuarine Inflow Reduction (acft/yr)	2,550	3,510	4,420	5,760
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$24,813,930	$31,039,830	$38,486,000	$50,837,120
Road Relocations	$0	$0	$0	$3,148,000
Land Acquisition	$2,488,700	$4,256,100	$6,660,900	$9,985,500
Environmental Mitigation	$368,365	$809,818	$1,391,600	$2,236,500
Engineering, Legal, Financial, and Misc.	$5,534,199	$7,221,150	$9,307,700	$13,241,424
Total Capital Cost	$33,205,194	$43,326,897	$55,846,200	$79,448,544
Capital Cost / Unit Capacity	$2,012	$1,050	$677	$482
Annual Capital Cost	$2,978,506	$3,886,423	$5,009,404	$7,126,534
Operations and Maintenance	$1,192,550	$1,221,401	$1,256,388	$1,313,348
Water Rights Mitigation	$493,410	$537,660	$593,950	$759,840
Total Annual Cost	$4,664,466	$5,645,484	$6,859,743	$9,199,723
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$446	$437	$470	$630
Average Conditions	$222	$213	$228	$267

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.


RECHARGE ENHANCEMENT SUMMARY

DOWNSTREAM IMPACT SUMMARY

RECHARGE PROJECT COST SUMMARY

RECHARGE PROJECT OPTIMIZATION SUMMARY

NOTE: FIGURES ASSUME PURCHASE OF WATER RIGHTS.

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PLANNING STUDY PHASE III

INDIAN CREEK PROJECT EVALUATION SUMMARY

FIGURE 3.2-2

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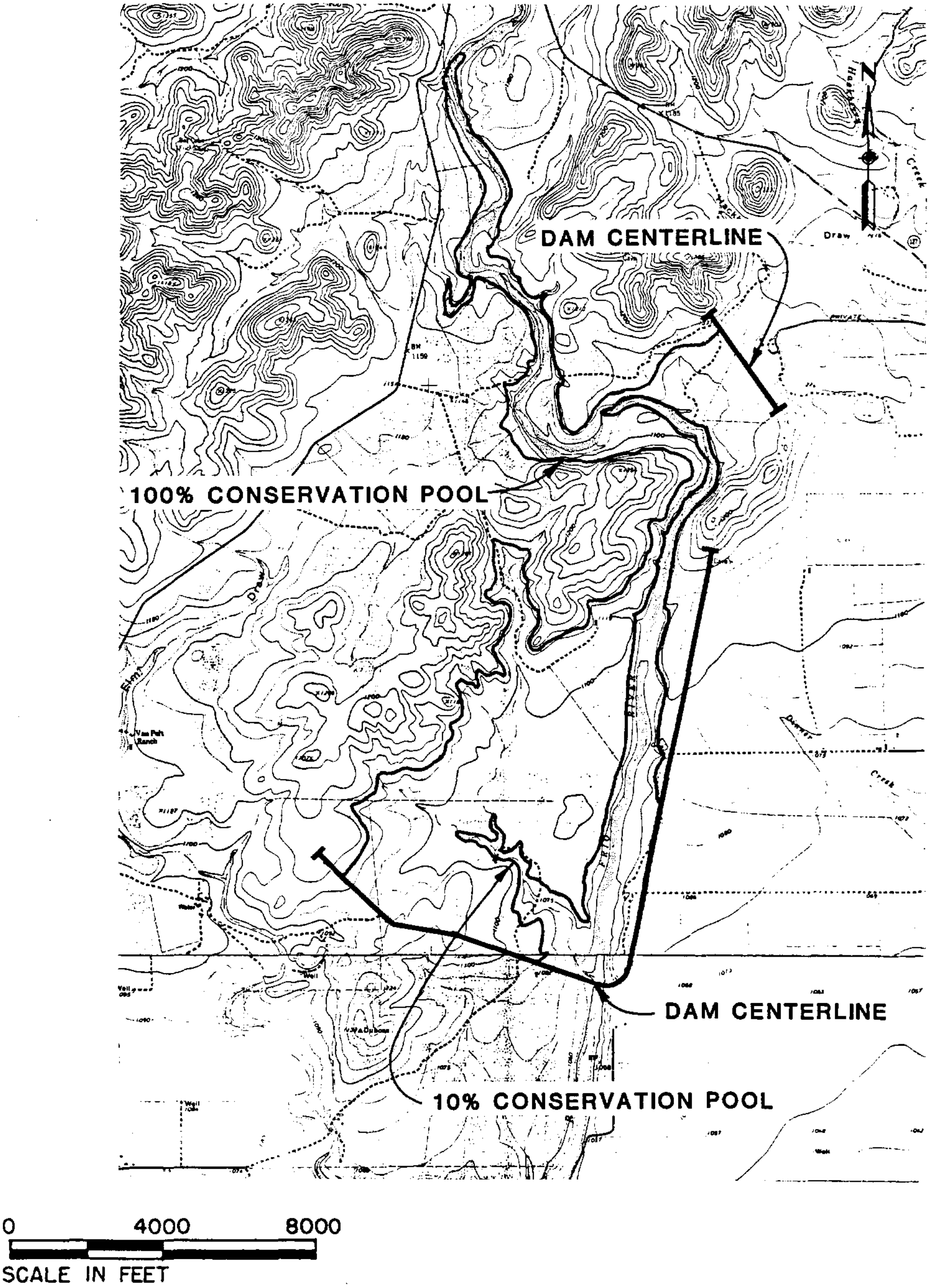
flows from the Nueces River Basin Model indicate that the frequency of overbank inundation would be reduced by less than 1% while the frequency of zero flow would be unaffected by project implementation and operation.

3.2.2 Lower Frio Project

The Lower Frio Project is located on the Frio River approximately 7 miles north of Knippa in Uvalde County. It is a Type 2 recharge enhancement project with a maximum conservation capacity of 50,000 ac-ft and surface area of 1,760 acres. As is apparent in Figure 3.2-3, the project is located in a relatively remote area and no significant relocations would be necessitated by project development. Environmental considerations associated with the development of this project are believed to be limited to basic environmental reports and investigations of cultural resources and values.

The composite embankment / roller compacted concrete dam type was selected for this site due to the flood potential associated with the large upstream drainage area and the availability of construction materials. Abundant gravel deposits were noted both in the channel and on terraces along the right bank during the field reconnaissance.

Project cost and data summaries subject to the two water rights scenarios are included as Tables 3.2-2a and 3.2-2b and Figure 3.2-4 graphically summarizes project evaluation. Due to the high recharge capacity of the Frio River bed, the Lower Frio Project would have no significant impact on the yield of the CC/LCC System because waters originating above the site would not have arrived at Choke Canyon Reservoir during the critical drought under natural conditions. The project would, however, reduce inflows to the CC/LCC System during years outside of the critical drought period. As indicated in the



**NUECES RIVER BASIN
REGIONAL WATER SUPPLY
PLANNING STUDY PHASE III**

LOWER FRIO PROJECT
SITE MAP

FIGURE 3.2-3

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TABLE 3.2-2a
Lower Frio Project Cost and Data Summary

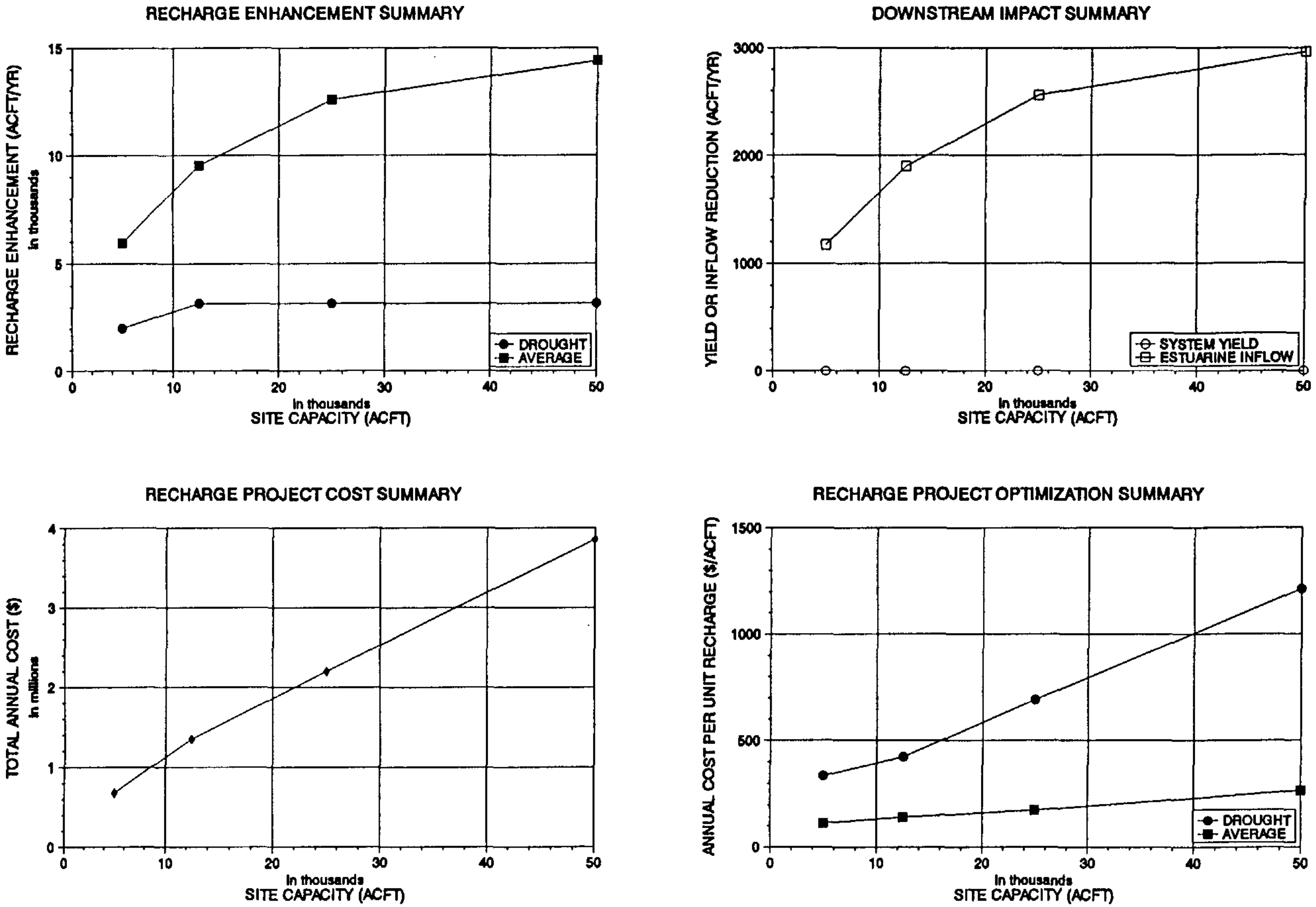
Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	RCC Composite	RCC Composite	RCC Composite	RCC Composite
Conservation Pool:				
Elevation (ft-msl)	1082.1	1094.9	1106.7	1123.2
Surface Area (ac)	340	820	1,280	1,760
Capacity (acft)	5,000	12,500	25,000	50,000
25-Year Flood Pool:				
Elevation (ft-msl)	1087.9	1100.8	1112.6	1129.0
Surface Area (ac)	540	1,080	1,470	1,960
100-Year Flood Pool:				
Elevation (ft-msl)	1089.1	1101.9	1113.6	1130.2
Surface Area (ac)	580	1,120	1,500	2,000
Top of Dam Elevation (ft-msl)	1099.9	1112.7	1124.5	1141.0
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	5	7	7	7
Average Conditions	2,470	4,100	5,400	6,640
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.0	0.0	0.0
Estuarine Inflow Reduction (acft/yr)	540	900	1,190	1,460
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$5,465,930	$10,838,710	$18,060,070	$32,385,260
Road Relocations	$0	$0	$0	$0
Land Acquisition	$452,000	$934,000	$1,241,000	$1,638,000
Environmental Mitigation	$22,197	$53,533	$83,564	$114,900
Engineering, Legal, Financial, and Misc.	$1,188,025	$2,365,249	$3,876,927	$6,827,632
Total Capital Cost	$7,128,152	$14,191,492	$23,261,560	$40,965,792
Capital Cost / Unit Capacity	$1,426	$1,135	$930	$819
Annual Capital Cost	$639,395	$1,272,977	$2,086,562	$3,674,632
Operations and Maintenance	$21,864	$43,355	$72,240	$129,541
Water Rights Mitigation	$8,640	$14,400	$19,040	$23,360
Total Annual Cost	$669,899	$1,330,732	$2,177,842	$3,827,533
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$133,980	$190,105	$311,120	$546,790
Average Conditions	$271	$325	$403	$576

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.2-2b
Lower Frio Project Cost and Data Summary With Purchase of Water Rights

	Percentage of Maximum Project Conservation Capacity			
Physical Data	**10%**	**25%**	**50%**	**100%**
Dam Type	RCC Composite	RCC Composite	RCC Composite	RCC Composite
Conservation Pool:				
Elevation (ft-msl)	1082.1	1094.9	1106.7	1123.2
Surface Area (ac)	340	820	1,280	1,760
Capacity (acft)	5,000	12,500	25,000	50,000
25-Year Flood Pool:				
Elevation (ft-msl)	1087.9	1100.8	1112.6	1129.0
Surface Area (ac)	540	1,080	1,470	1,960
100-Year Flood Pool:				
Elevation (ft-msl)	1089.1	1101.9	1113.6	1130.2
Surface Area (ac)	580	1,120	1,500	2,000
Top of Dam Elevation (ft-msl)	1099.9	1112.7	1124.5	1141.0
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	2,020	3,180	3,180	3,180
Average Conditions	5,940	9,530	12,570	14,400
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.3	0.3	0.3	0.3
Estuarine Inflow Reduction (acft/yr)	1,170	1,900	2,560	2,960
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$5,465,930	$10,838,710	$18,060,070	$32,385,260
Road Relocations	$0	$0	$0	$0
Land Acquisition	$452,000	$934,000	$1,241,000	$1,638,000
Environmental Mitigation	$22,197	$53,533	$83,564	$114,900
Engineering, Legal, Financial, and Misc.	$1,188,025	$2,365,249	$3,876,927	$6,827,632
Total Capital Cost	$7,128,152	$14,191,492	$23,261,560	$40,965,792
Capital Cost / Unit Capacity	$1,426	$1,135	$930	$819
Annual Capital Cost	$639,395	$1,272,977	$2,086,562	$3,674,632
Operations and Maintenance	$21,864	$43,355	$72,240	$129,541
Water Rights Mitigation	$18,720	$30,400	$40,960	$47,360
Total Annual Cost	$679,979	$1,346,732	$2,199,762	$3,851,533
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$337	$424	$692	$1,211
Average Conditions	$114	$141	$175	$267

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.



NOTE: FIGURES ASSUME PURCHASE OF WATER RIGHTS.

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LOWER FRIO PROJECT EVALUATION SUMMARY

FIGURE 3.2-4

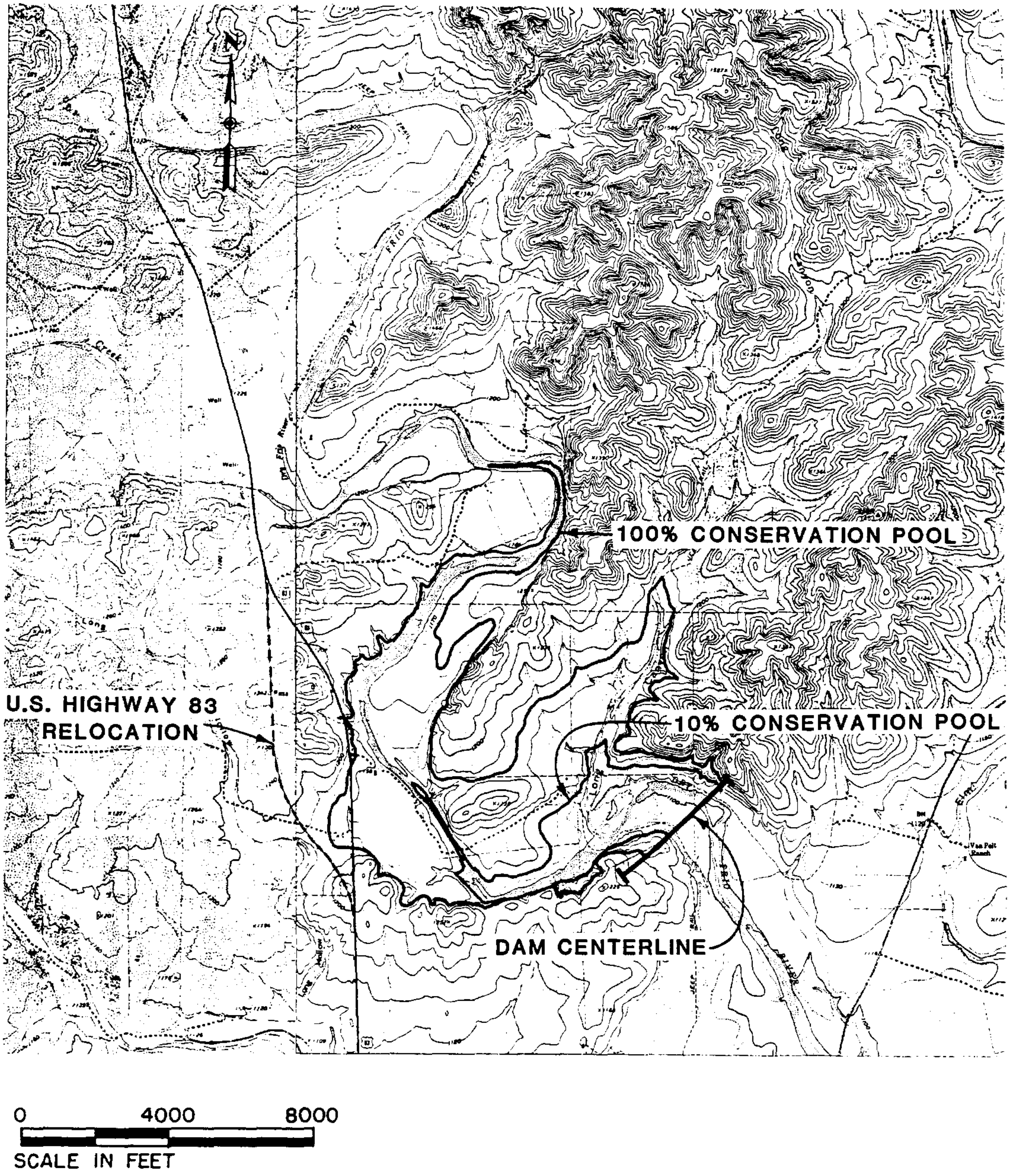
tables and figures, optimal site development is at about 10% of the maximum conservation capacity at a minimum cost per unit recharge enhancement of $114 per ac-ft per year assuming purchase of water rights from the owners of the CC/LCC System. This is a relatively low unit cost of recharge enhancement compared to many of the projects evaluated. Hence, it may be advantageous to construct the Lower Frio Project to a capacity in excess of the "optimum" because additional recharge enhancement may be obtained more economically at this site than by developing another project.

3.2.3 Lower Dry Frio Project

The Lower Dry Frio Project is located on the Dry Frio River approximately 7 miles northwest of Knippa in Uvalde County. It is a Type 2 recharge enhancement project with a maximum conservation capacity of 30,000 ac-ft and surface area of 1,190 acres. As is apparent in Figure 3.2-5, development of this project at capacities in excess of the 25% capacity would necessitate relocation of less than 2 miles of U.S. Highway 83. Environmental considerations associated with the development of this project are believed to be limited to basic environmental reports and investigations of cultural resources and values with the possible exception of a threatened / endangered species survey.

Both the embankment dam and the composite embankment / roller compacted concrete dam types were evaluated for this site with the composite dam proving more economical at the 10%, 25%, and 50% capacities and the embankment dam being more economical at the 100% capacity. Field reconnaissance indicated the presence of sufficient construction materials for either dam type.

Project cost and data summaries subject to the two water rights scenarios are



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LOWER DRY FRIO PROJECT
SITE MAP

FIGURE 3.2-5

included as Tables 3.2-3a and 3.2-3b and Figure 3.2-6 graphically summarizes project evaluation. Due to the high recharge capacity of the Dry Frio River bed, the Lower Dry Frio Project would have no significant impact on the yield of the CC/LCC System because waters originating above the site would not have arrived at Choke Canyon Reservoir during the critical drought under natural conditions. The project would, however, reduce inflows to the CC/LCC System during years outside of the critical drought period. As indicated in the tables and figures, optimal site development is at about 25% of the maximum conservation capacity at a minimum cost per unit recharge enhancement of $216 per ac-ft per year assuming purchase of water rights from the owners of the CC/LCC System.

3.2.4 Lower Sabinal Project

The Lower Sabinal Project is located on the Sabinal River approximately 5 miles north of Sabinal in Uvalde County. It is a Type 2 recharge enhancement project with a maximum conservation capacity of 35,000 ac-ft and surface area of 1,430 acres. As indicated in Figure 3.2-7, development of this project would necessitate only minor relocation of private roads. Environmental considerations associated with the development of this project are believed to be limited to basic environmental reports and investigations of cultural resources and values with the possible exception of a threatened / endangered species survey.

The composite enbankment / roller compacted concrete dam type was selected for this site due to topographic constraints and the availability of construction materials. Massive sand and gravel deposits were noted both in the channel and along the left bank during the field reconnaissance.

TABLE 3.2-3a
Lower Dry Frio Project Cost and Data Summary

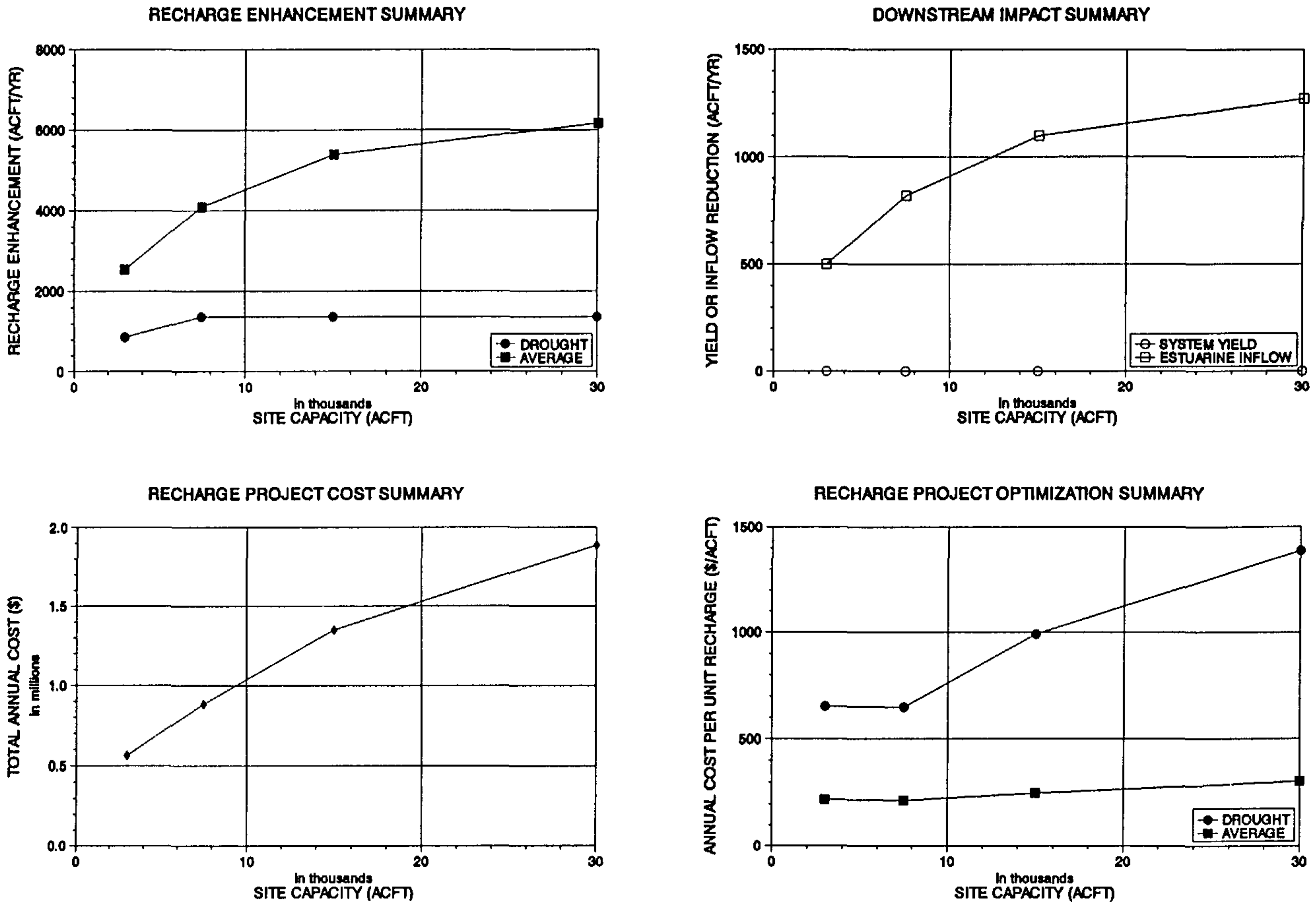
	Percentage of Maximum Project Conservation Capacity			
Physical Data	**10%**	**25%**	**50%**	**100%**
Dam Type	RCC Composite	RCC Composite	RCC Composite	Embankment
Conservation Pool:				
Elevation (ft-msl)	1128.1	1142.1	1155.0	1171.0
Surface Area (ac)	230	420	740	1,190
Capacity (acft)	3,000	7,500	15,000	30,000
25-Year Flood Pool:				
Elevation (ft-msl)	1135.3	1149.4	1162.0	1191.5
Surface Area (ac)	310	590	930	1,974
100-Year Flood Pool:				
Elevation (ft-msl)	1136.8	1150.9	1163.6	1194.2
Surface Area (ac)	330	630	970	2,077
Top of Dam Elevation (ft-msl)	1150.2	1164.2	1177.1	1205.2
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	2	3	3	3
Average Conditions	1,060	1,760	2,310	2,850
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.0	0.0	0.0
Estuarine Inflow Reduction (acft/yr)	240	390	510	630
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$4,605,890	$7,150,300	$10,176,780	$13,358,500
Road Relocations	$0	$0	$830,000	$1,660,000
Land Acquisition	$358,000	$642,000	$914,000	$1,730,700
Environmental Mitigation	$16,235	$29,647	$52,235	$84,000
Engineering, Legal, Financial, and Misc.	$996,025	$1,564,389	$2,394,603	$3,366,640
Total Capital Cost	$5,976,150	$9,386,336	$14,367,618	$20,199,840
Capital Cost / Unit Capacity	$1,992	$1,252	$958	$673
Annual Capital Cost	$536,061	$841,954	$1,288,775	$1,811,926
Operations and Maintenance	$18,424	$28,601	$40,707	$53,434
Water Rights Mitigation	$3,840	$6,240	$8,160	$10,080
Total Annual Cost	$558,324	$876,796	$1,337,642	$1,875,440
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$279,162	$292,265	$445,881	$625,147
Average Conditions	$527	$498	$579	$658

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.2-3b
Lower Dry Frio Project Cost and Data Summary With Purchase of Water Rights

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	**25%**	**50%**	**100%**
Dam Type	RCC Composite	RCC Composite	RCC Composite	Embankment
Conservation Pool:				
Elevation (ft-msl)	1128.1	1142.1	1155.0	1171.0
Surface Area (ac)	230	420	740	1,190
Capacity (acft)	3,000	7,500	15,000	30,000
25-Year Flood Pool:				
Elevation (ft-msl)	1135.3	1149.4	1162.0	1191.5
Surface Area (ac)	310	590	930	1,974
100-Year Flood Pool:				
Elevation (ft-msl)	1136.8	1150.9	1163.6	1194.2
Surface Area (ac)	330	630	970	2,077
Top of Dam Elevation (ft-msl)	1150.2	1164.2	1177.1	1205.2
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	860	1,360	1,360	1,360
Average Conditions	2,540	4,090	5,390	6,170
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.1	0.1	0.1	0.1
Estuarine Inflow Reduction (acft/yr)	500	820	1,100	1,270
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$4,605,890	$7,150,300	$10,176,780	$13,358,500
Road Relocations	$0	$0	$830,000	$1,660,000
Land Acquisition	$358,000	$642,000	$914,000	$1,730,700
Environmental Mitigation	$16,235	$29,647	$52,235	$84,000
Engineering, Legal, Financial, and Misc.	$996,025	$1,564,389	$2,394,603	$3,366,640
Total Capital Cost	$5,976,150	$9,386,336	$14,367,618	$20,199,840
Capital Cost / Unit Capacity	$1,992	$1,252	$958	$673
Annual Capital Cost	$536,061	$841,954	$1,288,775	$1,811,926
Operations and Maintenance	$18,424	$28,601	$40,707	$53,434
Water Rights Mitigation	$8,000	$13,120	$17,600	$20,320
Total Annual Cost	$562,484	$883,676	$1,347,082	$1,885,680
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$654	$650	$991	$1,387
Average Conditions	$221	$216	$250	$306

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.



NOTE: FIGURES ASSUME PURCHASE OF WATER RIGHTS.

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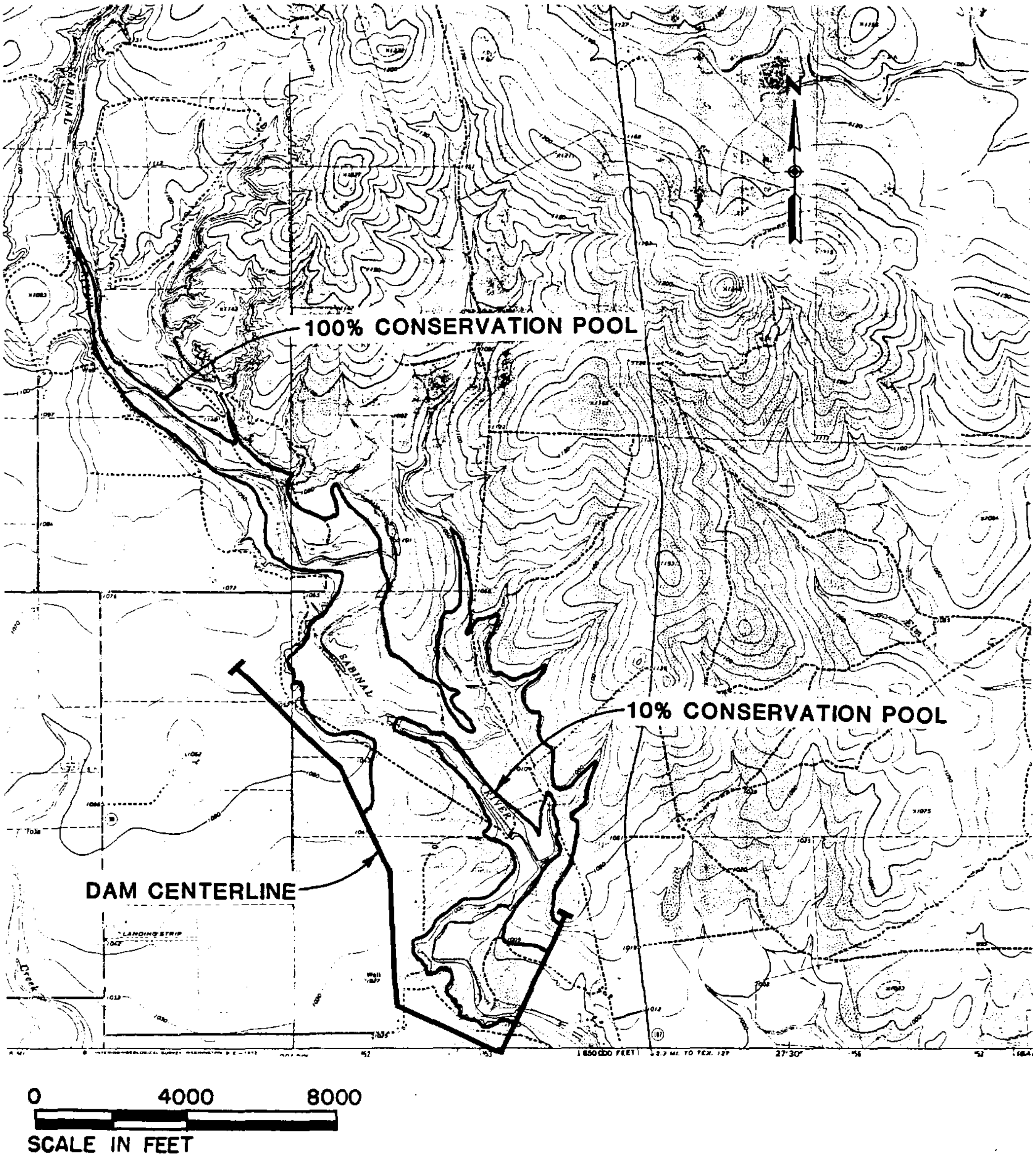
LOWER DRY FRIO PROJECT EVALUATION SUMMARY

FIGURE 3.2-6



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LOWER SABINAL PROJECT SITE MAP

FIGURE 3.2-7

Project cost and data summaries subject to the two water rights scenarios are included as Tables 3.2-4a and 3.2-4b and Figure 3.2-8 graphically summarizes project evaluation. As indicated in the tables and figures, optimal site development is at about 10% of the maximum conservation capacity at a minimum cost per unit recharge enhancement of $66 per ac-ft per year assuming purchase of water rights from the owners of the CC/LCC System. This is by far the lowest unit cost of recharge enhancement for any of the projects evaluated. Hence, it may be advantageous to construct the Lower Sabinal Project to a capacity in excess of the "optimum" because additional recharge enhancement may be obtained more economically at this site than by developing another project.

3.2.5 Lower Seco Project

The Lower Seco Project is located on Seco Creek approximately 10 miles north of D'Hanis in Medina County. It is a Type 2 recharge enhancement project with a maximum conservation capacity of 28,000 ac-ft and surface area of 1,630 acres. As indicated in Figure 3.2-9, development of this project would necessitate only relocation of some private roads. Environmental considerations associated with the development of this project are believed to be limited to basic environmental reports and investigations of cultural resources and values with the possible exception of a threatened / endangered species survey.

Project cost and data summaries subject to the two water rights scenarios are included as Tables 3.2-5a and 3.2-5b and Figure 3.2-10 graphically summarizes project evaluation. The composite enbankment / roller compacted concrete dam type was selected for this site due to topographic constraints and the availability of construction materials. As indicated in the tables and figures, optimal site development is at about 10% of the

TABLE 3.2-4a
Lower Sabinal Project Cost and Data Summary

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	**25%**	**50%**	**100%**
Dam Type	RCC Composite	RCC Composite	RCC Composite	RCC Composite
Conservation Pool:				
Elevation (ft-msl)	1005.1	1018.1	1030.1	1044.7
Surface Area (ac)	280	550	960	1,430
Capacity (acft)	3,500	8,750	17,500	35,000
25-Year Flood Pool:				
Elevation (ft-msl)	1011.0	1023.9	1035.9	1050.5
Surface Area (ac)	380	740	1,140	1,710
100-Year Flood Pool:				
Elevation (ft-msl)	1012.1	1025.1	1037.1	1051.5
Surface Area (ac)	410	780	1,180	1,750
Top of Dam Elevation (ft-msl)	1023.8	1036.8	1048.8	1063.4
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	8	10	10	10
Average Conditions	2,290	4,200	5,860	7,480
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.0	0.0	0.0
Estuarine Inflow Reduction (acft/yr)	500	930	1,290	1,650
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$3,922,400	$7,621,000	$12,701,820	$21,739,840
Road Relocations	$0	$13,333	$26,667	$40,000
Land Acquisition	$319,000	$612,000	$982,000	$1,488,000
Environmental Mitigation	$20,716	$40,692	$71,027	$105,800
Engineering, Legal, Financial, and Misc.	$852,423	$1,657,405	$2,756,303	$4,674,728
Total Capital Cost	$5,114,539	$9,944,431	$16,537,816	$28,048,368
Capital Cost / Unit Capacity	$1,461	$1,137	$945	$801
Annual Capital Cost	$458,774	$892,015	$1,483,442	$2,515,939
Operations and Maintenance	$15,690	$30,484	$50,807	$86,959
Water Rights Mitigation	$8,000	$14,880	$20,640	$26,400
Total Annual Cost	$482,464	$937,379	$1,554,889	$2,629,298
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$60,308	$93,738	$155,489	$262,930
Average Conditions	$211	$223	$265	$352

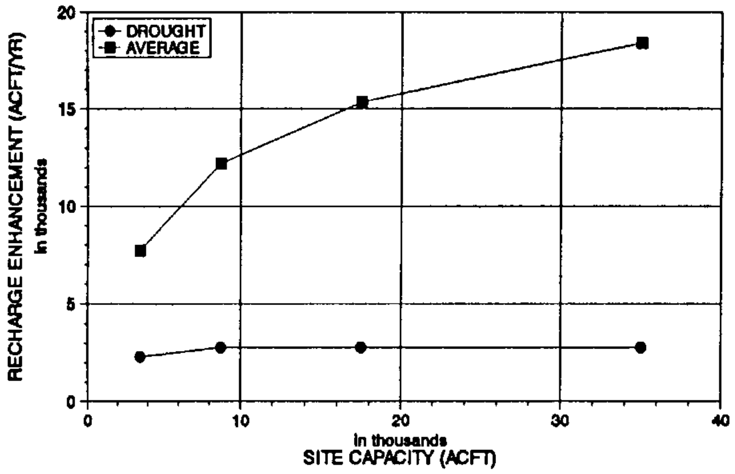
Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.2-4b
Lower Sabinal Project Cost and Data Summary With Purchase of Water Rights

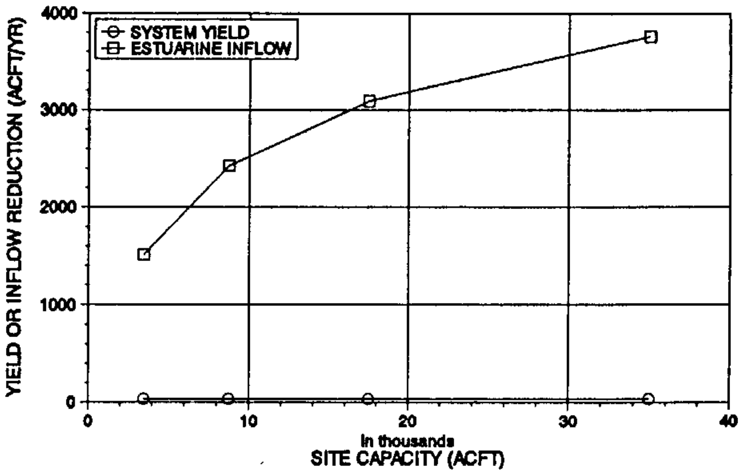
Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	**25%**	**50%**	**100%**
Dam Type	RCC Composite	RCC Composite	RCC Composite	RCC Composite
Conservation Pool:				
Elevation (ft-msl)	1005.1	1018.1	1030.1	1044.7
Surface Area (ac)	280	550	960	1,430
Capacity (acft)	3,500	8,750	17,500	35,000
25-Year Flood Pool:				
Elevation (ft-msl)	1011.0	1023.9	1035.9	1050.5
Surface Area (ac)	380	740	1,140	1,710
100-Year Flood Pool:				
Elevation (ft-msl)	1012.1	1025.1	1037.1	1051.5
Surface Area (ac)	410	780	1,180	1,750
Top of Dam Elevation (ft-msl)	1023.8	1036.8	1048.8	1063.4
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	2,300	2,770	2,770	2,770
Average Conditions	7,720	12,190	15,350	18,400
CC/LCC System Yield Reduction (acft/yr)	30	30	30	30
Median CC/LCC System Storage Reduction (%)	0.4	0.6	0.7	0.7
Estuarine Inflow Reduction (acft/yr)	1,510	2,430	3,090	3,760
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$3,922,400	$7,621,000	$12,701,820	$21,739,840
Road Relocations	$0	$13,333	$26,667	$40,000
Land Acquisition	$319,000	$612,000	$982,000	$1,488,000
Environmental Mitigation	$20,716	$40,692	$71,027	$105,800
Engineering, Legal, Financial, and Misc.	$852,423	$1,657,405	$2,756,303	$4,674,728
Total Capital Cost	$5,114,539	$9,944,431	$16,537,816	$28,048,368
Capital Cost / Unit Capacity	$1,461	$1,137	$945	$801
Annual Capital Cost	$458,774	$892,015	$1,483,442	$2,515,939
Operations and Maintenance	$15,690	$30,484	$50,807	$86,959
Water Rights Mitigation	$33,790	$48,510	$59,070	$69,790
Total Annual Cost	$508,254	$971,009	$1,593,319	$2,672,688
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$221	$351	$575	$965
Average Conditions	$66	$80	$104	$145

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

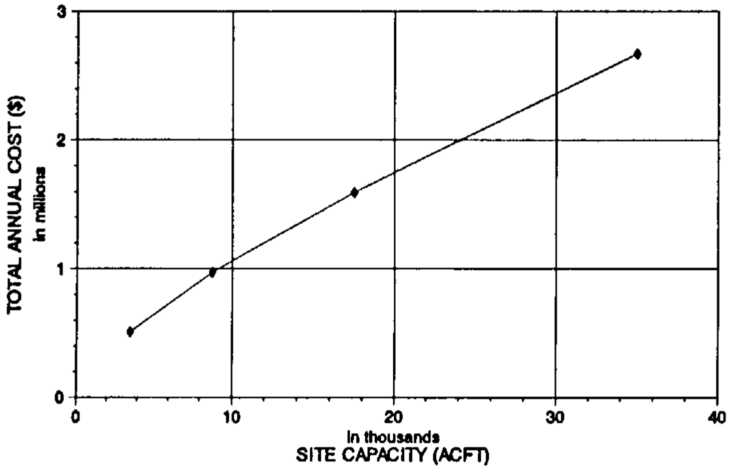
RECHARGE ENHANCEMENT SUMMARY



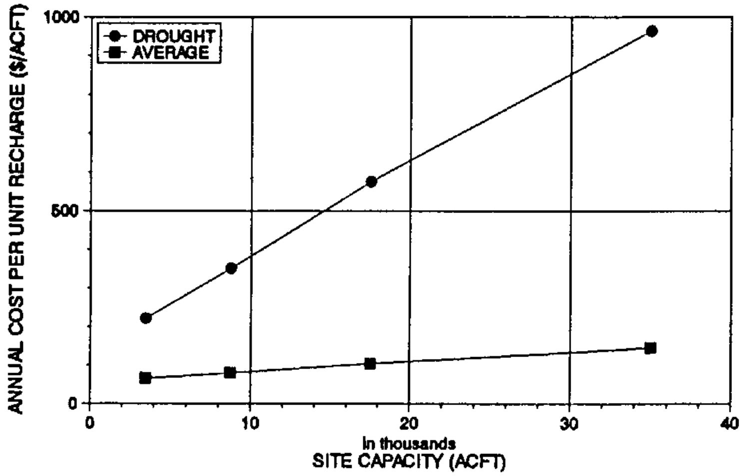
DOWNSTREAM IMPACT SUMMARY



RECHARGE PROJECT COST SUMMARY



RECHARGE PROJECT OPTIMIZATION SUMMARY



NOTE: FIGURES ASSUME PURCHASE OF WATER RIGHTS.

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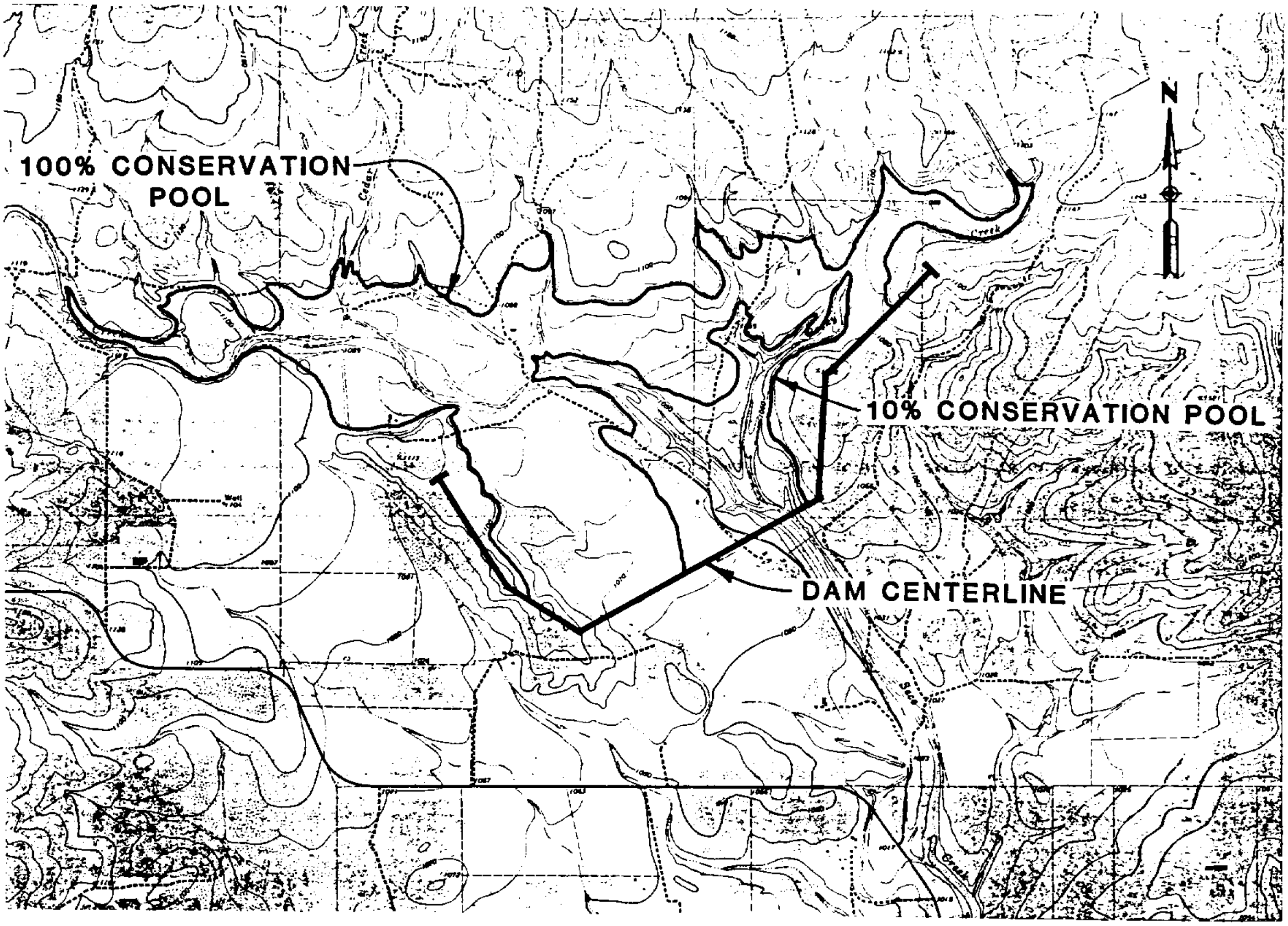
LOWER SABINAL PROJECT EVALUATION SUMMARY

FIGURE 3.2-8



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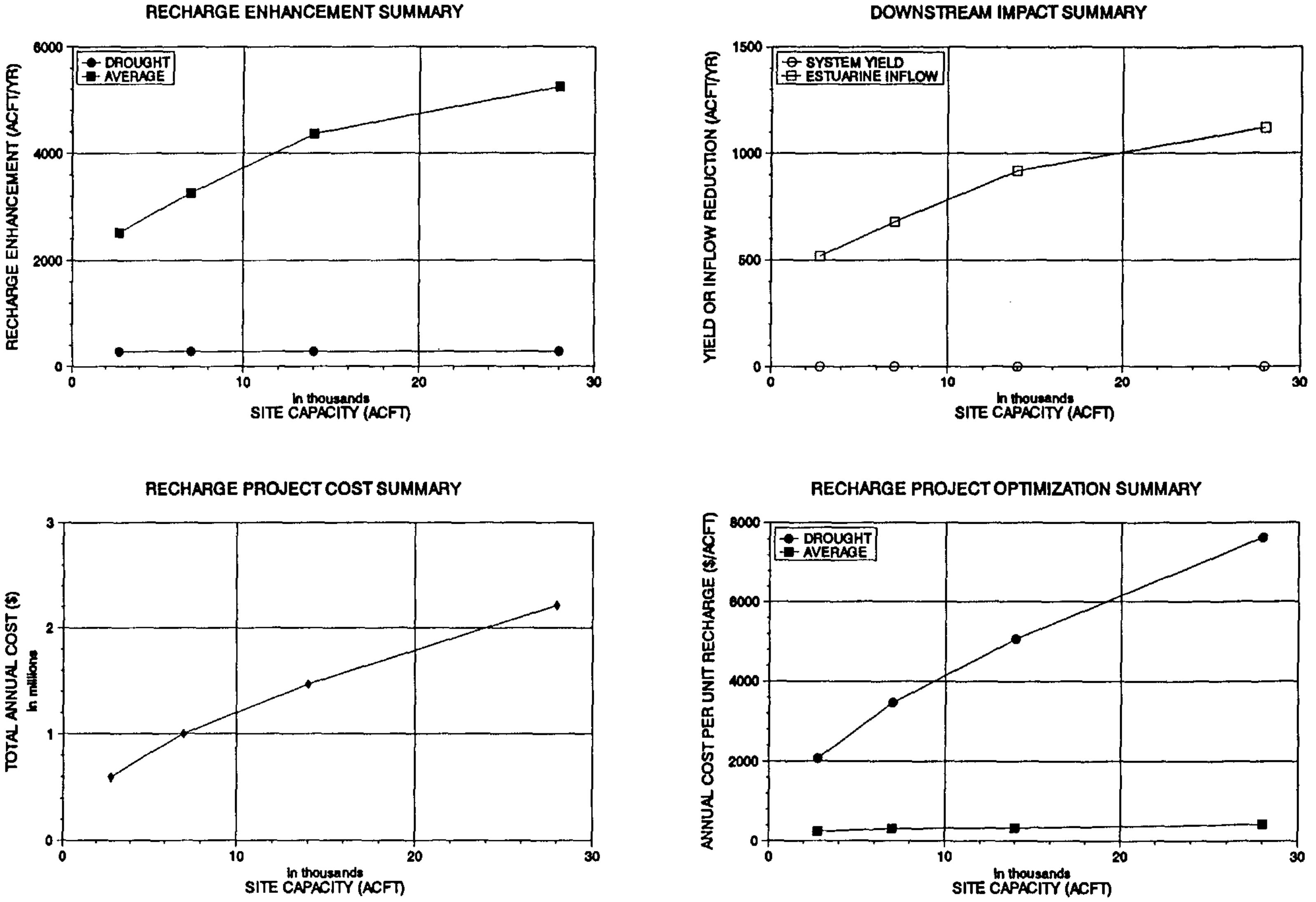
LOWER SECO PROJECT SITE MAP

FIGURE 3.2-9

TABLE 3.2-5a
Lower Seco Project Cost and Data Summary

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	RCC Composite	RCC Composite	RCC Composite	RCC Composite
Conservation Pool:				
Elevation (ft-msl)	1060.2	1070.3	1078.8	1089.7
Surface Area (ac)	220	620	990	1,630
Capacity (acft)	2,800	7,000	14,000	28,000
25-Year Flood Pool:				
Elevation (ft-msl)	1066.1	1076.0	1084.3	1094.9
Surface Area (ac)	480	870	1,300	1,890
100-Year Flood Pool:				
Elevation (ft-msl)	1067.2	1077.1	1085.5	1096.1
Surface Area (ac)	500	920	1,370	1,950
Top of Dam Elevation (ft-msl)	1077.9	1088.0	1096.5	1107.4
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	0	0	0	0
Average Conditions	1,050	1,540	2,240	2,830
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.0	0.0	0.0
Estuarine Inflow Reduction (acft/yr)	230	340	490	620
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$4,857,210	$8,038,650	$11,569,120	$17,665,930
Road Relocations	$0	$58,333	$116,667	$175,000
Land Acquisition	$444,000	$771,000	$1,325,000	$1,792,000
Environmental Mitigation	$14,307	$40,319	$64,380	$106,000
Engineering, Legal, Financial, and Misc.	$1,063,103	$1,781,660	$2,615,033	$3,947,786
Total Capital Cost	$6,378,620	$10,689,963	$15,690,200	$23,686,716
Capital Cost / Unit Capacity	$2,278	$1,527	$1,121	$846
Annual Capital Cost	$572,162	$958,890	$1,407,411	$2,124,698
Operations and Maintenance	$19,429	$32,155	$46,276	$70,664
Water Rights Mitigation	$3,680	$5,440	$7,840	$9,920
Total Annual Cost	$595,271	$996,484	$1,461,527	$2,205,282
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	n/a	n/a	n/a	n/a
Average Conditions	$567	$647	$652	$779

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.



RECHARGE ENHANCEMENT SUMMARY

DOWNSTREAM IMPACT SUMMARY

RECHARGE PROJECT COST SUMMARY

RECHARGE PROJECT OPTIMIZATION SUMMARY

NOTE: FIGURES ASSUME PURCHASE OF WATER RIGHTS.

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LOWER SECO PROJECT EVALUATION SUMMARY

FIGURE 3.2-10

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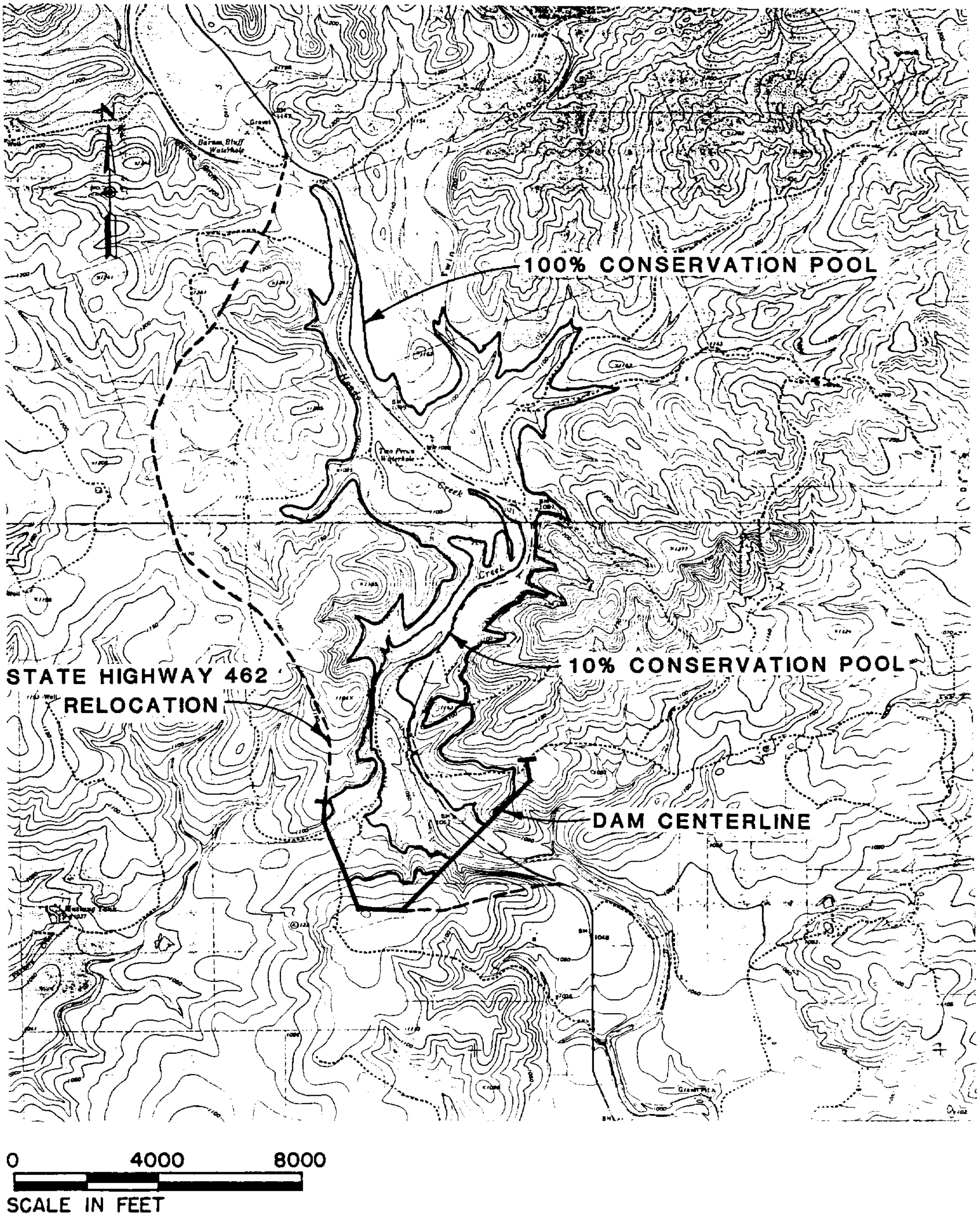
maximum conservation capacity at a minimum cost per unit recharge enhancement of $238 per ac-ft per year assuming purchase of water rights from the owners of the CC/LCC System making the Lower Seco Project the least economical of all Type 2 Mainstem projects evaluated.

3.2.6 Lower Hondo Project

The Lower Hondo Project is located on Hondo Creek approximately 10 miles north by northwest of Hondo in Medina County. It is a Type 2 recharge enhancement project with a maximum conservation capacity of 28,000 ac-ft and surface area of 1,260 acres. As indicated in Figure 3.2-11, development of this project would necessitate relocation of State Highway 462. Environmental considerations associated with the development of this project are believed to be limited to basic environmental reports and investigations of cultural resources and values.

Both the embankment dam and the composite embankment / roller compacted concrete dam types were evaluated for this site with the composite dam proving more economical at all capacities. Field reconnaissance indicated the presence of sufficient construction materials including abundant sands and gravels for either dam type.

Project cost and data summaries subject to the two water rights scenarios are included as Tables 3.2-6a and 3.2-6b and Figure 3.2-12 graphically summarizes project evaluation. As indicated in the tables and figures, optimal site development is at about 10% of the maximum conservation capacity at a minimum cost per unit recharge enhancement of $150 per ac-ft per year assuming purchase of water rights from the owners of the CC/LCC System.



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LOWER HONDO PROJECT
SITE MAP

FIGURE 3.2-11

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TABLE 3.2-6a
Lower Hondo Project Cost and Data Summary

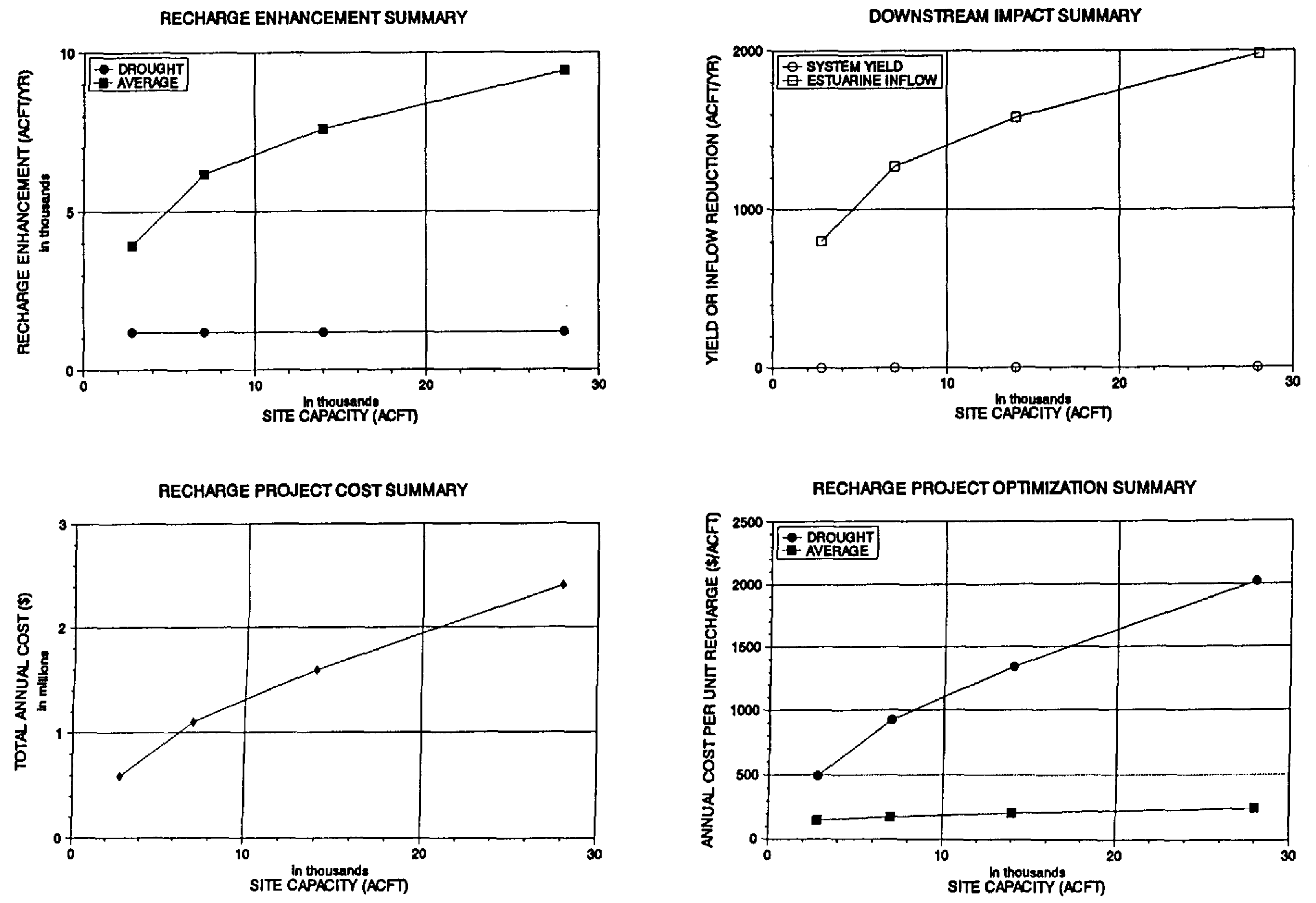
Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	RCC Composite	RCC Composite	RCC Composite	RCC Composite
Conservation Pool:				
Elevation (ft-msl)	1064.4	1077.6	1087.6	1102.4
Surface Area (ac)	230	490	770	1,260
Capacity (acft)	2,800	7,000	14,000	28,000
25-Year Flood Pool:				
Elevation (ft-msl)	1071.1	1084.1	1094.0	1108.0
Surface Area (ac)	360	660	960	1,550
100-Year Flood Pool:				
Elevation (ft-msl)	1072.4	1085.4	1095.3	1109.5
Surface Area (ac)	390	700	1,000	1,620
Top of Dam Elevation (ft-msl)	1085.8	1099.0	1109.0	1123.8
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	3	3	3	3
Average Conditions	1,280	2,290	3,220	4,230
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.0	0.0	0.0
Estuarine Inflow Reduction (acft/yr)	280	510	710	930
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$3,600,630	$6,201,580	$8,733,540	$13,767,960
Road Relocations	$1,187,500	$2,810,667	$4,433,833	$6,057,000
Land Acquisition	$403,000	$748,000	$1,038,000	$1,625,000
Environmental Mitigation	$15,406	$32,822	$51,578	$84,400
Engineering, Legal, Financial, and Misc.	$1,041,307	$1,958,614	$2,851,390	$4,306,872
Total Capital Cost	$6,247,844	$11,751,683	$17,108,341	$25,841,232
Capital Cost / Unit Capacity	$2,231	$1,679	$1,222	$923
Annual Capital Cost	$560,432	$1,054,126	$1,534,618	$2,317,959
Operations and Maintenance	$14,403	$24,806	$34,934	$55,072
Water Rights Mitigation	$4,480	$8,160	$11,360	$14,880
Total Annual Cost	$579,314	$1,087,092	$1,580,912	$2,387,910
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$193,105	$362,364	$526,971	$795,970
Average Conditions	$453	$475	$491	$565

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.2-6b
Lower Hondo Project Cost and Data Summary With Purchase of Water Rights

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	RCC Composite	RCC Composite	RCC Composite	RCC Composite
Conservation Pool:				
Elevation (ft-msl)	1064.4	1077.6	1087.6	1102.4
Surface Area (ac)	230	490	770	1,260
Capacity (acft)	2,800	7,000	14,000	28,000
25-Year Flood Pool:				
Elevation (ft-msl)	1071.1	1084.1	1094.0	1108.0
Surface Area (ac)	360	660	960	1,550
100-Year Flood Pool:				
Elevation (ft-msl)	1072.4	1085.4	1095.3	1109.5
Surface Area (ac)	390	700	1,000	1,620
Top of Dam Elevation (ft-msl)	1085.8	1099.0	1109.0	1123.8
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	1,190	1,190	1,190	1,190
Average Conditions	3,930	6,170	7,601	9,420
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.1	0.1	0.2	0.2
Estuarine Inflow Reduction (acft/yr)	800	1,270	1,580	1,980
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$3,600,630	$6,201,580	$8,733,540	$13,767,960
Road Relocations	$1,187,500	$2,810,667	$4,433,833	$6,057,000
Land Acquisition	$403,000	$748,000	$1,038,000	$1,625,000
Environmental Mitigation	$15,406	$32,822	$51,578	$84,400
Engineering, Legal, Financial, and Misc.	$1,041,307	$1,958,614	$2,851,390	$4,306,872
Total Capital Cost	$6,247,844	$11,751,683	$17,108,341	$25,841,232
Capital Cost / Unit Capacity	$2,231	$1,679	$1,222	$923
Annual Capital Cost	$560,432	$1,054,126	$1,534,618	$2,317,959
Operations and Maintenance	$14,403	$24,806	$34,934	$55,072
Water Rights Mitigation	$12,800	$20,320	$25,280	$31,680
Total Annual Cost	$587,634	$1,099,252	$1,594,832	$2,404,710
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$494	$924	$1,340	$2,021
Average Conditions	$150	$178	$210	$255

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.



NOTE: FIGURES ASSUME PURCHASE OF WATER RIGHTS.

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LOWER HONDO PROJECT EVALUATION SUMMARY

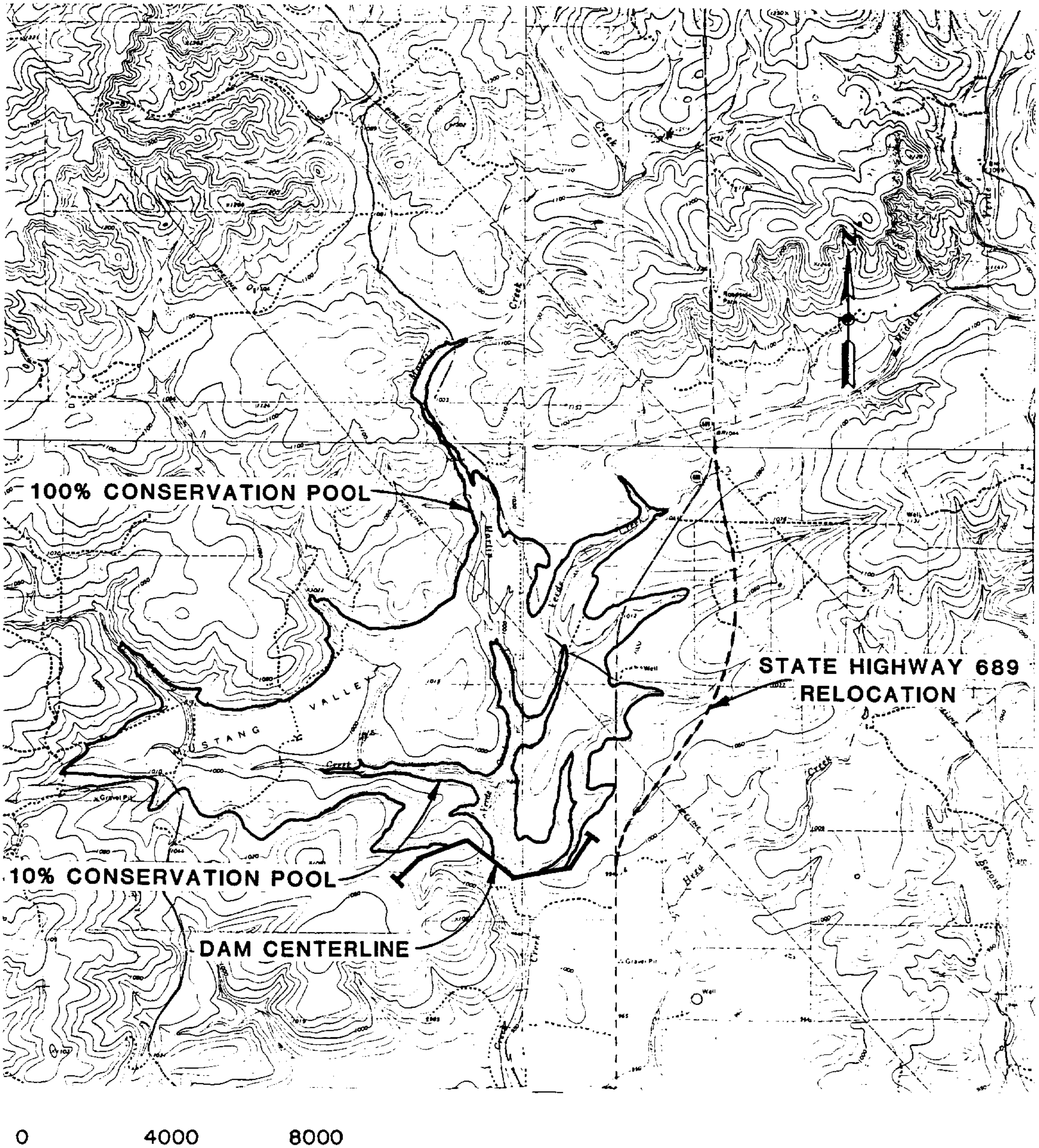
FIGURE 3.2-12

3.2.7 Lower Verde Project

The Lower Verde Project is located on Verde Creek approximately 9 miles north of Hondo in Medina County. It is a Type 2 recharge enhancement project with a maximum conservation capacity of 24,000 ac-ft and surface area of 1,730 acres. As indicated in Figure 3.2-13, development of this project at maximum capacity would necessitate relocation of about 2 miles of State Highway 689. Environmental considerations associated with the development of this project are believed to be limited to basic environmental reports and investigations of cultural resources and values.

Both the embankment dam and the composite embankment / roller compacted concrete dam types were evaluated for this site with the composite dam proving more economical at the 10%, 25%, and 50% capacities and the embankment dam being more economical at the 100% capacity. Field reconnaissance indicated a highly fractured limestone creek bed with visible evidence of faulting as well as the presence of sufficient construction materials for either dam type.

Project cost and data summaries subject to the two water rights scenarios are included as Tables 3.2-7a and 3.2-7b and Figure 3.2-14 graphically summarizes project evaluation. As indicated in the tables and figures, optimal site development is at about 10% of the maximum conservation capacity at a minimum cost per unit recharge enhancement of $134 per ac-ft per year assuming purchase of water rights from the owners of the CC/LCC System. This is a relatively low unit cost of recharge enhancement compared to many of the projects evaluated. Hence, it may be advantageous to construct the Lower Verde Project to a capacity in excess of the "optimum" because additional recharge



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LOWER VERDE PROJECT SITE MAP

FIGURE 3.2-13

TABLE 3.2-7a
Lower Verde Project Cost and Data Summary

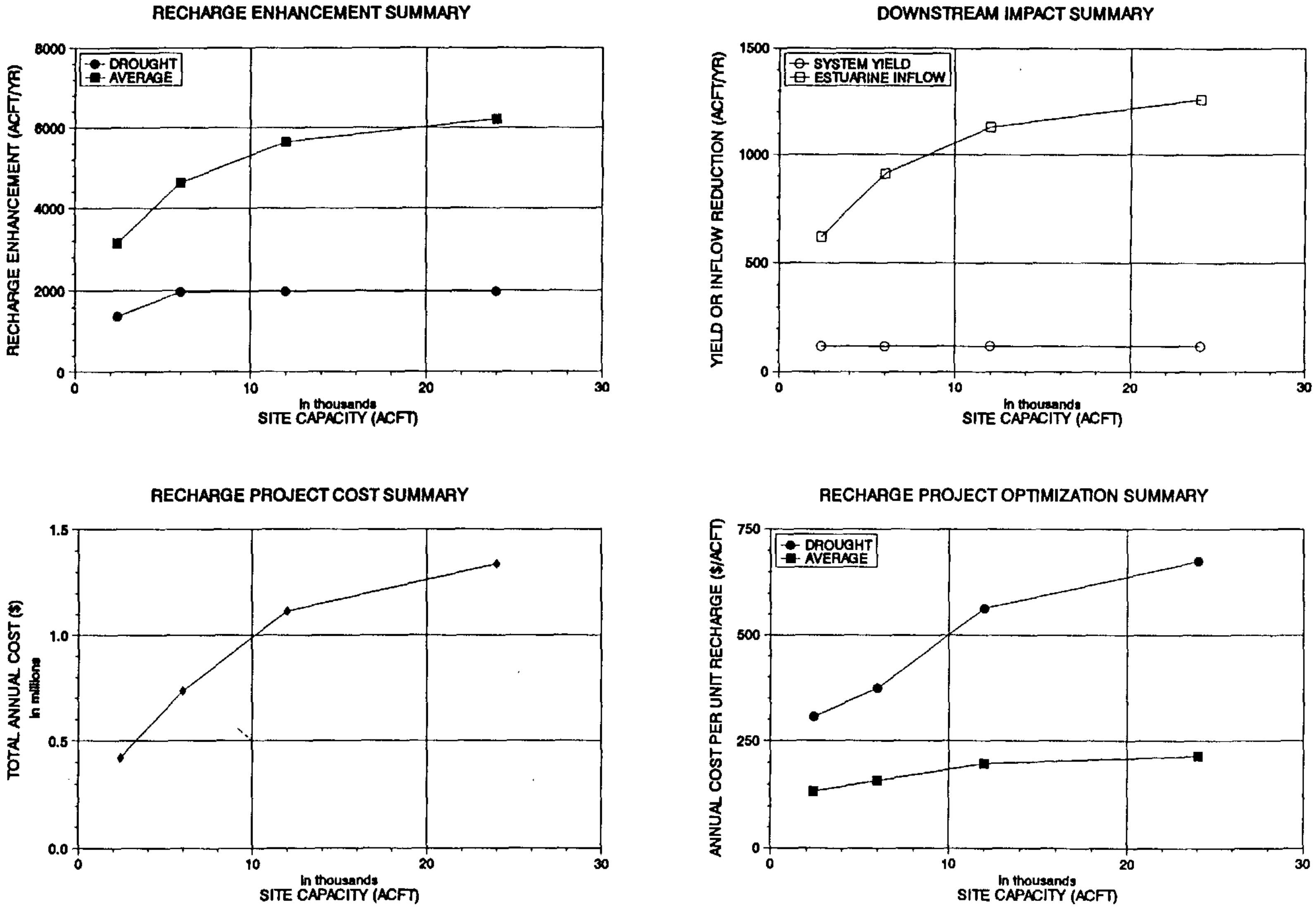
Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	RCC Composite	RCC Composite	RCC Composite	Embankment
Conservation Pool:				
Elevation (ft-msl)	985.6	995.6	1003.7	1012.8
Surface Area (ac)	230	500	980	1,730
Capacity (acft)	2,400	6,000	12,000	24,000
25-Year Flood Pool:				
Elevation (ft-msl)	992.6	1002.3	1010.1	1024.2
Surface Area (ac)	400	860	1,550	2,480
100-Year Flood Pool:				
Elevation (ft-msl)	993.9	1003.6	1011.2	1025.9
Surface Area (ac)	450	980	1,620	2,590
Top of Dam Elevation (ft-msl)	1006.2	1016.2	1024.3	1038.0
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	0	0	0	0
Average Conditions	920	1,660	2,290	2,800
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.0	0.0	0.0
Estuarine Inflow Reduction (acft/yr)	210	370	510	620
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$2,857,990	$4,397,120	$6,038,490	$6,210,490
Road Relocations	$0	$846,667	$1,693,333	$2,540,000
Land Acquisition	$495,000	$898,000	$1,825,000	$2,788,800
Environmental Mitigation	$14,810	$32,197	$63,105	$111,400
Engineering, Legal, Financial, and Misc.	$673,560	$1,234,797	$1,923,986	$2,330,138
Total Capital Cost	$4,041,360	$7,408,780	$11,543,914	$13,980,828
Capital Cost / Unit Capacity	$1,684	$1,235	$962	$583
Annual Capital Cost	$362,510	$664,568	$1,035,489	$1,254,080
Operations and Maintenance	$11,432	$17,588	$24,154	$24,842
Water Rights Mitigation	$3,360	$5,920	$8,160	$9,920
Total Annual Cost	$377,302	$688,076	$1,067,803	$1,288,842
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	n/a	n/a	n/a	n/a
Average Conditions	$410	$415	$466	$460

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.2-7b
Lower Verde Project Cost and Data Summary With Purchase of Water Rights

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	RCC Composite	RCC Composite	RCC Composite	Embankment
Conservation Pool:				
Elevation (ft-msl)	985.6	995.6	1003.7	1012.8
Surface Area (ac)	230	500	980	1,730
Capacity (acft)	2,400	6,000	12,000	24,000
25-Year Flood Pool:				
Elevation (ft-msl)	992.6	1002.3	1010.1	1024.2
Surface Area (ac)	400	860	1,550	2,480
100-Year Flood Pool:				
Elevation (ft-msl)	993.9	1003.6	1011.2	1025.9
Surface Area (ac)	450	980	1,620	2,590
Top of Dam Elevation (ft-msl)	1006.2	1016.2	1024.3	1038.0
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	1,380	1,970	1,980	1,980
Average Conditions	3,150	4,630	5,640	6,220
CC/LCC System Yield Reduction (acft/yr)	120	120	120	120
Median CC/LCC System Storage Reduction (%)	0.1	0.1	0.2	0.2
Estuarine Inflow Reduction (acft/yr)	620	910	1,130	1,260
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$2,857,990	$4,397,120	$6,038,490	$6,210,490
Road Relocations	$0	$846,667	$1,693,333	$2,540,000
Land Acquisition	$495,000	$898,000	$1,825,000	$2,788,800
Environmental Mitigation	$14,810	$32,197	$63,105	$111,400
Engineering, Legal, Financial, and Misc.	$673,560	$1,234,797	$1,923,986	$2,330,138
Total Capital Cost	$4,041,360	$7,408,780	$11,543,914	$13,980,828
Capital Cost / Unit Capacity	$1,684	$1,235	$962	$583
Annual Capital Cost	$362,510	$664,568	$1,035,489	$1,254,080
Operations and Maintenance	$11,432	$17,588	$24,154	$24,842
Water Rights Mitigation	$48,440	$53,080	$56,600	$58,680
Total Annual Cost	$422,382	$735,236	$1,116,243	$1,337,602
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$306	$373	$564	$676
Average Conditions	$134	$159	$198	$215

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.



NOTE: FIGURES ASSUME PURCHASE OF WATER RIGHTS.

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LOWER VERDE PROJECT EVALUATION SUMMARY

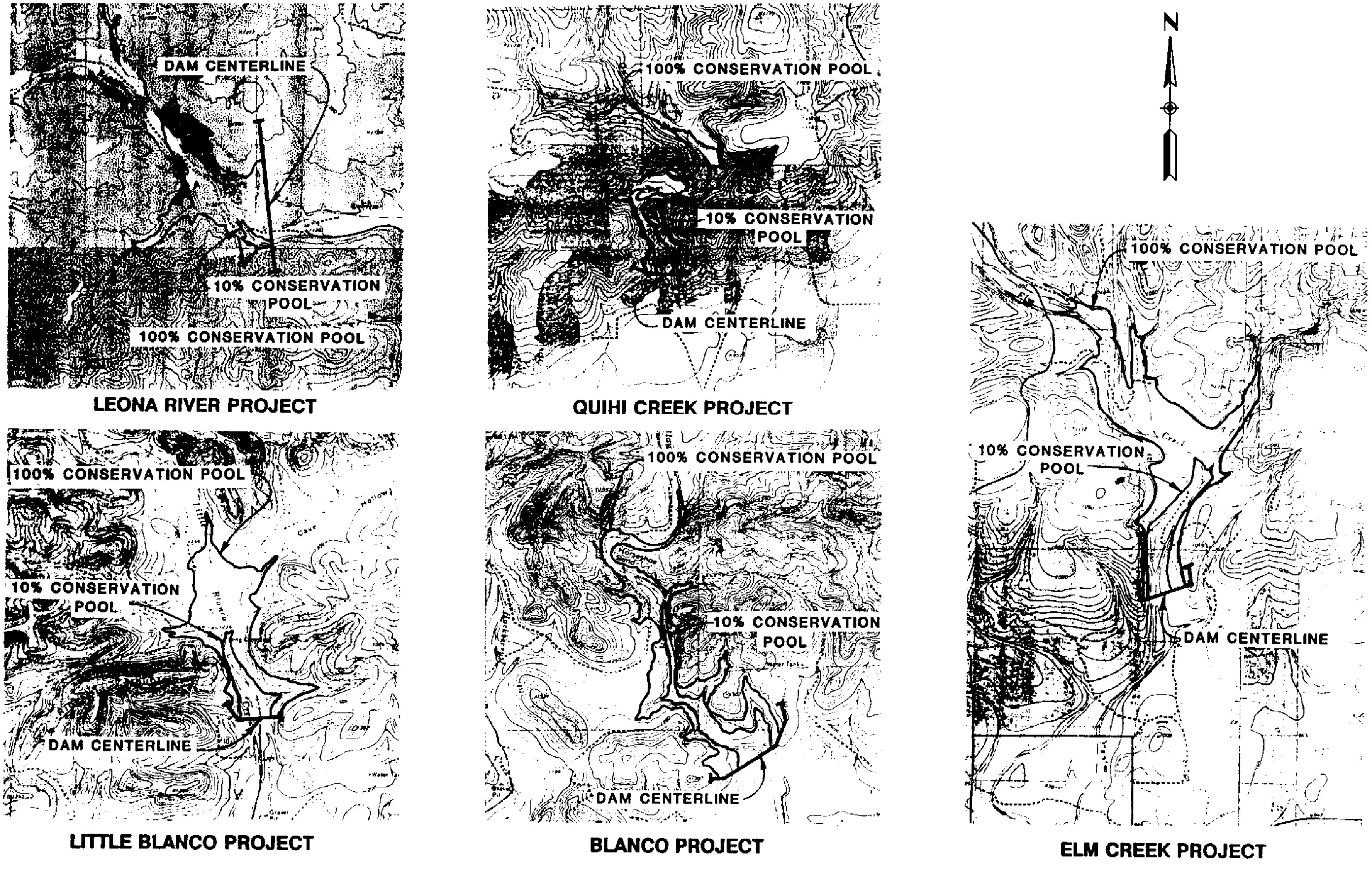
FIGURE 3.2-14

enhancement may be obtained more economically at this site than by developing another project.

3.3 Type 2 Tributary Recharge Enhancement Projects

A total of five Type 2 tributary recharge enhancement projects including the Leona River, Blanco, Little Blanco, Elm Creek, and Quihi Creek Projects were evaluated in the performance of this study. The general locations of these sites are shown in Figure 2.1-2 while site maps are presented in Figure 3.3-1. Maxium conservation capacities (and surface areas) for these projects ranged from 1,570 ac-ft (120 acres) at Quihi Creek to 6,940 ac-ft (370 acres) at Elm Creek. As indicated in Figure 3.3-1, none of these projects would necessitate highway relocations, however, some private road relocations would be required at the Leona River and Little Blanco sites. Environmental considerations associated with the development of these projects are believed to be limited to basic environmental reports and investigations of cultural resources and values except at the Blanco, Little Blanco, and Elm Creek sites where threatened/endangered species surveys may be required.

Project cost and data summaries subject to the two water rights scenarios are included as Tables 3.3-1a and 3.3-1b through Tables 3.3-5a and 3.3-5b. Embankment dams were assumed to be the most economical for all Type 2 tributary sites at all percentages of maximum conservation capacity and estimated construction costs were comparable with those for the existing Parker Creek dam (after adjustment for inflation). As indicated in the tables, optimal development of each site under average climatic conditions is at the maximum conservation capacity assuming purchase of water rights from the owners of the CC/LCC System. The minimum cost per unit recharge enhancement amongst these



LEONA RIVER PROJECT

QUIHI CREEK PROJECT

LITTLE BLANCO PROJECT

BLANCO PROJECT

ELM CREEK PROJECT

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0 3000 6000
SCALE IN FEET

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TYPE 2 TRIBUTARY PROJECTS SITE MAPS

FIGURE 3.3-1

TABLE 3.3-1a
Leona River Project Cost and Data Summary

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	Embankment	Embankment	Embankment	Embankment
Conservation Pool:				
Elevation (ft-msl)	1132.2	1139.0	1145.3	1153.3
Surface Area (ac)	50	90	140	220
Capacity (acft)	293	733	1,465	2,930
25-Year Flood Pool:				
Elevation (ft-msl)	1152.0	1152.0	1152.0	1152.0
Surface Area (ac)	190	190	190	190
100-Year Flood Pool:				
Elevation (ft-msl)	1153.0	1153.0	1153.0	1153.0
Surface Area (ac)	200	200	200	200
Top of Dam Elevation (ft-msl)	1161.6	1161.6	1161.6	1161.6
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	0	0	0	0
Average Conditions	10	30	50	80
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.0	0.0	0.0
Estuarine Inflow Reduction (acft/yr)	0	10	10	20
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$1,985,990	$1,985,990	$1,985,990	$1,985,990
Road Relocations	$105,000	$105,000	$105,000	$105,000
Land Acquisition	$157,400	$157,400	$157,400	$157,400
Environmental Mitigation	$8,977	$16,159	$25,136	$39,500
Engineering, Legal, Financial, and Misc.	$451,473	$452,910	$454,705	$457,578
Total Capital Cost	$2,708,841	$2,717,459	$2,728,232	$2,745,468
Capital Cost / Unit Capacity	$9,245	$3,707	$1,862	$937
Annual Capital Cost	$242,983	$243,756	$244,722	$246,268
Operations and Maintenance	$7,944	$7,944	$7,944	$7,944
Water Rights Mitigation	$0	$160	$160	$320
Total Annual Cost	$250,927	$251,860	$252,826	$254,532
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	n/a	n/a	n/a	n/a
Average Conditions	$25,093	$8,395	$5,057	$3,182

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.3-1b
Leona River Project Cost and Data Summary With Purchase of Water Rights

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	Embankment	Embankment	Embankment	Embankment
Conservation Pool:				
Elevation (ft-msl)	1132.2	1139.0	1145.3	1153.3
Surface Area (ac)	50	90	140	220
Capacity (acft)	293	733	1,465	2,930
25-Year Flood Pool:				
Elevation (ft-msl)	1152.0	1152.0	1152.0	1152.0
Surface Area (ac)	190	190	190	190
100-Year Flood Pool:				
Elevation (ft-msl)	1153.0	1153.0	1153.0	1153.0
Surface Area (ac)	200	200	200	200
Top of Dam Elevation (ft-msl)	1161.6	1161.6	1161.6	1161.6
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	30	60	60	60
Average Conditions	60	120	190	280
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.0	0.1	0.1
Estuarine Inflow Reduction (acft/yr)	10	30	40	60
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$1,985,990	$1,985,990	$1,985,990	$1,985,990
Road Relocations	$105,000	$105,000	$105,000	$105,000
Land Acquisition	$157,400	$157,400	$157,400	$157,400
Environmental Mitigation	$8,977	$16,159	$25,136	$39,500
Engineering, Legal, Financial, and Misc.	$451,473	$452,910	$454,705	$457,578
Total Capital Cost	$2,708,841	$2,717,459	$2,728,232	$2,745,468
Capital Cost / Unit Capacity	$9,245	$3,707	$1,862	$937
Annual Capital Cost	$242,983	$243,756	$244,722	$246,268
Operations and Maintenance	$7,944	$7,944	$7,944	$7,944
Water Rights Mitigation	$160	$480	$640	$960
Total Annual Cost	$251,087	$252,180	$253,306	$255,172
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$8,370	$4,203	$4,222	$4,253
Average Conditions	$4,185	$2,102	$1,333	$911

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.3-2a
Blanco Project Cost and Data Summary

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	Embankment	Embankment	Embankment	Embankment
Conservation Pool:				
Elevation (ft-msl)	1190.2	1201.8	1214.1	1230.4
Surface Area (ac)	60	100	160	260
Capacity (acft)	660	1,640	3,290	6,580
25-Year Flood Pool:				
Elevation (ft-msl)	1231.8	1231.8	1231.8	1231.8
Surface Area (ac)	270	1	1	1
100-Year Flood Pool:				
Elevation (ft-msl)	1233.4	1233.4	1233.4	1233.4
Surface Area (ac)	290	290	290	290
Top of Dam Elevation (ft-msl)	1245.0	1245.0	1245.0	1245.0
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	0	0	0	0
Average Conditions	20	60	90	100
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.1	0.1	0.1
Estuarine Inflow Reduction (acft/yr)	10	10	20	20
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$4,107,000	$4,107,000	$4,107,000	$4,107,000
Road Relocations	$0	$0	$0	$0
Land Acquisition	$223,500	$223,500	$223,500	$223,500
Environmental Mitigation	$8,308	$13,846	$22,154	$36,000
Engineering, Legal, Financial, and Misc.	$867,762	$868,869	$870,531	$873,300
Total Capital Cost	$5,206,569	$5,213,215	$5,223,185	$5,239,800
Capital Cost / Unit Capacity	$7,889	$3,179	$1,588	$796
Annual Capital Cost	$467,029	$467,625	$468,520	$470,010
Operations and Maintenance	$16,428	$16,428	$16,428	$16,428
Water Rights Mitigation	$160	$160	$320	$320
Total Annual Cost	$483,617	$484,213	$485,268	$486,758
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	n/a	n/a	n/a	n/a
Average Conditions	$24,181	$8,070	$5,392	$4,868

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.3-2b
Blanco Project Cost and Data Summary With Purchase of Water Rights

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	Embankment	Embankment	Embankment	Embankment
Conservation Pool:				
Elevation (ft-msl)	1190.2	1201.8	1214.1	1230.4
Surface Area (ac)	60	100	160	260
Capacity (acft)	660	1,640	3,290	6,580
25-Year Flood Pool:				
Elevation (ft-msl)	1231.8	1231.8	1231.8	1231.8
Surface Area (ac)	270	1	1	1
100-Year Flood Pool:				
Elevation (ft-msl)	1233.4	1233.4	1233.4	1233.4
Surface Area (ac)	290	290	290	290
Top of Dam Elevation (ft-msl)	1245.0	1245.0	1245.0	1245.0
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	70	110	110	110
Average Conditions	120	240	360	370
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.1	0.1	0.1
Estuarine Inflow Reduction (acft/yr)	30	50	70	80
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$4,107,000	$4,107,000	$4,107,000	$4,107,000
Road Relocations	$0	$0	$0	$0
Land Acquisition	$223,500	$223,500	$223,500	$223,500
Environmental Mitigation	$8,308	$13,846	$22,154	$36,000
Engineering, Legal, Financial, and Misc.	$867,762	$868,869	$870,531	$873,300
Total Capital Cost	$5,206,569	$5,213,215	$5,223,185	$5,239,800
Capital Cost / Unit Capacity	$7,889	$3,179	$1,588	$796
Annual Capital Cost	$467,029	$467,625	$468,520	$470,010
Operations and Maintenance	$16,428	$16,428	$16,428	$16,428
Water Rights Mitigation	$480	$800	$1,120	$1,280
Total Annual Cost	$483,937	$484,853	$486,068	$487,718
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$6,913	$4,408	$4,419	$4,434
Average Conditions	$4,033	$2,020	$1,350	$1,318

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.3-3a
Little Blanco Project Cost and Data Summary

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	Embankment	Embankment	Embankment	Embankment
Conservation Pool:				
Elevation (ft-msl)	1225.3	1233.8	1241.7	1250.8
Surface Area (ac)	30	70	120	210
Capacity (acft)	293	733	1,465	2,930
25-Year Flood Pool:				
Elevation (ft-msl)	1250.8	1250.8	1250.8	1250.8
Surface Area (ac)	220	220	220	220
100-Year Flood Pool:				
Elevation (ft-msl)	1252.0	1252.0	1252.0	1252.0
Surface Area (ac)	230	230	230	230
Top of Dam Elevation (ft-msl)	1263.2	1263.2	1263.2	1263.2
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	0	0	0	0
Average Conditions	20	50	90	140
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.0	0.0	0.0
Estuarine Inflow Reduction (acft/yr)	10	10	20	30
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$1,970,110	$1,970,110	$1,970,110	$1,970,110
Road Relocations	$132,500	$132,500	$132,500	$132,500
Land Acquisition	$177,500	$177,500	$177,500	$177,500
Environmental Mitigation	$4,857	$11,333	$19,429	$34,000
Engineering, Legal, Financial, and Misc.	$456,993	$458,289	$459,908	$462,822
Total Capital Cost	$2,741,961	$2,749,732	$2,759,446	$2,776,932
Capital Cost / Unit Capacity	$9,358	$3,751	$1,884	$948
Annual Capital Cost	$245,954	$246,651	$247,522	$249,091
Operations and Maintenance	$7,880	$7,880	$7,880	$7,880
Water Rights Mitigation	$160	$160	$320	$480
Total Annual Cost	$253,994	$254,691	$255,723	$257,451
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	n/a	n/a	n/a	n/a
Average Conditions	$12,700	$5,094	$2,841	$1,839

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.3-3b
Little Blanco Project Cost and Data Summary With Purchase of Water Rights

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	Embankment	Embankment	Embankment	Embankment
Conservation Pool:				
Elevation (ft-msl)	1225.3	1233.8	1241.7	1250.8
Surface Area (ac)	30	70	120	210
Capacity (acft)	293	733	1,465	2,930
25-Year Flood Pool:				
Elevation (ft-msl)	1250.8	1250.8	1250.8	1250.8
Surface Area (ac)	220	220	220	220
100-Year Flood Pool:				
Elevation (ft-msl)	1252.0	1252.0	1252.0	1252.0
Surface Area (ac)	230	230	230	230
Top of Dam Elevation (ft-msl)	1263.2	1263.2	1263.2	1263.2
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	70	100	100	100
Average Conditions	70	150	250	390
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.0	0.0	0.0
Estuarine Inflow Reduction (acft/yr)	10	30	50	80
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$1,970,110	$1,970,110	$1,970,110	$1,970,110
Road Relocations	$132,500	$132,500	$132,500	$132,500
Land Acquisition	$177,500	$177,500	$177,500	$177,500
Environmental Mitigation	$4,857	$11,333	$19,429	$34,000
Engineering, Legal, Financial, and Misc.	$456,993	$458,289	$459,908	$462,822
Total Capital Cost	$2,741,961	$2,749,732	$2,759,446	$2,776,932
Capital Cost / Unit Capacity	$9,358	$3,751	$1,884	$948
Annual Capital Cost	$245,954	$246,651	$247,522	$249,091
Operations and Maintenance	$7,880	$7,880	$7,880	$7,880
Water Rights Mitigation	$160	$480	$800	$1,280
Total Annual Cost	$253,994	$255,011	$256,203	$258,251
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$3,628	$2,550	$2,562	$2,583
Average Conditions	$3,628	$1,700	$1,025	$662

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.3-4a
Elm Creek Project Cost and Data Summary

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	Embankment	Embankment	Embankment	Embankment
Conservation Pool:				
Elevation (ft-msl)	966.2	975.9	985.2	996.7
Surface Area (ac)	70	140	240	370
Capacity (acft)	694	1,735	3,470	6,940
25-Year Flood Pool:				
Elevation (ft-msl)	999.0	999.0	999.0	999.0
Surface Area (ac)	400	400	400	400
100-Year Flood Pool:				
Elevation (ft-msl)	1000.7	1000.7	1000.7	1000.7
Surface Area (ac)	430	430	430	430
Top of Dam Elevation (ft-msl)	1011.9	1011.9	1011.9	1011.9
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	0	0	0	0
Average Conditions	110	220	350	370
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.0	0.0	0.0
Estuarine Inflow Reduction (acft/yr)	20	50	80	80
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$2,345,680	$2,345,680	$2,345,680	$2,345,680
Road Relocations	$0	$0	$0	$0
Land Acquisition	$385,400	$385,400	$385,400	$385,400
Environmental Mitigation	$7,927	$15,854	$27,178	$41,900
Engineering, Legal, Financial, and Misc.	$547,801	$549,387	$551,652	$554,596
Total Capital Cost	$3,286,808	$3,296,321	$3,309,910	$3,327,576
Capital Cost / Unit Capacity	$4,736	$1,900	$954	$479
Annual Capital Cost	$294,827	$295,680	$296,899	$298,484
Operations and Maintenance	$9,383	$9,383	$9,383	$9,383
Water Rights Mitigation	$320	$800	$1,280	$1,280
Total Annual Cost	$304,529	$305,863	$307,562	$309,146
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	n/a	n/a	n/a	n/a
Average Conditions	$2,768	$1,390	$879	$836

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.3-4b
Elm Creek Project Cost and Data Summary With Purchase of Water Rights

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	Embankment	Embankment	Embankment	Embankment
Conservation Pool:				
Elevation (ft-msl)	966.2	975.9	985.2	996.7
Surface Area (ac)	70	140	240	370
Capacity (acft)	694	1,735	3,470	6,940
25-Year Flood Pool:				
Elevation (ft-msl)	999.0	999.0	999.0	999.0
Surface Area (ac)	400	400	400	400
100-Year Flood Pool:				
Elevation (ft-msl)	1000.7	1000.7	1000.7	1000.7
Surface Area (ac)	430	430	430	430
Top of Dam Elevation (ft-msl)	1011.9	1011.9	1011.9	1011.9
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	110	120	120	120
Average Conditions	280	480	650	670
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.0	0.0	0.0
Estuarine Inflow Reduction (acft/yr)	60	100	140	140
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$2,345,680	$2,345,680	$2,345,680	$2,345,680
Road Relocations	$0	$0	$0	$0
Land Acquisition	$385,400	$385,400	$385,400	$385,400
Environmental Mitigation	$7,927	$15,854	$27,178	$41,900
Engineering, Legal, Financial, and Misc.	$547,801	$549,387	$551,652	$554,596
Total Capital Cost	$3,286,808	$3,296,321	$3,309,910	$3,327,576
Capital Cost / Unit Capacity	$4,736	$1,900	$954	$479
Annual Capital Cost	$294,827	$295,680	$296,899	$298,484
Operations and Maintenance	$9,383	$9,383	$9,383	$9,383
Water Rights Mitigation	$960	$1,600	$2,240	$2,240
Total Annual Cost	$305,169	$306,663	$308,522	$310,106
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$2,774	$2,556	$2,571	$2,584
Average Conditions	$1,090	$639	$475	$463

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.3-5a
Quihi Creek Project Cost and Data Summary

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	Embankment	Embankment	Embankment	Embankment
Conservation Pool:				
Elevation (ft-msl)	981.7	987.4	993.2	1001.0
Surface Area (ac)	30	50	80	120
Capacity (acft)	157	393	785	1,570
25-Year Flood Pool:				
Elevation (ft-msl)	1001.0	1001.0	1001.0	1001.0
Surface Area (ac)	120	120	120	120
100-Year Flood Pool:				
Elevation (ft-msl)	1002.2	1002.2	1002.2	1002.2
Surface Area (ac)	125	125	125	125
Top of Dam Elevation (ft-msl)	1011.0	1011.0	1011.0	1011.0
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	0	0	0	0
Average Conditions	20	50	80	80
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.0	0.0	0.0
Estuarine Inflow Reduction (acft/yr)	10	10	20	20
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$961,750	$961,750	$961,750	$961,750
Road Relocations	$0	$0	$0	$0
Land Acquisition	$97,700	$97,700	$97,700	$97,700
Environmental Mitigation	$7,750	$12,917	$20,667	$31,000
Engineering, Legal, Financial, and Misc.	$213,440	$214,473	$216,023	$218,090
Total Capital Cost	$1,280,640	$1,286,840	$1,296,140	$1,308,540
Capital Cost / Unit Capacity	$8,157	$3,274	$1,651	$833
Annual Capital Cost	$114,873	$115,430	$116,264	$117,376
Operations and Maintenance	$3,847	$3,847	$3,847	$3,847
Water Rights Mitigation	$160	$160	$320	$320
Total Annual Cost	$118,880	$119,437	$120,431	$121,543
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	n/a	n/a	n/a	n/a
Average Conditions	$5,944	$2,389	$1,505	$1,519

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

TABLE 3.3-5b
Quihi Creek Project Cost and Data Summary With Purchase of Water Rights

Physical Data	Percentage of Maximum Project Conservation Capacity			
	10%	25%	50%	100%
Dam Type	Embankment	Embankment	Embankment	Embankment
Conservation Pool:				
Elevation (ft-msl)	981.7	987.4	993.2	1001.0
Surface Area (ac)	30	50	80	120
Capacity (acft)	157	393	785	1,570
25-Year Flood Pool:				
Elevation (ft-msl)	1001.0	1001.0	1001.0	1001.0
Surface Area (ac)	120	120	120	120
100-Year Flood Pool:				
Elevation (ft-msl)	1002.2	1002.2	1002.2	1002.2
Surface Area (ac)	125	125	125	125
Top of Dam Elevation (ft-msl)	1011.0	1011.0	1011.0	1011.0
Hydrologic Data				
Recharge Enhancement (acft/yr):				
Drought Conditions	20	30	30	30
Average Conditions	60	100	140	150
CC/LCC System Yield Reduction (acft/yr)	0	0	0	0
Median CC/LCC System Storage Reduction (%)	0.0	0.0	0.0	0.0
Estuarine Inflow Reduction (acft/yr)	10	20	30	30
Summary of Project Costs				
Dam, Spillway, and Appurtenant Works	$961,750	$961,750	$961,750	$961,750
Road Relocations	$0	$0	$0	$0
Land Acquisition	$97,700	$97,700	$97,700	$97,700
Environmental Mitigation	$7,750	$12,917	$20,667	$31,000
Engineering, Legal, Financial, and Misc.	$213,440	$214,473	$216,023	$218,090
Total Capital Cost	$1,280,640	$1,286,840	$1,296,140	$1,308,540
Capital Cost / Unit Capacity	$8,157	$3,274	$1,651	$833
Annual Capital Cost	$114,873	$115,430	$116,264	$117,376
Operations and Maintenance	$3,847	$3,847	$3,847	$3,847
Water Rights Mitigation	$160	$320	$480	$480
Total Annual Cost	$118,880	$119,597	$120,591	$121,703
Annual Cost / Unit Recharge Enhancement:				
Drought Conditions	$5,944	$3,987	$4,020	$4,057
Average Conditions	$1,981	$1,196	$861	$811

Refer to Appendix B for summary and Section 2 for explanation of assumptions on which project cost and data are based.

projects, however, was $463 per ac-ft per year which is almost twice the unit cost of the least economical Type 2 mainstem site.

4.0 CONCLUSIONS

Significant findings and conclusions of this study are summarized as follows:

- A program of selected Type 2 projects appears to be the most feasible alternative for recharge enhancement in the Nueces River Basin. This Type 2 Program will include mitigation of impacts to the CC/LCC System and the agreement of the owners of the CC/LCC System. A program of Type 1 projects is more attractive on a unit cost basis if the impacts to the CC/LCC System cannot be mitigated.

- When honoring all existing water rights and purchasing impacts to those rights related to the CC/LCC System, a program of Type 2 recharge enhancement projects is more economical than a program of Type 1 projects. In this case, mitigation of impacts to water rights held by the owners of the CC/LCC System is achieved through compensation based on the replacement cost of water. Implementation of a Type 2 Program with each recharge reservoir sized at 100% Conservation Capacity would result in average recharge enhancement of 96,210 ac-ft/yr with an average unit cost of $260/ac-ft/yr. This recharge enhancement volume is slightly different from that in the Phase I report due to changes in the rate of diversion from the Indian Creek Project to the Dry Frio River and in the modelling of downstream water rights for individual recharge projects rather than considering all Type 2 projects simultaneously. Development of each identified site at Optimum Conservation Capacity would result in average recharge enhancement of 55,710 acft/yr at an average unit cost of $193/ac-ft/yr.

- Implementation of the Example Type 2 Program presented in the Executive Summary would result in average recharge enhancement of 64,030 ac-ft/yr at an average unit cost of $169/ac-ft/yr. Downstream impacts associated with the Example Type 2 Program would be small. The 1990 firm yield of the CC/LCC System would be reduced by 0.8% and the median inflow to the Nueces Estuary would be reduced by about 2% while natural recharge of the Carrizo-Wilcox Aquifer would be reduced by less than 1%. Frequency of overbank inundation in the braided reach of the Nueces River would be reduced by less than 1% while the frequency of zero flows (which presently occur about 40% of the time) would be essentially unaffected.

- Sediment accumulation within the recharge enhancement reservoirs should not constitute a significant impediment to the long-term recharge enhancement developed by either program. Preliminary analyses indicate reductions in storage capacity after 50 years of operation of approximately 8% for the Example Type 2 Program. Sediment accumulation in Type 2 reservoirs may eventually reduce direct percolation rates somewhat, however, waters entering the aquifer may be of higher quality due to filtration through the sediments. Periodic removal (and sale) of accumulated sediments in Type 2 reservoirs is also a possibility.

- When honoring all existing water rights, a program of Type 1 recharge enhancement projects is more economical than a program of Type 2 projects. Implementation of a Type 1 Program with each identified site at 100% Conservation Capacity would result in average recharge enhancement of 87,280 ac-ft/yr with an average unit cost of $383/ac-ft/yr. This recharge enhancement volume is slightly different from that in the Phase I report due to changes in the rate of diversion from the Montell Project to the Dry Frio River and in the modelling of downstream water rights for individual recharge projects rather than considering all Type 1 projects simultaneously. Development of each identified site at Optimum Conservation Capacity would result in average recharge enhancement of 62,580 acft/yr at an average unit cost of $227/ac-ft/yr.

- Although environmental considerations do not preclude the development of any of the potential recharge enhancement projects of either type, it is clear that implementation of a Type 1 Program would necessitate substantially greater expenditure of effort and funds to address environmental concerns. A program of Type 2 reservoirs is believed to be preferable from an environmental standpoint. Some of the most significant environmental concerns associated primarily with the Type 1 projects are: 1) Permanent inundation of the reservoir area necessitating acquisition and management of wooded mitigation lands and purchase of valuable waterfront property and dwellings; 2) Modification of established habitats and recreational uses associated with streams having significant base flows; 3) More numerous identified sites of archaeological or historical significance (particularly at the Montell site); and 4) More likely presence of threatened/endangered species.

4.1 Recommendations

The findings and conclusions of this study indicate that substantial enhancement of recharge to the Edwards Aquifer can be achieved through the development of a program of recharge projects in the headwaters of the Nueces River Basin. On the basis of recharge enhancement potential, minimization of environmental impacts, and annual unit cost of water delivered to the aquifer, it is recommended that projects comprising a Selected Type 2 Program be further investigated as Phase IV. The following Phase IV studies and

2 Program be further investigated as Phase IV. The following Phase IV studies and investigations are recommended in order make final recharge enhancement project selections and assure program feasibility:

1) Establish criteria for project selection (size, unit cost, location, etc.)

2) Initiate negotiations with the owners of the CC/LCC System with the intent of establishing a mutually acceptable form of compensation to mitigate relatively small, but unavoidable impacts to water availability in the CC/LCC System. Evaluate potential impacts of recharge enhancement projects on the CC/LCC System subject to operational constraints and estuarine inflow requirements presently under consideration before the Texas Water Commission.

3) Further optimize site location and development for projects comprising the Selected Type 2 Program based on preliminary site investigations focusing on specific geologic and environmental considerations, sites of archaeological significance, and major relocations.

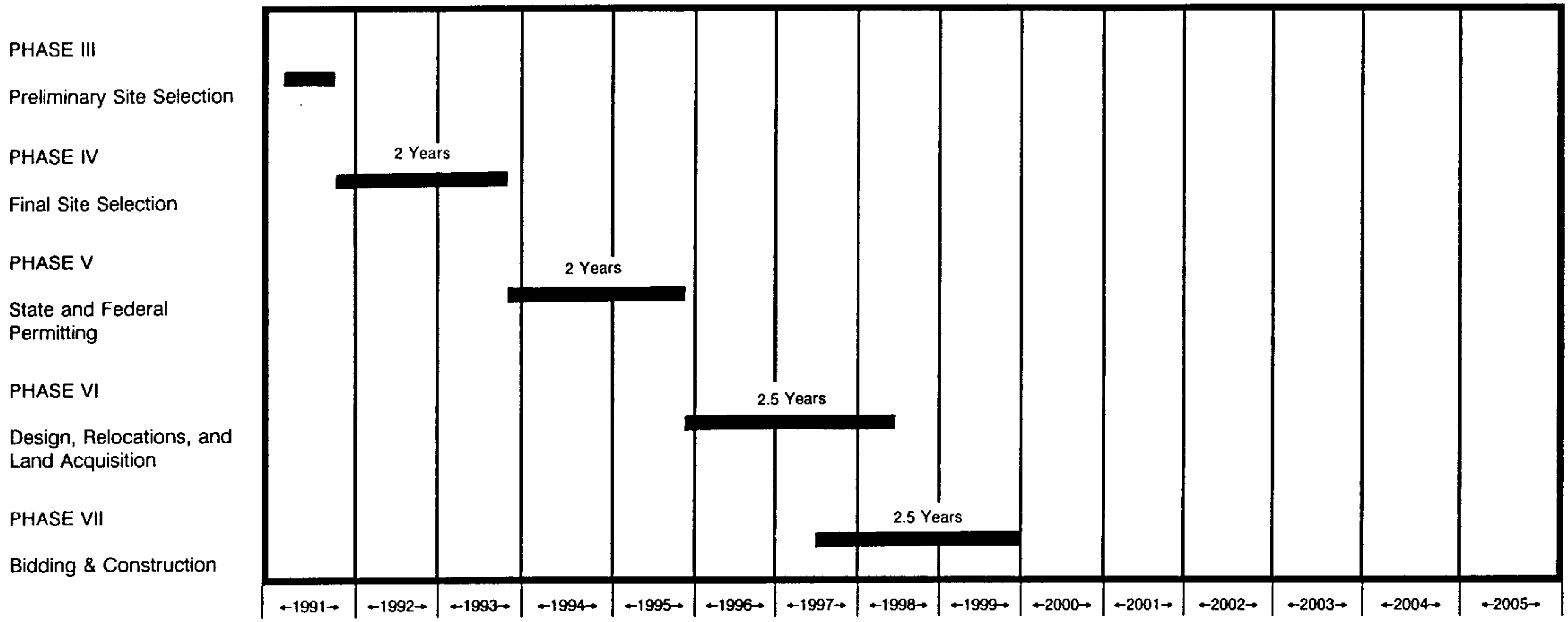
4) Install streamflow and precipitation gaging stations as necessary to more firmly establish relationships between rainfall, runoff, and recharge in selected subwatersheds.

5) Finalize site selection and assure project feasibility by conducting preliminary geotechnical and detailed archaeological investigations and obtaining detailed aerial photography and topographic mapping.

6) Prepare report(s) suitable for permitting addressing pertinent engineering, environmental, and archaeological considerations associated with the development of selected projects.

4.2 Typical Project Development Schedules

Recharge enhancement project development schedules typical of medium and small projects and large projects are presented in Figures 4.2-1 and 4.2-2, respectively. As indicated in Figure 4.2-1, medium and small projects such as Lower Sabinal, Lower Hondo, and Lower Verde could be completed as early as 1999. This typical schedule is based on

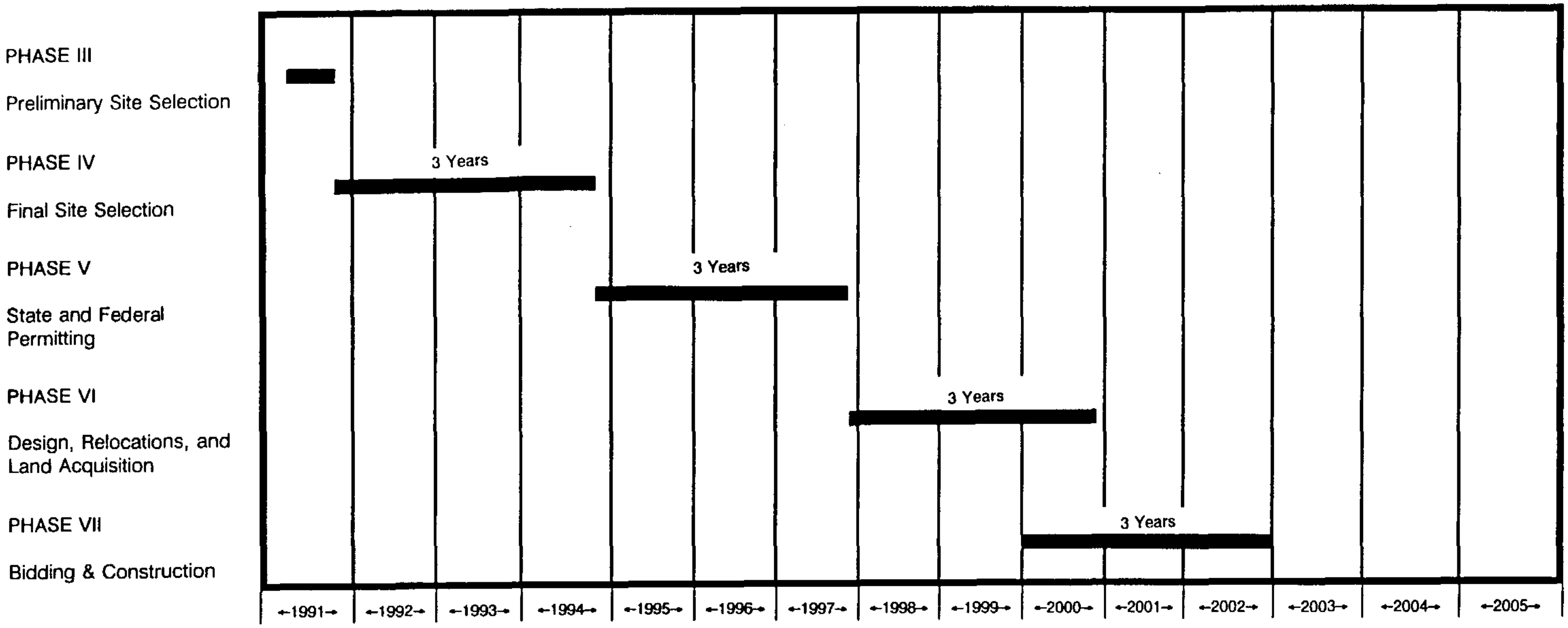


HDR Engineering, Inc.

**NUECES RIVER BASIN
REGIONAL WATER SUPPLY
PLANNING STUDY PHASE III**

**TYPICAL SCHEDULE
MEDIUM AND SMALL PROJECTS**

FIGURE 4.2-1



HDR Engineering, Inc.

NUECES RIVER BASIN
REGIONAL WATER SUPPLY
PLANNING STUDY PHASE III

TYPICAL SCHEDULE LARGE PROJECTS

FIGURE 4.2-2

allocation of consecutive 2-year periods for final site selection studies (Phase IV) and State and Federal permitting (Phase V) and partially concurrent 2.5-year periods for design, relocations, and land acquisition (Phase VI) and bidding and construction (Phase VII). As indicated in Figure 4.2-2, a large project such as Indian Creek could be completed by about the 2002 allowing an additional 3 years to accommodate the additional complexities associated with all phases of large project development.

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NUECES RIVER BASIN
REGIONAL WATER SUPPLY
PLANNING STUDY
ENVIRONMENTAL CONSIDERATIONS

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TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Purpose and Scope

This report further examines the 19 recharge enhancement sites identified in the Nueces River Basin Regional Water Supply Planning Study, Phase I, and depicted in Figure 7.0-1 of Volume II - Technical Report (HDR, 1991). Here we focus on environmental features that might render a site unsuitable or impractical for the proposed use, and characterize the important environmental features, known cultural resources, and human uses of each site in order to rank them with respect to environmental sensitivity and mitigation liability. The reservoir sites were identified in the Phase I report solely for their Edwards Aquifer recharge potential and without regard to economic, ecological, or human environmental considerations or costs.

The need for environmental studies and mitigation activities as part of a proposed project generally results from the need to obtain state and federal permits that allow necessary project activities to go forward. With respect to these reservoir sites, the regulations that will require environmental compliance include the Clean Water Act (33 USC 1344), the Endangered Species Act (16 USC 1531 *et seq*), and portions of the Texas Water Code involving water rights permits. Section 404 of the Clean Water Act prohibits the discharge of dredged or fill material into the waters of the United States, including adjacent wetlands, without a permit from the U.S. Army Corps of Engineers. Even though some of the Type 2 sites may not contain significant amounts of jurisdictional wetland, a 404 permit will be required as even intermittent streams are considered part of the waters of the United States unless the affected reach is "above the headwaters", generally defined as the point at which discharge averages less than

5 cfs (33 CFR 330.5 [a] [26] [i]). Cultural resource protection on public lands, or lands affected by projects regulated under the federal permits mentioned above, is afforded by the National Historic Preservation Act (PL 96-515), the Archaeological and Historic Preservation Act (PL 93-291), and the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resources Code of 1977).

The proposed reservoirs are located in the Nueces River Basin headwaters along the southern edge of the Edwards Plateau in Medina and Uvalde Counties. Two reservoir types are proposed in Phase I report: The Type 1 design is a conventional reservoir located upstream of the Edwards Aquifer recharge zone, and is intended to capture and store water that could be released downstream to enhance recharge, or withdrawn directly for local use. Farther downstream, the Type 2 reservoir is designed to impound streamflow directly over the recharge zone to increase direct recharge to the underlying Edwards Aquifer.

1.2 Materials and Methods

The dam locations, maximum reservoir elevations and surface areas of the prospective reservoirs obtained from HDR Engineering were used to delineate the potential area of environmental effects on topographic maps and aerial photographs. Within the reservoir area direct construction impacts resulting from clearing and building, and operational impacts from temporary and permanent flooding, are expected. Other direct and indirect operational effects will include changes in downstream flow, increased recharge, and increased use of, or access to, areas that have been private. Land uses, habitat types and values, and wetland occurrences within each reservoir footprint have been identified and evaluated using available literature and a variety of other sources, including the Texas Natural Resources Information System's aerial photography and map data base, Texas Parks and Wildlife Department, Resource Protection Division's data and mapping files for endangered, protected and sensitive resources, the U.S. Fish and Wildlife Service' National Wetland Inventory (NWI) maps, the Edwards Aquifer Research and Data Center, the Nature Conservancy, Bat Conservation International, and the Cave Conservancy. Cultural resources were identified and evaluated using a similar procedure by Lone Star Archaeological Services. This data base, including archaeological sites, bat caves, state natural areas, protected species, and potential wetland areas is on 7.5 minute quadrangles maintained in the Nueces River Authority data file.

2.0 REGIONAL SETTING

2.1 Edwards Plateau and South Texas Plains Ecological Areas

The study area encompasses the headwaters of the Nueces River Basin along the southern margin of the Edwards plateau in Medina and Uvalde Counties. The Edwards limestones that cap the plateau were deposited approximately 140 million years ago as layers of shells and corals were deposited during the early to late Cretaceous Period when Central Texas lay under a shallow, tropical sea. After the sea receded, geologic events about 15 million years ago uplifted the area, exposing the porous Edwards limestones. The same geologic events that uplifted the Edwards Plateau also created the Balcones Fault at the plateau's southern and eastern margin. In the southern third of Medina and Uvalde Counties the plateau drops dramatically along the Balcones Escarpment to the South Texas Plains (Edwards Underground Water District, 1990). The two regions are distinct physiographically and in their vegetation, and are, consequently, distinct in the types and distribution of aquatic and terrestrial habitats they exhibit.

The topography of the Edwards Plateau is generally flat to rolling over most of its surface, but the margins, including that in Medina and Uvalde Counties, is a highly dissected area of canyons and steep, well drained hillsides. Soils are mostly shallow with a wide range of surface textures, and are underlain by limestones that may form cliffs, overhangs and grottoes where they are exposed in stream-cuts or canyon walls along the escarpment. Edwards Plateau vegetation consists of a tall or mid-grass understory and a brushy overstory complex of live oak (*Quercus virginiana*) and other oaks (*Q. fusiformis, Q. buckleyi, Q sinuata* var. *breviloba*), ashe junipers (*Juniperus ashei*) and mesquite (*Prosopis glandulosa*). The most important climax grasses include switchgrass (*Panicum virgatum*), several species of bluestem (*Schizachyrium*and *Andropogon* spp.), gramas (*Bouteloua* spp.), Indian grass (*Sorghastrum nutans*), Candian wild rye (*Elymus canadensis*), buffalo grass (*Buchloe dactyloides*) and curly mesquite (*Hilaria belangeri*). Juniper and mesquite brush are generally considered invaders into a presumed climax of largely grassland or savannah, except on the steeper slopes which have continually supported a dense cedar - oak thicket. Bald cypress (*Taxodium distichum*) occurs along perennial streams and rivers, while pecan (*Carya illinoiensis*), Arizona and little walnut (*Juglans major, J. microcarpa*) hackberry (*Celtis laevigata*), black and sandbar willow (*Salix nigra, S. interior*), and eastern cottonwood (*Populus deltoides*) are more widely distributed in riparian areas of both perennial and intermittent streams.

The wooded and brushland areas provide food and cover for a variety of birds and mammals including white tailed deer (*Odocoileus virginianus*) raccoons (*Procyon lotor*), ringtails (*Bassariscus astutus*), several species of skunks, gray foxes (*Urocyon cinereoargenteus*), coyotes (*Canis latrans*), beaver (*Castor canadensis*) and bobcats (*Felis rufus*). Wintering songbirds such as robins and cedar waxwings feed on the juniper mast. Native wild turkeys feed on the juniper berries. The white-tailed deer is an abundant and important species to this area. On the Edwards plateau, this deer's abundance is strongly associated with the progress of juniper from the hillsides to the level savannahs where deer now have both cover and forage (Bryan, F. C. in Rodiek and Bolen et al, 1991). Cultivated fields are generally in the relatively broad, level stream valleys where deeper soils have accumulated (Correll and Johnson, 1979). Upland agriculture consists primarily of livestock grazing and harvest of cedar and oak for (respectively) fence posts and firewood.

South of the Balcones escarpment, the South Texas Plains Ecological Area is characterized by a level to rolling topography with sandy, gravelly and loamy soils generally deeper than those of the Edwards Plateau and without the pervasive limestone outcrops. Upland vegetation consists primarily of brushy grassland or savannah, but substantial clearing for both irrigated and dryland farming is common in Medina and Uvalde Counties. Important species include mesquite, live oak, bluewood (*Condalia hookeri*), huisache (*Acacia* spp.), blackbush (*Acacia rigidula*), catclaw (*Acacia greggii*), lotebush (*Ziziphus obtusifolia*), lechuquilla (*Agave lechuquilla*), prickly pear (*Opuntia* spp.) and others common to the South Texas Plains and Tamaulipan Thorn Scrub, mixed with the grassland and juniper - oak brush common to the Edwards Plateau. Because of a lack of perennial surface water, or springs and seeps, in the recharge zone, riparian woodland tends to be poorly developed, if present at all, in the South Texas Plains portion of the study area. Wildlife assemblages are similar to those of the adjacent Edwards Plateau, although relative abundances may differ widely, and some woodland bird species may not be present at all.

The east to west gradient in aridity (Texas Department of Water Resources, 1983) is evident in vegetational community composition and structure in both ecological areas, but the transition in the recharge zone on the South Texas Plains from the live oak-juniper dominated communities of Medina County to the mesquite-acacia brushlands of western Uvalde County is particularly pronounced. While all the riparian species mentioned above may be found at the more mesic Type 1 sites in Medina County, cottonwood-willow stands are the rule at the Dry Frio and Nueces River Type 1 sites, although Montell supports substantial areas of probably cultivated pecan bottom.

2.2 Edwards Aquifer

The porous, honey-combed formations making up the Edwards and associated limestones constitute the three functional parts of the Edwards Aquifer. These three parts are the drainage, or catchment area, the recharge zone, and the reservoir. Input to the aquifer comes from the rainfall on the porous limestones and thin, rocky soils capping the Edwards Plateau catchment area. Percolation through the Edwards limestone is stopped by relatively impermeable layers in the older Glen Rose formation. Where rivers flowing across the plateau have carved deep canyons and exposed the base of the Edwards Limestone spring fed streams arise and flow southward over the impermeable older formations to the recharge zone.

The Edwards recharge zone has a surface area of about 1,500 square miles with over a third of that in Uvalde County, and the remainder in Kinney, Medina , Bexar, Comal and Hays Counties. Recharge occurs along the Balcones fault zone through porous and faulted limestone in stream beds, sinkholes, and fractures rather than over the general land surface (Caran et al 1982). About 75 percent of the recharge volume enters the aquifer in stream channels (U.S. Geological Survey, 1988). Since faulting is most intense in the western portion of the recharge zone it is not surprising that most recharge occurs in the western river basins, the Nueces, Dry Frio, Frio, and Sabinal. These rivers account for an average annual recharge of 342.1 thousand acre-feet, about 56.6 percent of the total 604.5 thousand acre-feet average annual recharge (Edwards Underground Water District, 1990 and U. S. Geological Survey, 1989).

The aquifer reservoir is confined below by relatively impermeable zones in the Glen Rose Formation, and at the upper boundary, in the artesian area, by a confining layer of impermeable Del Rio Clay. The catchment area generally corresponds to the areas of the Nueces and Guadalupe River Basins on the Edwards Plateau. The recharge and reservoir zones of the Edwards Aquifer together form a crescent shaped area extending from Brackettville in Kinney County in the west, to the eastern tip near Kyle in Hays County. The width varies from about 5 to about 30 miles (Edwards Underground Water District, 1990). Water in the reservoir zone exhibits progressively increasing levels of dissolved minerals and lower dissolved oxygen concentrations toward the south as the aquifer plunges deeper into the earth and circulation slows. This indistinct boundary is termed the "bad water" line.

Aquatic habitat types within the study area include the aquifer itself, springs that flow from the aquifer, permanent streams immediately downstream from, and substantially influenced by, springs, lotic and pool habitats in other perennial and intermittent streams, and impoundments, most of which were constructed for stock watering. Perennial creeks and streams are found upstream of the recharge zone, where all the Type 1 reservoir sites are located. With the exception of the site on the Lower Frio River, all of the Type 2 sites are located on intermittent stream reaches over the recharge zone. The subterranean aquatic habitats associated with the Edwards supports a diverse subterranean aquatic ecosystem. Species have been found in the aquifer at depths ranging from 190 to 2,000 feet in the artesian parts of the aquifer. The Edwards Aquifer is the only underground aquatic habitat in which species live in Texas (Edwards et al, 1986). Several springs in Uvalde County support populations of *Eurycea neotenes,* the Texas Salamander, a rare species that is restricted to, and dependant on, spring habitats. This type of adaptation is not uncommon in constant temperature spring habitats, and may go even farther, to endemism, wherein a species may be entirely restricted to a particular spring.

The large, perennial, spring fed streams above the recharge zone support unique (for Texas) clear water communities lined with bald cypress and typically exhibiting diverse and abundant assemblages of aquatic vegetation. The invertebrate and fish fauna, likewise tends to be somewhat distinct from surrounding areas. For example, the State Fish is the Guadalupe bass (*Micropterus treculi*) which lives only in the streams of the Edwards Plateau region. Originally confined to parts of the San Antonio-Guadalupe, Colorado and Brazos basins, it was introduced into the headwaters of the Nueces by Texas Parks and Wildlife Department in 1973 (Garrett, 1990).

2.3 Protected Species

Species considered Endangered or Threatened under the Endangered Species Act (16 USC 1536) by the U.S. Fish and Wildlife Service, and having some likelihood of being present in Medina or Uvalde County are listed in Table 2-1. Of those species most likely to be present, only the golden-cheeked warbler, the tobusch fishhook cactus and, to some extent, the black-capped vireo are strongly

TABLE 2-1

Endangered and Threatened Species of Medina and Uvalde Counties, Texas Listed by the U. S. Department of the Interior
(50 CFR 17.11 & 17.12, 16 April 1990)

Taxa		County[1]
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	M***,U**
Bald Eagle	*Haliaeetus leucocephalus*	M**, U**
Black-capped vireo	*Vireo atricapillus*	M***,U***
Golden-Cheeked Warbler	*Dendroica chrysoparia*	M***,U***
Interior Least Tern	*Sterna antillarum athalassas*	M*
White-faced Ibis	*Plegadis chihi*	M**,U***
Wood Stork	*Mycteria americana*	M***,U***
Tobusch Fishhook Cactus	*Ancistrocactus tobuschii*	U***

[1] County occurrence information from Texas Parks and Wildlife Department Endangered/ Threatened species file:
M, Medina County
U, Uvalde County
***verified recent occurrence
**within general distribution of species
*periphery of known distribution

associated with, and dependant on, specific habitats that may be in short supply. The other species tend to be winter migrants for whom non-nesting habitat is probably not limiting.

The golden-checked warbler, an early spring migrant to the Edwards Plateau nests only in mature juniper-oak woodlands, typically of a type most common on steep slopes in the canyons of the plateau margins. To support one nesting pair, 8 to 10 hectares of dense juniper with intermingled deciduous oak trees are required. Its range includes the northern quarters of both Medina and Uvalde Counties (U.S. Fish and Wildlife Services, 1987).

The black-capped vireo inhabits dry limestone hilltops, ridges, and slopes on the eastern and southern portions of the Edwards Plateau, but its nesting range extends into the canyons of the Stockton Plateau to the west, and north into central Oklahoma. Its habitat usually includes oaks, mountain laurel, sumacs, redbud, Texas persimmon, ashe juniper, mesquite and agarita. Species composition may be less important than the presence of adequate broad-leafed shrubs having dense foliage extending to ground level, and a two layer structure consisting of clumps of low (to 6 feet), dense brush in an open woodland of mature oaks and junipers. The vireo habitat is mid-successional in nature, developing after a disturbance such as fire or clearing, is sensitive to land use practices, and can be created by intentional management. Physical habitat availability may not be limiting considering present levels of cowbird (*Molothrus ater*) nest parasitism and the presence of fire ants (*Solenopsis invicta*).

The Tobusch fishhook cactus is typically found on gravel terraces along drainages, on limestone ledges, ridges and rocky hills in openings of live oak-juniper woodlands. These cacti have been found in floodplains, but above normal flood levels.

State designated protected non-game species that may occur in Medina and Uvalde Counties are listed in Table 2-2. The species most likely to be present in aquatic or riparian habitats include the white-faced ibis, Rio Grande Siren, the two salamanders, the indigo snake and the blue sucker. The ibis does not nest in Texas, but often exhibits a postnesting wandering period during which they may occur very irregularly at inland locations (Oberholser, 1974). The indigo snake is typically an inhabitant of riparian woodlands in the South Texas Plains, while the blue sucker is a large river fish most likely to be found in the perennial reaches of the Nueces River (Tennant, 1985; Hubbs, 1982, Conner and Suttkus, 1986).

2.4 Land Use and Economy

Within the Nueces River Basin, the primary land use is agricultural. In the Phase I Report, about 84% of the area of Medina and Uvalde Counties was estimated to be rangeland, 6% pasture, and 10% cropland. The Texas Almanac (1989) and Texas Facts (Clements, 1988) and the Texas Department of Water Resources Land Use/Land Cover Maps (1978) agree that this distribution of land use is typical of Uvalde and Medina Counties.

Agribusiness and tourism are the leading industries in both Medina and Uvalde Counties. Table 2-3 compares state agricultural land use and employment with agricultural land use and employment in Medina and Uvalde Counties. Cattle, sheep and angora goats are important domestic stock in both counties.

Uvalde is the nation's leading Angora goat and mohair producing region and one of the leading sheep and wool areas. Hunting deer and turkey, fishing, camping,

TABLE 2-2

Threatened (31 TAC Sec. 65-171-65.177) and Endangered (31 TAC Sec. 65.181-65.184) Species Listed by the State of Texas that are of Known or Possible Occurrence in Medina and Uvalde Counties

Taxa		County[1]
Black bear	*Ursus americanus*	M*,U*
Coati	*Nasua nasua*	M*,U*
American swallow-tailed kite	*Elanoides forficatus*	M*
Black-common Hawk	*Buteogallus anthracinus*	U**
Lesser Rio Grande siren	*Siren intermedia texana*	M*,U*
White-faced Ibis	*Plegadis chihi*	U***
White-tailed hawk	*Buteo albicaudatus*	M***
Zone-tailed hawk	*Buteo albonotatus*	M**
Blind Comal salamander	*Eurycea tridentifera*	M*
Cascade Cavern salamander	*Eurycea latitans*	M*
Texas tortoise	*Gopherus berlandieri*	M***,U***
Reticulate collared lizard	*Crotaphytus reticulatus*	U***
Texas horned lizard	*Phrynosoma cornutum*	U***
Texas indigo snake	*Drymarchon corais erebennus*	M***,U***
Blue sucker	*Cycleptus elongatus*	U***

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[1] County occurrence information from Texas Parks and Wildlife Department Endangered/ Threatened species file:

M, Medina County,
U, Uvalde County
***verified recent occurrence
**within general distribution of species
*periphery of known distribution

TABLE 2-3

Land Use and Employment in Medina and Uvalde Counties Compared to the State [1]

	State	Medina	Uvalde
Land Area, Acreage	167,693,000	852,000	1,001,000
Land in Farms/Ranches, Acreage	136,300,000	709,000	853,000
1987 Employment Profile			
civilian labor	8,264,300	11,492	13,136
total employment	7,566,700	10,819	11,810
agricultural	76,565	227	1,007
mining	181,400	61	198
construction	346,000	212	311
manufacturing	928,300	582	834
transportation / public utility	468,900	160	305
trade	1,642,400	1,593	2,185
financial/ insurance/ real estate	442,800	176	363
services / other	1,429,800	1,115	1,007
state government	232,000	108	233
local government	716,700	1,249	1,437
Total annual wage ($ millions)	123,285	72	93
Average weekly wage	304	247	233
Federal employment	195,716	60	111
Total annual federal wage ($ thous)	4,891,252	1,415	2,842

1 Flying the Colors: Texas Facts (Clements, 1988)

canoeing, birding, and scenic drives are important tourist activities (Texas Almanac, 1989). Of this counties' 853,000 acres in agricultural production, 10% was harvested cropland and 8% was irrigated. It ranked 43rd in the state in agricultural receipts, of which 56% were from crops. Primary crops are feed corn, upland cotton, and wheat. Primary vegetables include onions, carrots, cantaloupes and cabbage. The county was ranked first in cabbage production and second in carrot production, statewide. Primary fruits and nuts are peaches and pecans. The primary livestock are beef cattle, angora goats, sheep, and hogs. Tourism travel expenditures were $9,783,000 in 1986 which generated 103 jobs and $1,085,000 in payroll.

Medina County ranked 64th in 1985 state agricultural receipts, of which 58% were in livestock and livestock products. In 1985, about 83% of the total 852,000 acres of land was in farm or ranches. About 16% of the agricultural land was in harvested cropland and 6% was irrigated. The primary livestock and products are beef and dairy cattle, sheep, wool, angora goats and mohair. Primary crops are feed sorghum and corn, and wheat. Fruits and vegetables, including peaches, pecans, carrots, potatoes and cabbages are important in some areas. Tourism travel expenditures in 1986 generated about 122 jobs $1,704,000 in payroll.

The state has designated a Texas Hill Country Trail which runs through Medina and Uvalde Counties, and other scenic regions of south central Texas. Of particular interest is the Frio River Canyon along U.S. 83, FM 1050 and Texas 127(Texas Almanac, 1989; Clements, 1988). The Hill County Natural Area is a 5,373-acre tract of typical hill county terrain and vegetation that is located on the boundary of Bandera and Medina Counties eight miles east of Bandera. Hiking, bird-watching, horse back riding, over night primitive camping, and other non consumptive activities are allowed (TPWD, 1989). Public hunts are conducted under the Texas Parks and Wildlife Type I Management Program. Located in Uvalde County, Garner State Park covers 1,420 acres with camping and trailer sites as fishing, swimming, miniature golf and pedal boats. Major rivers for boating and fishing are the Leona, Nueces, Frio, Dry Frio, Sabinal and East Elm creek.

Land Use and Employment in Medina and Uvalde Counties are summarized in Table 2-3.

2.5 Cultural Resources

Cultural resources in the proposed reservoir area were researched and a comprehensive inventory of the study area developed to allow estimates to be made of the probable survey, testing and mitigation costs at each reservoir site. Detailed cultural resources information is archived in the project file, and is summarized and discussed in a report prepared by Lone Star Archaeological Services.

Texas Archaeological Research Laboratory files were examined and data on 231 archaeological sites determined to occur in the upper Nueces Basin were compiled. Known historic sites in the study area were compiled from the National Register of Historic Places. All site locations were plotted on 7.5 minute quadrangle maps and assessed for the probability that they would be affected by construction of one of the proposed recharge reservoirs. Because of the very uneven coverage of the records, average densities, types and topographic locations of archaeological sites were considered in assessing probable survey and testing needs, and mitigation liabilities.

Of the 231 sites known to be in the study area, 217 (94%) occur in Uvalde County, and less than 50 (< 22%) might be affected if all recharge sites were fully developed. However, these statistics reflect strong sample bias and an absolute lack of information from some areas. Burned rock middens are the most common (130, 56%) type of site recorded in the area, followed by prehistoric open terrace sites (53, 23%), rock quarries (9), rock shelters (5), and caves (3). Nine historic sites are recorded in the study area, and at 22 sites (9.5%), no information beyond the location is available.

3.0 RECHARGE DAM SITE EVALUATIONS

3.1 Recharge Site Characteristics

The characteristics of each proposed reservoir site are summarized in Table 3-1. The eight sites in Medina County are all relatively small, with maximum surface areas ranging from 120 acres at Quihi Creek to 2,000 acres at Upper Hondo. The sites in Uvalde County are similar, but three proposed reservoirs have surface areas in excess of 3800 acres (Montell, 6190; Indian Creek, 7650; Concan, 3840). The only sites exhibiting a preponderance of woodland are the two on Verde Creek. The Elm, and Upper Hondo and Seco Creek sites are predominantly open woodland or savannah. These are likely to be managed grazing lands (native pasture) with an understory dominated by domesticated grasses.

Although wetland acreages within each site are given as they appear on the NWI maps (FWS, 1990), the classification system is both subjective and redundant. Actual wetland types are restricted to perennial and intermittent streams and stock ponds (the various "palustrine" categories). The wetland acreages in this table probably represent maxima, and where onsite delineations are performed,

TABLE 3-1
RESERVOIR SITE SUMMARY

Medina County	Quihi Creek	Elm Creek	Upper Verde	Lower Verde
Reservoir Type	2	2	1	2
Normal pool elevation MSL/Acre	1001/120	997/370	1301/880	1013/1730
Vegetational Type (TPWD,1984)				
Live oak-ashe juniper park	X	X	X	X
Live oak-ashe juniper wood				
Mesquite-live oak-bluewood				
Mesquite-blackbrush brush				
Land cover (based on NHAP, 1990)				
percent wood			85	97
percent scattered wood		90		
percent brush	100			
percent pasture/field		10	15	3
Wetlands acreage (USFWS, 1990)				
riverine/lwr perennial/UB				
riverine/lwr perennial/SB				
riverine/lwr perennial/US			3	
riverine/intermittent/SB	1.3	3		1.2
riverine/intermittent/UB				
palustrine/UB	1.5		9	7
palustrine/US		1.5		
palustrine/SS-BLD			2	
palustrine/SS-NLD				
palustrine/FO-BLD	1			
palustrine/emergent				
*Endangered Species (USFWS)				
*Important Species/ Habitat				
**Recreational Importance	1	1	3	2

TABLE 3-1 (Continued)
RESERVOIR SITE SUMMARY

Medina County	Upper Hondo	Lower Hondo	Upper Seco	Lower Seco
Reservoir Type	1	2	1	2
Normal pool elevation MSL/Acre	1266/2000	1102/1260	1441/900	1090/1630
Vegetational Type (TPWD,1984)				
Live oak-ashe juniper park	X	X	X	X
Live oak-ashe juniper wood				
Mesquite-live oak-bluewood				
Mesquite-blackbrush brush				
Land cover (based on NHAP, 1990)				
percent wood	80			
percent scattered wood		30	60	30
percent brush				
percent pasture/field	20	70	40	70
Wetlands acreage (USFWS, 1990)				
riverine/lwr perennial/UB				
riverine/lwr perennial/SB			6	
riverine/lwr perennial/US				
riverine/intermittent/SB	6.4	1.2		
riverine/intermittent/UB				
palustrine/UB				
palustrine/US	7	0.25		
palustrine/SS-BLD		4	5	1
palustrine/SS-NLD				
palustrine/FO-BLD				
palustrine/emergent				
*Endangered species (USFWS)				
*Important species/ Habitat	3	1	3	
**Recreational importance	3	3	3	1

TABLE 3-1 (Continued)
RESERVOIR SITE SUMMARY

Uvalde County	Upper Sabinal	Lower Sabinal	Little Blanco	Blanco
Reservoir Type	1	2	2	2
Normal pool elevation MSL/Acre	1266/3110	1045/1430	1251/210	1230/260
Vegetational Type (TPWD,1984)				
Live oak-ashe juniper prk	X	X	X	X
Live oak-ashe juniper wood				
Live oak-juniper-bluewd prk				
Mesquite-blackbrush brush				
Land cover (based on NHAP, 1990)				
percent wood	30	1	10	5
percent scattered wood				
percent brush		70	10	95
percent pasture/field	70	29	80	
Wetlands acreage (USFWS, 1990)				
riverine/lwr perennial/UB	2.4			
riverine/lwr/perennial/SB				
riverine/lwr perennial/US				
riverine/intermittent/SB		1.8	1.6	1.6
riverine/intermittent/UB				
palustrine/UB	5			
palustrine/US		1		
palustrine/SS-BLD	7			
palustrine/SS-NLD				
palustrine/FO-BLD	7.4			
palustrine/emergent	5			
*Endangered species (USFWS)				
*Important species/ Habitat	3	3		
**Recreational importance	3	1	3	3

TABLE 3-1 (Continued)
RESERVOIR SITE SUMMARY

Uvalde County	Concan	Lower Frio	Upper Dry Frio	Lower Dry Frio
Reservoir Type	1	2	1	2
Normal pool elevation MSL/Acre	1365/3840	1123/1760	1438/1800	1171/1190
Vegetational Type (TPWD,1984)				
Live oak-juniper park	X	X	X	X
Live oak-ashe juniper wood			X	
Live oak-juniper-bluewd prk		X		X
Mesquite-blackbrush brush				
Land cover (based on NHAP, 1990)				
percent wood	20		25	
percent scattered wood				
percent brush	40	80		75
percent pasture/field	40	20	75	25
Wetlands acreage (USFWS, 1990)				
riverine/lwr perennial/UB		0.6		
riverine/lwr perennial/SB				
riverine/lwr perennial/US		1.8	1.2	
riverine/intermittent/SB	1.8			2.4
riverine/intermittent/UB				
palustrine/UB				
palustrine/US		5	1	
palustrine/SS-BLD			3	
palustrine/SS-NLD			1	
palustrine/FO-BLD				
palustrine/emergent				
*Endangered species (USFWS)	2,3			3
*Important species/ Habitat	1,2,3	3	3	3
**Recreational importance	4	4	4	4

TABLE 3-1 (Concluded)
RESERVOIR SITE SUMMARY

Wetlands:
UB = unconsolidated bottom
SB = streambed
US = unconsolidated shore
SS-BLD = scrub-shrub - broad-leaved deciduous
SS-NLD = scrub-shrub - needle-leaved deciduous
FO-BLD = forested - broad-leaved deciduous

* Key to Endangered species and Important species/Habitat Code:

1 = within reservoir
2 = within one - two miles of reservoir
3 = within the vicinity, but not necessarily within drainage of the reservoir

**Key to Recreational importance:

4 = very high use and esthetic attraction, established recreational facility within the vicinity
3 = high use and esthetic attraction, recreational use activities like boating and fishing
2 = seasonal recreational use and esthetic attraction
1 = no public access

jurisdictional wetlands may be less. In any case, even the largest sites exhibit only minor amounts of wetland.

With respect to federally listed Endangered and Threatened species, occurrences have been reported from the vicinity of the Lower Dry Frio and Concan sites. State listed species, or species and resources of special concern to Texas Parks and Wildlife Department, have been reported within, or in the vicinity of, several additional sites. The latter species and resources are not protected by either state or federal law, but are considered to occur in only limited numbers, to have restricted distribution, or to be sensitive to disturbance. Some of these are "Category 2" species that are currently under study and may at some time be listed as Endangered or Threatened by the U.S. Fish and Wildlife Service. This information is presented in detail in Table 3-2.

Recreational importance is based on available access and reported level of use. The categories used, low, medium, high and very high, are relative only to the other sites.

3.2 Environmental Effects and Mitigation Requirements

All things being equal, the environmental effects of a particular project should be proportional to the size of the area affected. Although this will be roughly true for the 19 sites addressed here, they are not all equivalent in terms of environmental importance or sensitivity, and neither are all the projects equal in the nature and distribution of their effects on the landscape, biological communities and human activities and cultural resources. Only the latter, if defined in terms of archaeological sites, appears to be reasonably evenly distributed so that effort and cost for archaeological study and mitigation will be proportional to reservoir area, except, perhaps, in the case of the Montell site. To

TABLE 3-2

IMPORTANT SPECIES AND HABITATS REPORTED IN THE AREA OF THE PROPOSED RESERVOIR SITES

Texas Parks and Wildlife, Resource Protection Division, 1991

Taxa		Federal Status	State Status	State Rank	Reservoir *
Ghost-faced bat	*Mormoops megalophylla*			S2	Concan 3 U. Seco 3 L. Dry Frio 3
Black-capped vireo	*Vireo atricapillus*	LE	E	S2	Concan 2
Gold-cheeked warbler	*Dendroica chrysoparia*	LE	E	S2	Concan 3
Texas Salamander	*Eurycea neotenes*	C2		S3	Montell 1,2,3 Concan 1,2 U. Sabinal 3 L. Sabinal 3 U. Seco 3 U. Hondo 3
Guadalupe Bass	*Micropterus Treculi*	C2		S3	Montell 3 Indian Creek 3
Bracted twistflower	*Streptamthus bracteatus*	C2		S2	Concan 3
Buckley tridens	*Tridens buckleyanus*			S2	Concan 3
Comal snakewood	*Colubrina Stricta*	C2		S1	Indian Creek 3
Dark noseburn	*Tregia nigricans*			S3	Concan 2, 3 U. Dry Frio 3
Hill country mercury	*Argythamnia aphoroides*	C2		S2	Concan 3
Montell fourwort	*Tetramerium platystegium*			S3	Montell 1
Sabinal prairie-clover	*Dalea Sabinal*	C2		S1	Indian Creek 3

TABLE 3-2 (Continued)

Taxa		Federal Status	State Status	State Rank	Reservoir *
Texas amorpha	*Amorpha Roemerana*	3C		S3	Concan 1,3 U. Dry Frio 3
Texas grease bush	*Forsellesia Texensis*	C2		S1	Indian Creek 3
Texas large seed bittercrest	*Cardamine macrocarpa var Texana*			S2	Indian Creek 3
Texas mock-orange	*Philadelpus Texensis*	3C		S2	Concan 3 U. Hondo 3 L. Hondo 1
Tobusch fishhook cactus	*Ancistrocactus Tobuschii*	LE	E	S2	Concan 3 L. Dry Frio 3
Texas oak series	*Quercus Texana*			S3	Concan 3
Baldcypress- sycamore series	*Taxodium distichum-Platanus occidentalis*			S3	Concan 3
Guajillo series	*Acacia berlandieri*			S5	Concan 3
Ashe-juniper oak series	*Juniperus ashei-Quercus*			S4	Concan 3
Frio bat cave				Private	Concan 3
Ney cave				Private	L. Dry Frio 3
Valdina farms sinkhole				Private	U. Seco 3
Frio springs				Private	Concan 1
Montell springs				Private	Montell 1
Seco creek spring				Private	U. Seco 3

TABLE 3-2 (Concluded)

Key to notes and codes used in Table

* proximity to the reservoir:
1 = within reservoir
2 = within one - two miles
3 = in vicinity of reservoir, not necessarily the drainage area

Federal:

LE = listed as endangered

C2 = candidate category 2; under review for possible listing, but USFWS needs more information

3C = no longer under federal review for listing; either more abundant or widespread than thought.

State Status:

E = Endangered

State Rank:

S1 = less than 6 occurrences known in state; critically imperiled in state; especially vulnerable to extirpation from the state.

S2 = 6-20 known occurrences in state; imperiled because of rarity; very vulnerable to extirpation from the state.

S3 = 21-100 known state occurrences; either rare or uncommon in state.

S4 = more than 100 occurrences in state; apparently secure, though may be quite rare in some areas of state.

S5 = Demonstrably secure in state.

Private = located on privately owned land.

predict the level of effort that will be required to address and mitigate the environmental consequences of each of the 19 proposed reservoir sites, the environmental significance and sensitivity of each site, and the effects of each particular structure and its operation, must be evaluated to obtain a probable impacts scenario. This scenario is then used to generate a set of necessary, permit related activities and probable mitigative requirements that can be roughly costed.

As an ecological generalization, it has long been recognized that species diversity is directly related to the physical complexity of the environment, Particularly where variations in complexity result from vegetational composition and structure, and are therefore directly related to the availability of food and cover. In central and south Texas, wooded and brushy areas typically exhibit the highest species diversity and are inhabited by species that also occur (perhaps even more abundantly) in grasslands, but the converse is rarely true. With respect to the 19 reservoir sites, therefore, we can begin assessing environmental value in terms of the proportion of woodland and brush versus open lands (pasture/field). Woodland development can also be used as an index of environmental sensitivity as it takes longer to regenerate the habitats and biotic resources of a mature woodland, relative to a grassland or brush cover in a given region. In the study area, moreover, the live oak-ashe juniper woodlands are known to be important to several Endangered and rare species, allowing some additional discrimination with respect to sensitivity.

Considering freshwater aquatic habitats, the qualities of permanence and consistency are excellent indicators of both biological importance and sensitivity. Species diversity and productivity are both nearly always greater in perennially flowing streams and springs than in intermittent systems, even when permanent reach in which no flow occurs at the upstream end about 43% of the time. Operation of either Montell or Indian Creek would decrease median inflow to this reach from 350 to 250 acre-feet/month. This effect results from reductions in flow frequencies spread throughout the intermediate flow range (300-40,000 acre-feet/month), with no significant changes at either low flows or at flood flows. The frequency of overbanking flows (>800 cfs) would be reduced by less than 1%. Therefore, neither would zero or low flow episodes be extended or made more frequent, nor would flood events necessary for channel flushing and inundation of perched wetlands be reduced, and total annual inflows would be reduced by about 8% (unpublished hydrologic analysis, HDR Engineering, Inc.).

The evaluation criteria discussed above are summarized in Table 3-3, the environmental impacts evaluation matrix. The 19 proposed reservoirs are arraigned in descending order of predicted environmental impact in this table. While it is recognized that the exact order may be a matter of conjecture, the reservoirs do fall into three rather distinct groups: 1) Highest probable impact, **Montell** because of size, extensive woodlands, cultural resources, permanent inundation, affects a perennial reach and will probably require scheduled releases, possible presence of protected species or resources, and extensive relocations; and **Concan** because of possible presence of Endangered species and protected resources, permanent inundation of a perennial reach, downstream flow needs, and extensive relocations; 2) Medium probable impact, the remaining Type 1 reservoirs; and 3) Lowest probable impact, consisting of the Type 2 reservoirs. The Indian Creek site is intermediate in environmental and operating characteristics between reservoir Types 1 and 2. While the Nueces is intermittent here, it apparently does flow for a substantial proportion of time, and permanent pool habitats are maintained throughout the recharge zone. Recharge is so slow

TABLE 3-3

Environmental Impacts Evaluation Matrix

	Montell	Concan	U. Dry Frio	U. Hondo	U. Sabinal	U. Seco
Woods (acres)	4643	768	450	1,600	933	540
Brush (acres)	1238	1536				
Wood type	O/J	O/J	O/J	O/J	O/J	O/J
Stream Flow (S,P,I,R)	P	P, S	P	I, S	P, S	P, S
Special Resources [1]	NO	YES	YES	YES	YES	YES
Permanent innundation	YES	YES	YES	YES	YES	YES
Instream flow requirement	POSSIBLE	POSSIBLE	POSSIBLE	POSSIBLE	POSSIBLE	POSSIBLE

O/J = live oak - ashe juniper woods
M/O = mesquite - live oak - bluewood parks
M/B = mesquite - blackbrush brush
Stream flow code:
S = Spring
P = Perennial
I = Intermittent
R = Recharge Zone

[1] Special Resources are endangered species, important species or important habitats, detailed in Tables 3-1 and 3-2

TABLE 3-3 (Continued)

Environmental Impacts Evaluation Matrix

	U. Verde	Indian Creek	L. Dry Frio	L. Sabinal	L Verde	L Frio
Woods (acres)	748			14.3	1,678	
Brush (acres)		6,120	893	1,001		1,408
Wood type	O/J	M/B	M/O	O/J	O/J	M/O
Stream Flow (S,P,I,R)	P, S	I		R, S	R	R, I
Special Resources [1]	NO	YES	YES	YES	NO	YES
Permanent innundation	YES	YES	NO	NO	NO	NO
Instream flow requirement	POSSIBLE					

O/J = live oak - ashe juniper woods
M/O = mesquite - live oak- bluewood parks
M/B = mesquite - Blackbrush brush
Stream flow code:
S = Spring
P = Perennial
I = Intermittent
R = Recharge Zone

[1] Special Resources are endangered species, important species or important habitats, detailed in Tables 3-1 and 3-2

TABLE 3-3 (Concluded)

Environmental Impacts Evaluation Matrix

	L. Hondo	Blanco	Little Blanco	Elm Creek	Quihi Creek	Leona	L. Seco
Woods (acres)	378	13	21	33			489
Brush (acres)		247	21		120	220	
Wood type	O/J	O/J	O/J	O/J		M/B	O/J
Stream Flow (S,P,I,R)	R	R	R	R	R	R, S	R
Special Resources [1]	YES	NO	NO	NO	NO	NO	NO
Permanent innundation	NO	NO	NO	NO	NO	NO	NO
Instream flow requirement							

O/J = live oak - ashe juniper woods
M/O = mesquite - live oak- bluewood parks
M/B = mesquite - Blackbrush brush
Stream flow code:
S = Spring
P = Perennial
I = Intermittent
R = Recharge Zone

[1] Special Resources are endangered species, important species or important habitats, detailed in Tables 3-1 and 3-2

at Indian Creek that once filled, it may take more than a year to drain, and its contents would have to be diverted to the Lower Dry Frio site for recharge.

Table 3-4 summarizes projected costs for environmental and archaeological work, and probable mitigation requirements, for each site. These estimates are based on the 100% capacity designs to allow planners and environmental professionals immediate information on the maximum potential impacts and mitigation liabilities of each site. Impacts and mitigation requirements for reduced capacity designs can often be reduced roughly in proportion to the reduction in conservation pool area. Environmental report costs are assumed to include baseline studies, a comprehensive Environmental Assessment, and permit support. With respect to the Type 2 sites, it is conceivable that although a dam could be constructed in a non-wetland location to avoid obtaining a 404 permit from the U.S. Army Corps of Engineers, a water rights permit from Texas Water Commission would be required. Notations indicate where the probable need for additional efforts (endangered species, instream flows) have significantly affected projected Environmental report costs. Mitigation land costs are given only for Type 1 sites, and Indian Creek, where long term impoundment would eliminate terrestrial habitat. These costs are based on acquisition of an acreage equal to that in the proposed conservation pools at a cost of $800/acre. More refined estimates of mitigation land costs are not practical or justified at this stage, as mitigation acreage is typically negotiated with the resource agencies, and will be sensitive to reservoir site characteristics, and to the availability of suitable mitigation sites. Costs for habitat evaluation and site selection studies are expected to fall in the range of $5,000-$20,000 per site, depending on the area and vegetation types involved. Management costs are based on $10/acre/year and is in addition to any preparatory work (eg, fence construction) required before acceptance by a management agency.

If several sites are to be constructed as parts of a single project, a comprehensive Environmental Assessment should be performed, as an Environmental Impact Statement - level study that addresses all related project actions would likely be required by the Texas Water Commission and U.S. Army Corps of Engineers. Cost for a comprehensive EA will be similar to the sum of costs for the individual sites.

TABLE 3-4

PROJECTED COSTS

	Quihi Creek	Elm Creek	U. Verde	L. Verde	U. Hondo
100% normal pool elevation/surface area MSL/acres	1001/120	997/370	1301/880	1013/1730	1266/2000
Reservoir Type	2	2	1	2	1
Environmental reports ($)	15,000	15,000	50,000	35,000	75,000
Threatened/endangered species survey	NO	YES	YES	NO	YES
Section 7 consultation	NO	NO	?	NO	?
Instream flow studies	NO	NO	YES	NO	YES
Environmental mitigation	NO	NO	YES	NO	YES
Habitat Evaluation Program (HEP) ($)			2,500		2,500
Land costs ($)			704,000		1,600,000
Management ($/year)			8,800		20,000
Geotechnical-geomorphology ($)	3,200	6,400	6,000	14,200	15,900
Archeological & historical survey ($)	2,100	6,300	12,400	22,600	25,600
Testing for National Register Eligibility ($)	1,700	5,200	12,000	23,600	24,400
Cultural Resources mitigation, USCE (404) permit ($)	9,000	9,000	149,600	16,000	272,000
TOTAL COST ($)	31,000	41,900	936,500	111,400	2,015,400

TABLE 3-4 (Continued)

PROJECTED COSTS

	U. Seco	L. Seco	Little Blanco	Blanco	U. Sabinal
100% normal pool elevation/ surface MSL / acres	1441/900	1090/1630	1251/210	1230/260	1266/3110
Reservoir Type	1	2	2	2	1
Environmental reports ($)	50,000	35,000	15,000	15,000	75,000
Threatened/endangered species survey	YES	YES	YES	YES	YES
Section 7 consultation	?	NO	NO	NO	YES
Instream flow studies	YES	NO	NO	NO	YES
Environmental mitigation	YES	NO	NO	NO	YES
Habitat Evaluation Program (HEP) ($)	2,500				3,500
Land costs ($)	720,000				2,488,000
Management ($/year)	9,000				31,100
Geotechnical-geomorphology ($)	8,700	11,400	3,400	3,800	21,200
Archeological & historical survey ($)	15,300	22,300	3,600	4,500	37,400
Testing for National Register Eligibility ($)	11,800	21,300	3,000	3,700	37,700
Cultural Resources mitigation, USCE (404) permit ($)	144,000	16,000	9,000	9,000	404,300
TOTAL COST ($)	952,300	106,000	34,000	36,000	3,067,100

TABLE 3-4 (Continued)

PROJECTED COSTS

	L. Sabinal	Concan	Montell	Leona River	Indian Creek
100% normal pool elevation/ surface MSL / acres	1045/1430	1365/3840	1335/6190	1153/220	1013/7650
Reservoir Type	2	1	1	2	1/2#
Environmental reports ($)	35,000	125,000	150,000	15,000	100,000
Threatened/endangered species survey	YES	YES	YES	NO	YES
Section 7 consultation	?	YES	YES	NO	?
Instream flow studies	NO	YES	YES	NO	NO
Environmental mitigation	NO	YES	YES	NO	YES
Habitat Evaluation Program (HEP) ($)		3,500	5,000		2,500
Land costs ($)		3,072,000	4,952,000		1,600,000
Management ($/year)		38,400	61,900		20,000
Geotechnical-geomorphology ($)	16,900	22,000	32,200	8,600	35,700
Archeological & historical survey ($)	19,500	46,900	73,100	3,800	90,300
Testing for National Register Eligibility ($)	18,400	46,500	71,200	3,100	88,000
Cultural Resources mitigation , USCE (404) permit ($)	16,000	499,200	742,800	9,000	320,000
TOTAL COST ($)	105,800	3,815,100	6,026,300	39,500	2,236,500

2,000 acres of permanent inundation

TABLE 3-4 (Concluded)

PROJECTED COSTS

	L. Dry Frio	U. Dry Frio	L. Frio	L. Hondo
100% normal pool elevation/ surface MSL / acres	1171/1190	1438/1800	1123/1760	1102/1260
Reservoir Type	2	1	2	2
Environmental reports ($)	25,000	75,000	35,000	25,000
Threatened/endangered species survey	YES	?	NO	NO
Section 7 consultation	?	NO	NO	NO
Instream flow studies	NO	YES	NO	NO
Environmental mitigation	NO	YES	NO	NO
Habitat Evaluation Program (HEP) ($)		2,500		
Land costs ($)		1,440,000		
Management ($/year)		18,000		
Geotechnical-geomorphology ($)	11,200	19,400	16,900	9,700
Archeological & historical survey ($)	16,300	24,600	24,000	17,200
Testing for National Register Eligibility ($)	15,500	23,500	23,000	16,500
Cultural Resources-mitigation (404) permit ($)	16,000	288,000	16,000	16,000
TOTAL COST ($)	84,000	1,873,000	114,900	84,400

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APPENDIX B

Project Cost and Data Summary Tables
Pertinent Notes and Assumptions

General Notes

1. All estimated costs are in 1991 dollars.
2. Although capital and annual project costs are presented to the nearest dollar, there is no implied accuracy beyond the fourth significant digit.
3. Although unit costs are presented to the nearest dollar, there is no implied accuracy beyond the second significant digit.
4. Calculated water surface elevations are presented to the nearest tenth of a foot for comparative purposes only as they are based on topographic mapping generally having a 10-foot or 20-foot contour interval.
5. Tables identified with the extension "a" in the heading are based on the first water rights scenario of honoring all water rights to the maximum extent possible.
6. Tables identified with the extension "b" in the heading are based on the second water rights scenario of honoring all water rights to the maximum extent possible assuming the limited purchase of water rights from the owners of the CC/LCC System.

Item Specific Notes

1. Dam, Spillway, and Appurtenant Works Costs include 20% contingencies.
2. Road Relocation Costs at 25% and 50% of maximum conservation capacity are generally computed by linear interpolation of costs for the 10% and 100% capacities.
3. Land Acquisition Costs are based on purchase of land up to the 25-year flood level at $800/ac, easement purchase between the 25-year and 100-year flood levels at $500/ac, $50,000/unit for purchase of habitable structures within the reservoir, and $10,000/ac for the purchase of premium waterfront property affected by Type 1 reservoirs.
4. Environmental Mitigation Costs are calculated by multiplying the ratio of surface areas at the applicable and maximum conservation capacities by the mitigation cost for the maximum conservation capacity.
5. Engineering, Legal, Financial, and Misc. Costs are assumed equal to 20% of related capital costs.
6. Annual Capital Costs are based on a 25-year finance period at an annual interest rate of 7.5%.
7. Operations and Maintenance Costs are based on 0.4% of Total Capital Cost and include power and mitigation land management costs for some projects.
8. Water Rights Mitigation Costs are based on $321/ac-ft of CC/LCC System Yield Reduction and $16/ac-ft of Estuarine Inflow Reduction.

Appendix C
Summary of Type 1 Recharge Enhancement Programs Honoring All Water Rights

Maximum Incremental Cost ($/acft/yr)	Program	Percent Capacity	Average Conditions		Drought Conditions		Annual Cost ($)
			Recharge (acft/yr)	Unit Cost ($/acft/yr)	Recharge (acft/yr)	Unit Cost ($/acft/yr)	
$164	Upper Sabinal	10	10,080	163	2,520	650	1,638,828
$211	Upper Sabinal	10	10,080	163	2,520	650	1,638,828
	Upper Verde	25	3,990	210	1,390	603	838,600
	Sum or Average		14,070	176	3,910	634	2,477,428
$218	Upper Sabinal	10	10,080	163	2,520	650	1,638,828
	Upper Verde	25	3,990	210	1,390	603	838,600
	Concan	10	8,190	217	3,085	577	1,780,037
	Sum or Average		22,260	191	6,995	609	4,257,465
$222	Upper Sabinal	10	10,080	163	2,520	650	1,638,828
	Upper Verde	25	3,990	210	1,390	603	838,600
	Concan	10	8,190	217	3,085	577	1,780,037
	Upper Dry Frio	10	5,840	221	2,630	491	1,291,856
	Sum or Average		28,100	197	9,625	577	5,549,321
$241	Upper Sabinal	10	10,080	163	2,520	650	1,638,828
	Upper Verde	25	3,990	210	1,390	603	838,600
	Concan	10	8,190	217	3,085	577	1,780,037
	Upper Dry Frio	10	5,840	221	2,630	491	1,291,856
	Montell	10	26,370	240	9,200	688	6,333,172
	Sum or Average		54,470	218	18,825	631	11,882,493
$249	Upper Sabinal	10	10,080	163	2,520	650	1,638,828
	Upper Verde	25	3,990	210	1,390	603	838,600
	Concan	10	8,190	217	3,085	577	1,780,037
	Upper Dry Frio	10	5,840	221	2,630	491	1,291,856
	Montell	10	26,370	240	9,200	688	6,333,172
	Upper Hondo	10	4,700	248	1,140	1,024	1,166,935
	Sum or Average		59,170	221	19,965	654	13,049,428

Appendix C
Summary of Type 1 Recharge Enhancement Programs Honoring All Water Rights

Maximum Incremental Cost ($/acft/yr)	Program	Percent Capacity	Average Conditions		Drought Conditions		Annual Cost ($)
			Recharge (acft/yr)	Unit Cost ($/acft/yr)	Recharge (acft/yr)	Unit Cost ($/acft/yr)	
$289	Upper Sabinal	10	10,080	163	2,520	650	1,638,828
	Upper Verde	25	3,990	210	1,390	603	838,600
	Concan	10	8,190	217	3,085	577	1,780,037
	Upper Dry Frio	10	5,840	221	2,630	491	1,291,856
	Montell	10	26,370	240	9,200	688	6,333,172
	Upper Hondo	25	7,030	262	1,140	1,613	1,838,632
	Sum or Average		61,500	223	19,965	687	13,721,125
$293	Upper Sabinal	10	10,080	163	2,520	650	1,638,828
	Upper Verde	25	3,990	210	1,390	603	838,600
	Concan	10	8,190	217	3,085	577	1,780,037
	Upper Dry Frio	25	8,360	243	2,900	699	2,027,901
	Montell	10	26,370	240	9,200	688	6333172
	Upper Hondo	25	7,030	262	1,140	1,613	1,838,632
	Sum or Average		64,020	226	20,235	714	14,457,170
$336	Upper Sabinal	10	10,080	163	2,520	650	1,638,828
	Upper Verde	25	3,990	210	1,390	603	838,600
	Concan	10	8,190	217	3,085	577	1,780,037
	Upper Dry Frio	25	8,360	243	2,900	699	2,027,901
	Montell	10	26,370	240	9,200	688	6,333,172
	Upper Hondo	25	7,030	262	1,140	1,613	1,838,632
	Upper Seco	50	3,410	335	290	3,944	1,143,739
	Sum or Average		67,430	231	20,525	760	15,600,909
$496	Upper Sabinal	10	10,080	163	2,520	650	1,638,828
	Upper Verde	25	3,990	210	1,390	603	838,600
	Concan	10	8,190	217	3,085	577	1,780,037
	Upper Dry Frio	50	9,400	271	2,900	877	2,543,659
	Montell	10	26,370	240	9,200	688	6,333,172
	Upper Hondo	25	7,030	262	1,140	1,613	1,838,632
	Upper Seco	50	3,410	335	290	3,944	1,143,739
	Sum or Average		68,470	235	20,525	785	16,116,667

Appendix D
Summary of Type 2 Recharge Enhancement Programs With Purchase of Water Rights

Maximum Incremental Cost ($/acft/yr)	Program	Percent Capacity	Average Conditions		Drought Conditions		Annual Cost ($)
			Recharge (acft/yr)	Unit Cost ($/acft/yr)	Recharge (acft/yr)	Unit Cost ($/acft/yr)	
$67	Lower Sabinal	10	7,720	66	2,300	221	508,254
$104	Lower Sabinal	25	12,190	80	2,770	351	971,009
$115	Lower Sabinal	25	12,190	80	2,770	351	971,009
	Lower Frio	10	5,940	114	2,020	337	679,979
	Sum or Average		18,130	91	4,790	345	1,650,988
$135	Lower Sabinal	25	12,190	80	2,770	351	971,009
	Lower Frio	10	5,940	114	2,020	337	679,979
	Lower Verde	10	3,150	134	1,380	306	422,382
	Sum or Average		21,280	97	6,170	336	2,073,370
$151	Lower Sabinal	25	12,190	80	2,770	351	971,009
	Lower Frio	10	5,940	114	2,020	337	679,979
	Lower Verde	10	3,150	134	1,380	306	422,382
	Lower Hondo	10	3,930	150	1,190	494	587,634
	Sum or Average		25,210	106	7,360	362	2,661,004
$186	Lower Sabinal	25	12,190	80	2,770	351	971,009
	Lower Frio	25	9,530	141	3,180	424	1,346,732
	Lower Verde	10	3,150	134	1,380	306	422,382
	Lower Hondo	10	3,930	150	1,190	494	587,634
	Sum or Average		28,800	116	8,520	391	3,327,757
$197	Lower Sabinal	50	15,350	104	2,770	575	1,593,319
	Lower Frio	25	9,530	141	3,180	424	1,346,732
	Lower Verde	10	3,150	134	1,380	306	422,382
	Lower Hondo	10	3,930	150	1,190	494	587,634
	Sum or Average		31,960	124	8,520	464	3,950,067
$212	Lower Sabinal	50	15,350	104	2,770	575	1,593,319
	Lower Frio	25	9,530	141	3,180	424	1,346,732
	Lower Verde	25	4,630	159	1,970	373	735,236
	Lower Hondo	10	3,930	150	1,190	494	587,634
	Sum or Average		33,440	127	9,110	468	4,262,921

Appendix D
Summary of Type 2 Recharge Enhancement Programs With Purchase of Water Rights

Maximum Incremental Cost ($/acft/yr)	Program	Percent Capacity	Average Conditions		Drought Conditions		Annual Cost ($)
			Recharge (acft/yr)	Unit Cost ($/acft/yr)	Recharge (acft/yr)	Unit Cost ($/acft/yr)	
$214	Lower Sabinal	50	15,350	104	2,770	575	1,593,319
	Lower Frio	25	9,530	141	3,180	424	1,346,732
	Lower Verde	25	4,630	159	1,970	373	735,236
	Lower Hondo	10	3,930	150	1,190	494	587,634
	Indian Creek	25	26,500	213	12,920	437	5,645,484
	Sum or Average		59,940	165	22,030	450	9,908,405
$217	Lower Sabinal	50	15,350	104	2,770	575	1,593,319
	Lower Frio	25	9,530	141	3,180	424	1,346,732
	Lower Verde	25	4,630	159	1,970	373	735,236
	Lower Hondo	10	3,930	150	1,190	494	587,634
	Indian Creek	25	26,500	213	12,920	437	5,645,484
	Lower Dry Frio	25	4,090	216	1,360	650	883,676
	Sum or Average		64,030	169	23,390	461	10,792,081
$229	Lower Sabinal	50	15,350	104	2,770	575	1,593,319
	Lower Frio	25	9,530	141	3,180	424	1,346,732
	Lower Verde	25	4,630	159	1,970	373	735,236
	Lower Hondo	25	6,170	178	1,190	924	1,099,252
	Indian Creek	25	26,500	213	12,920	437	5,645,484
	Lower Dry Frio	25	4,090	216	1,360	650	883,676
	Sum or Average		66,270	171	23,390	483	11,303,699
$239	Lower Sabinal	50	15,350	104	2,770	575	1,593,319
	Lower Frio	25	9,530	141	3,180	424	1,346,732
	Lower Verde	25	4,630	159	1,970	373	735,236
	Lower Hondo	25	6,170	178	1,190	924	1,099,252
	Indian Creek	25	26,500	213	12,920	437	5,645,484
	Lower Dry Frio	25	4,090	216	1,360	650	883,676
	Lower Seco	10	2,520	238	290	2,069	599,911
	Sum or Average		68,790	173	23,680	503	11,903,610
$281	Lower Sabinal	50	15,350	104	2,770	575	1,593,319
	Lower Frio	50	12,570	175	3,180	692	2,199,762
	Lower Verde	25	4,630	159	1,970	373	735,236
	Lower Hondo	25	6,170	178	1,190	924	1,099,252
	Indian Creek	25	26,500	213	12,920	437	5,645,484
	Lower Dry Frio	25	4,090	216	1,360	650	883,676
	Lower Seco	10	2,520	238	290	2,069	599,911
	Sum or Average		71,830	178	23,680	539	12,756,640

Appendix D
Summary of Type 2 Recharge Enhancement Programs With Purchase of Water Rights

Maximum Incremental Cost ($/acft/yr)	Program	Percent Capacity	Average Conditions		Drought Conditions		Annual Cost ($)
			Recharge (acft/yr)	Unit Cost ($/acft/yr)	Recharge (acft/yr)	Unit Cost ($/acft/yr)	
$335	Lower Sabinal	50	15,350	104	2,770	575	1,593,319
	Lower Frio	50	12,570	175	3,180	692	2,199,762
	Lower Verde	25	4,630	159	1,970	373	735,236
	Lower Hondo	25	6,170	178	1,190	924	1,099,252
	Indian Creek	50	30,130	228	14,600	470	6,859,743
	Lower Dry Frio	25	4,090	216	1,360	650	883,676
	Lower Seco	10	2,520	238	290	2,069	599,911
	Sum or Average		75,460	185	25,360	551	13,970,899
$347	Lower Sabinal	50	15,350	104	2,770	575	1,593,319
	Lower Frio	50	12,570	175	3,180	692	2,199,762
	Lower Verde	25	4,630	159	1,970	373	735,236
	Lower Hondo	50	7,600	210	1,190	1,340	1,594,832
	Indian Creek	50	30,130	228	14,600	470	6,859,743
	Lower Dry Frio	25	4,090	216	1,360	650	883,676
	Lower Seco	10	2,520	238	290	2,069	599,911
	Sum or Average		76,890	188	25,360	570	14,466,479
$354	Lower Sabinal	100	18,400	145	2,770	965	2,672,688
	Lower Frio	50	12,570	175	3,180	692	2,199,762
	Lower Verde	25	4,630	159	1,970	373	735,236
	Lower Hondo	50	7,600	210	1,190	1,340	1,594,832
	Indian Creek	50	30,130	228	14,600	470	6,859,743
	Lower Dry Frio	25	4,090	216	1,360	650	883,676
	Lower Seco	10	2,520	238	290	2,069	599,911
	Sum or Average		79,940	194	25,360	613	15,545,848
$357	Lower Sabinal	100	18,400	145	2,770	965	2,672,688
	Lower Frio	50	12,570	175	3,180	692	2,199,762
	Lower Verde	25	4,630	159	1,970	373	735,236
	Lower Hondo	50	7,600	210	1,190	1,340	1,594,832
	Indian Creek	50	30,130	228	14,600	470	6,859,743
	Lower Dry Frio	50	5,390	250	1,360	991	1,347,082
	Lower Seco	10	2,520	238	290	2,069	599,911
	Sum or Average		81,240	197	25,360	631	16,009,254

Appendix D
Summary of Type 2 Recharge Enhancement Programs With Purchase of Water Rights

Maximum Incremental Cost ($/acft/yr)	Program	Percent Capacity	Average Conditions		Drought Conditions		Annual Cost ($)
			Recharge (acft/yr)	Unit Cost ($/acft/yr)	Recharge (acft/yr)	Unit Cost ($/acft/yr)	
$378	Lower Sabinal	100	18,400	145	2,770	965	2,672,688
	Lower Frio	50	12,570	175	3,180	692	2,199,762
	Lower Verde	50	5,640	198	1,980	564	1,116,243
	Lower Hondo	50	7,600	210	1,190	1,340	1,594,832
	Indian Creek	50	30,130	228	14,600	470	6,859,743
	Lower Dry Frio	50	5,390	250	1,360	991	1,347,082
	Lower Seco	10	2,520	238	290	2,069	599,911
	Sum or Average		82,250	199	25,370	646	16,390,261
$382	Lower Sabinal	100	18,400	145	2,770	965	2,672,688
	Lower Frio	50	12,570	175	3,180	692	2,199,762
	Lower Verde	100	6,220	215	1,980	676	1,337,602
	Lower Hondo	50	7,600	210	1,190	1,340	1,594,832
	Indian Creek	50	30,130	228	14,600	470	6,859,743
	Lower Dry Frio	50	5,390	250	1,360	991	1,347,082
	Lower Seco	10	2,520	238	290	2,069	599,911
	Sum or Average		82,830	201	25,370	655	16,611,620
$445	Lower Sabinal	100	18,400	145	2,770	965	2,672,688
	Lower Frio	50	12,570	175	3,180	692	2,199,762
	Lower Verde	100	6,220	215	1,980	676	1,337,602
	Lower Hondo	100	9,420	255	1,190	2,021	2,404,710
	Indian Creek	50	30,130	228	14,600	470	6,859,743
	Lower Dry Frio	50	5,390	250	1,360	991	1,347,082
	Lower Seco	10	2,520	238	290	2,069	599,911
	Sum or Average		84,650	206	25,370	687	17,421,498
$464	Lower Sabinal	100	18,400	145	2,770	965	2,672,688
	Lower Frio	50	12,570	175	3,180	692	2,199,762
	Lower Verde	100	6,220	215	1,980	676	1,337,602
	Lower Hondo	100	9,420	255	1,190	2,021	2,404,710
	Indian Creek	50	30,130	228	14,600	470	6,859,743
	Lower Dry Frio	50	5,390	250	1,360	991	1,347,082
	Lower Seco	10	2,520	238	290	2,069	599,911
	Elm Creek	100	670	463	120	2,584	310,106
	Sum or Average		85,320	208	25,490	696	17,731,604