Southern Bexar County
Medina Valley Surface Water Supply Study

Submitted To:

Bexar Metropolitan Water District
San Antonio, Texas

Texas Water Development Board
Austin, Texas

Submitted By:

Michael Sullivan & Assoc., Inc.
Austin, Texas
in association with
Donald G. Rauschuber & Assoc., Inc.
Austin, Texas

NOVEMBER 1994

MICHAEL SULLIVAN & ASSOCIATES, INC.
Engineering & Environmental Consultants

November 18, 1994

RECEIVED
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REGIONAL PLANNING & PROJECTS

Tom Moreno, General Manager
Bexar Metropolitan Water District
P.O. Box 3577
San Antonio, Texas 78211-0577

Ms. Carolyn Brittin, Director
Regional Water and Wastewater Planning Program
Texas Water Development Board
1700 North Congress
Austin, Texas 78711-3231

Re: Southern Bexar County - Medina Valley Regional Water Supply Study
Final Report

Dear Tom and Carolyn:

Accompanying this letter are you respective copies of the FINAL DRAFT of the Southern Bexar County - Medina Valley Regional Water Supply Study. Twelve (12) copies are intended for the Texas Water Development Board (TWDB) and thirty (30) copies for the Bexar Metropolitan Water District (BexarMet). Locally, copies have already been forwarded to Blackwell-Lackey and Assoc., Inc. and McGinnis Lochridge & Killgore, Inc. BexarMet will be responsible for the remainder of the distribution.

On October 28, 1994, a Public Meeting was held in San Antonio, Texas to brief the public on the contents of this study. The record was held open for twenty (20) days to allow written public comment on the study. No written public comment was received by any of the project sponsors, consultants or attorneys. Therefore, there is not a Response to Public Comment Section to this report. There was one oral comment at the Public Meeting that does require clarification.

The Evergreen Water District was offended at the apparent implication of the report that BexarMet intended to pursue development of Carrizo-Wilcox Formation wells in Atascosa County. The intent of BexarMet is to develop Carrizo-Willcox wells in Southern Bexar County. Any pursuit of wells in Atascosa County would be in conjunction with potential Aquifer Storage and Recovery (ASR) projects that could be developed in coordination with and the consent of the Evergreen Water District. Our apologies for this misinterpretation.

If you have any further questions or comments, please address them to Michael Sullivan and Assoc., Inc. 512/329-2949.

Sincerely,

Michael Sullivan

Michael Sullivan, Ph.D., P.E.
President

cc w/ Attachments: John Ward, Bexar-Medina-Atascosa WCID #1

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OCTOBER 1994

FORWARD

The Southern Bexar County-Medina Valley Regional Water Supply Study was initiated in December of 1991. The study was funded jointly by the Bexar Metropolitan Water District ("**BMWD**") and the Texas Water Development Board ("**Board**") through the Board's Regional Water and Wastewater Planning Fund. As a regional planning study, its purpose is to identify and evaluate potential water supply options for a specified planning area. The report preliminarily evaluates the feasibility of potential options and eliminates those options that were determined to be infeasible or too costly. This regional plan is analogous to an areal photograph taken at 60,000 ft. It is useful for identifying and evaluating broad options, rather than recommending specific engineering details such as specific line routings, or specific well locations.

During the course of this study, significant political and regulatory events changed future supply options available and restricted the use of others. The project was overtaken by events a number of times during its course. Beginning in 1989, there were a number of significant actions which affected this study. A partial list of those actions is presented below:

1989	A Task Force was established by the Edwards Underground Water District, Nueces, San Antonio and Guadalupe-Blanco River Authorities, and Cities of San Antonio, New Braunfels and San Marcos to develop management legislation for the Edwards aquifer. The proposed legislation was not adopted by the Texas Legislature.

June 1989	The Guadalupe-Blanco River Authority filed suit in State court seeking to declare the Edwards an "underground river".
August 1990	A special committee of the Texas Legislature initiated efforts to mediate the Edwards aquifer/river dispute.
March 1991	Mediation failed.
Spring 1991	The Living Water Catfish Farm well started flowing.
May 4, 1991	San Antonio voters rejected Applewhite Reservoir.
May 13, 1991	The Sierra Club filed suit in U.S. District Court alleging the U.S. Fish and Wildlife Service was not enforcing the Endangered Species Act with regard to Comal or San Marcos Springs, in that Spring flow levels had not been established et cetera.
April 14, 1991	A Texas Attorney General's Opinion stated that their previous opinion was incorrect, and that Section 28.011 of the Texas Water Code provided sufficient authority for the Texas Water Commission to regulate groundwater.
April 15, 1992	The Texas Water Commission issued an emergency rule declaring the Edwards aquifer to be an "underground river".
March 1992	The Greater San Antonio Area Citizen's Committee on Water issued a report to Mayor of San Antonio and City Council. That report called for the development of surface water supplies.
September 9, 1992	The Texas Water Commission adopted a permanent rule on the Edwards aquifer, based upon its earlier April 15, 1992 Emergency Rule and Public Comment.
September 11, 1992	In Travis County, a State District Court Judge ruled that the Edwards aquifer was not an "underground river" as a matter of law granting summary judgment against enforcement of the Texas Water Commission Rules of April 15th and September 9th. The Texas Water Commission Rules were declared invalid.
February 1, 1993	On the Endangered Species Act, U.S. District Judge Bunton ruled in favor of the Sierra Club. The Judge set interim spring flow levels and ordered that a satisfactory plan be developed to protect endangered or threatened species in Comal and San Marcos Springs. The judge gave the Texas Legislature until May 31, 1993 to develop its plan.

March 1, 1993	The Texas Water Commission submitted its Management Plan for the Edwards aquifer to the Federal Court.
March 3, 1993	The Texas Water Development Board submitted its Advisory Edwards Aquifer Management Strategy.
May 30, 1993	The Texas Legislature passed S.B. 1477, to be effective September 1, 1993 based on historical pumping patterns, and requiring permits to pump from the Edwards aquifer beginning on March 1, 1994.
May 30, 1993	The effect of S.B. 1477, as related to the South Bexar County study area, was to preclude use of Edwards aquifer water in areas of study not previously served by Edwards.
Summer 1993	The U.S. Department of Justice determined that S.B. 1477 violated the Federal Voting Rights Act and that S.B. 1477 was effectively voided.
February 25, 1994	The U.S. District Court appointed Joe G. Moore as Monitor.
September 30, 1994	The U.S. District Court ordered Joe G. Moore to form a panel, take action to form a plan and report to the Court.
October 20, 1994	U.S. District Court, District of Columbia, determined that Voting Rights Act is applicable to S.B. 1477, thereby requiring trial of case and revision of S.B. 1477 in 1995 Texas Legislative Session to accommodate issues of elected directors and successor status to existing three (3) county Edwards Underground Water District.

The original contract completion date for this study was to have been August 31, 1992. However, the Texas Water Development Board allowed the study to be kept open until the close of the 1993 Legislative Session to allow response to Edwards aquifer regulatory measures, ultimately resulting in passage of S.B. 1477. The first draft of the study was completed in June 1993. The purpose of deferring the completion date was to allow S.B. 1477 and its effect to be considered in this study.

Subsequently, the Bexar Metropolitan Water District requested that the study be kept open to facilitate additional analysis of the Lake Medina and Diversion Reservoir System in support of a Bexar-Medina-Atascosa Counties WCID #1 application to convert the permitted system yield from strictly agricultural to municipal, industrial, and agricultural uses.

Data and potential supply option analysis contained in this report are current as of June 1993.[1] This is prior to the invalidation of S.B. 1477. However, the invalidation of S.B. 1477 does not materially affect the assumptions of this study, since the U.S. District Court Orders remain in effect. The Edwards supply assumptions upon which this study was based remain, in the author's mind and the mind of the Federally appointed Edwards aquifer Monitor, unchanged. Those assumptions are:

1. The Edwards aquifer, based on trends of increased pumpage over the last thirty (30) years, cannot sustain the projected growth of the San Antonio area and serve as the "sole source"[2] of water supply. Additional sources must be developed;

2. Implementation of the U.S. District Court's Order to maintain San Marcos and New Braunfels springs at specified flow levels pursuant to the Endangered Species Act will limit the use of Edwards aquifer at critical periods of low rain (drought);

3. As a result of the Court ordered limit on Spring Flows, there will be either state or federally mandated limits to historical pumpage from the Edwards aquifer;

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[1]Water development activities are viewed as within the study area, i.e. within Bexar County. "Red Line" boundary.

[2]The Edwards has also been designated as "sole source" pursuant to the authority provided to E.P.A. pursuant to the "Gonzalez Amendment" to the Safe Drinking Water Act.

4. In response to the U.S. District Court's Judgment, the legislature passed S.B. 1477. Pursuant to S.B. 1477, which bases regulation on historic use, large geographic areas of the planning area in South Bexar County will not have any entitlement to Edwards aquifer water (additional wells are not possible because of bad water; even if physically possible, total pumping is to be capped);

5. The entities within the planning area are required to base their system operation on TNRCC "firm yield" criteria 30 TAC 290.41 which defines system dependability and back up requirements;

6. No single source will provide sufficient water to the study area to supplement the limited available Edwards aquifer or provide "other water" necessary to "substitute" for the unavailable Edwards water; and,

7. Storage facilities, to assist in retention of water under contract with the BMA, through development of artificial storage and retrieval ("**ASR**") projects,[3] off-channel reservoirs, and related "recharge" projects will require investigation and development that is beyond the scope of this study.

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[3]ASR project(s) which would anticipate storage in aquifers such as the Edwards, un-named shallow aquifers, Austin Chalk, and Carrizo would anticipate necessary to regulatory approvals, interlocal contracts and recharge benefits to the involved aquifer and landowners.

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1.0 INTRODUCTION

1.1 Background and Authorization

1.1.1 Background

The region of Central Texas, underlain by and dependent upon the Edwards Aquifer as its principle source of water, has experienced increasing pressure to develop alternative sources of supply (Figure 1-1). The intent is to relieve the stress on the aquifer as the sole source of supply to the City of San Antonio, other cities of the region, and agricultural interests to the west, and to aid in the preservation of spring flows at Comal and San Marcos. Continuous spring flow is necessary to protect several federally identified threatened or endangered species which depend on the springs or aquifer for life support.

Recent actions by the Texas Natural Resource Conservation Commission (TNRCC) and lawsuits have accelerated efforts to develop alternative water supplies for some users of the region. In July 1992, the Texas Water Commission (TWC), a predecessor agency of the TNRCC, declared the Edwards Aquifer an "underground river" and subject to the appropriative permit procedures and use management regulations of the TWC. Since that declaration, efforts have been ongoing to develop an equitable procedure for allocation of this precious resource amongst the numerous and varied historical users. After this study was started, the Sierra Club filed suit in Federal Court against multiple defendants. In very general terms, the lawsuit alleged that the United States Fish and Wildlife Service was not adequately protecting threatened endangered species that depend on the Edwards Aquifer for their existence. The Federal Court has ruled in favor of the Sierra Club and has ordered that threatened and endangered species in Comal and San Marcos Springs be protected by maintaining certain minimum stream flows at the springs. The court has retained jurisdiction over the case in order to monitor efforts of the parties to manage withdrawals from the Edwards.

Some Edwards Aquifer users have already begun to develop alternative surface supplies. In 1987, the Canyon Regional Water Authority (CRWA) was formed from four rural water supply corporations (WSCs), serving all or portions of five counties to the east of San Antonio. All four WCSs were directly or indirectly dependent on the Edwards Aquifer as a sole source of supply. The principal objective of the CRWA was to procure surface supplies and to reduce dependence on the Edwards Aquifer. The CRWA has purchased some future supplies from the Guadalupe-Blanco River Authority's (GBRA) Canyon Reservoir, located near New Braunfels. Construction of a surface water treatment plant and interconnected distribution system is to be completed in July 1994 of a million gallon per day plant.

In 1991, the Bexar Metropolitan Water District (BMWD) joined the CRWA as an Associate Member and accepted the challenge to reduce dependence on the Edwards Aquifer through development of alternative water supply sources. Through a partial grant from the Texas Water Development Board (TWDB), the BMWD will analyze, through this study, all available water supply options and select and develop the best option(s) to accommodate future water demands within its service area.

1.1.2 Authorization

The TWDB, through its continuing Regional Water Supply and Wastewater Planning Grant Program, has identified Bexar County and surrounding areas as a region that should begin developing alternative water sources. This study, financed in part by the TWDB, was initiated as a result of House Bill 2 and House Joint Resolution 6, passed by the 65th Texas Legislature in 1985, in order to encourage effective regional water and wastewater facility development.

The BMWD has expressed the intent to lead the development of alternative water sources for its users, and public and private water purveyors of the surrounding counties. The BMWD serves as the local sponsor of this study. The BMWD applied for and was awarded a 75%:25%, matching fund, TWDB Planning Grant to develop a Regional Plan to supply future municipal and industrial water needs of the area. Accordingly, the BMWD contracted with the consulting firm of Michael Sullivan and Associates, Inc. (MSA) to perform this regional water supply planning study.

1.2 Objectives and Scope

1.2.1 Objectives of This Study

The primary objective of this study is to identify and evaluate all potential future surface and groundwater supplies for the current BMWD service area. Of primary interest is the assessment of the supply and suitability of Lake Medina as a future source of supply. An additional objective is to identify prospective service areas that could benefit through development of these additional water sources, either as members of the CRWA, or as wholesale water customers of the BMWD.

1.2.2 Study Area

The Study Area includes portions of Bexar, Medina and Atascosa Counties (Figure 1-2). This area is bounded on the west by Lake Medina, on the south by the City of Natalia, on the east by the proposed Applewhite Reservoir site, and on the north by Castle Hills (a portion of San Antonio currently served by the BMWD). The Primary Planning Area, outlined in red on Figure 1-2, is limited to southern Bexar County, plus Castle Hills and all U.S. Military Reservations in the San Antonio area. Partially within the Primary Planning Area, but mostly to the southwest, is the service area of the Bexar-Medina-Atascosa Water Control and Improvement District No. 1 (BMA) (Figure 1-3). The BMA may play a pivotal role in the future water supply development of the BMWD.

1.2.2.1 Primary Planning Area

The Primary Planning Area measures approximately 371 sq. mi. (see Figure 1-2). Within this area there are currently 215,845 residents served by 22 active public and private water suppliers. Initial estimates indicate that by the year 2040, the population within this area will increase by at least 180%, and will require a firm water supply of at least 84,000 ac-ft/yr (75 MGD). The BMWD Service Area is a subset of the Primary Planning Area. Due in part to its geographical location in the Primary Planning Area, and in part to the proactive attitude of the BMWD Board and Managers, the BMWD is at the center of this planning effort.

1.2.2.2 BMA Service Area

One possible source of surface water supplies for the Primary Planning Area is the BMA. The BMA supplies irrigation water to users in southwestern Bexar, eastern Medina and northwestern Atascosa Counties (see Figure 1-3). The BMA system consists of 266 miles of unlined canals. The Main Canal conveys water from the Lake Medina Diversion Dam (approximately) 26 miles to the principal irrigation areas. The BMA has a water right from the Lake Medina and Diversion Reservoir (LM/DR) System of over 66,000 ac-ft/yr (Figure 1-4). However, historical annual average diversions are approximately 35,800 ac-ft/yr. With an historical average loss of 37.5% in the conveyance system, only 21,000 ac-ft/yr is actually applied to the fields. Reduction of losses in the BMA canal system will be of major interest in this study.

Reductions in transmission losses will translate directly into an additional surface supply available for diversion and use by the BMWD and other regional users.

1.3 Contents of Report

Section 2.0 is a detailed description and evaluation of the regional setting. Included in this description is a general characterization of the geographical location, geology and climate. A thorough literature review is included which describes the surface and groundwater hydrology of the region and studies performed by other entities. Historical flow records are analyzed for the Medina and San Antonio River Basins, the Edwards Aquifer, and other regional groundwater supplies. Also, significant ecological features of the region are highlighted, such as wetlands and threatened and endangered species habitats. Where possible, sensitive environs are delineated for special consideration in the remainder of the study.

Section 3.0 contains rigorous evaluation of current population, water demands and water sources of the region. Data gathered and evaluated include the BMWD service area, military reservations, other local water purveyors, and the BMA. Existing sources and distribution infrastructure are evaluated using TNRCC criteria.

Section 4.0 contains projected population and water demands through the year 2040. Using accepted TWDB methodologies and 1990 census data, future population is projected in ten-year increments for the BMWD as well as other regional water purveyors. Future water demands are evaluated under a number of typical growth scenarios, with and without the initiation of conservation measures. A final set of planning growth projections is developed for BMWD and other local purveyors.

Section 5.0 is an identification of future water supply options. Included are options to improve the efficiency of the BMA system and development options for the BMWD.

Section 6.0 is an evaluation of the identified water supply options.

Section 7.0 is a detailed cost evaluation of selected options.

Section 8.0 is a discussion of institutional, legal and financial considerations regarding the identified water supply options.

Section 9.0 contains the conclusions and recommendations.

2.0 EXISTING CONDITIONS

2.1 Physical Features of Study Area

2.1.1 Geographical Location

The study area consists of the southern and western portions of Bexar county, immediately south of the City of San Antonio and towards Lake Medina, the eastern half of Medina county and the northern tip of Atascosa county, and including southwest portions of the City of San Antonio. The area straddles the Balcones fault zone and includes portions of the Hill Country to the northwest and the Gulf Coastal Plain to the southeast. Moving from ten o'clock to four o'clock across the area, rugged limestone hills give way to rolling prairies and broad river bottoms. Whereas the hill country is characterized by sparse vegetation, primarily low trees and scrubs, the soils of the Gulf Plains are thick fertile clays, originally covered by native prairie grasses.

Elevations in the hill country generally range from 1,000 to 1,500 feet above sea level (MSL), except where dissected by stream beds. The Balcones escarpment provides a somewhat abrupt change in the relief. Traveling inland from the Gulf, it is the first break in the topographical relief and acts as an orographic influence on water-laden air masses, making the area prone to flood-producing storms. Southeast of the escarpment the land gradually slopes to an elevation at the southern boundary of Bexar county of 500 or 600 feet MSL.

Streamflow is predominantly in a southeasterly direction. The study area is dissected by the Medina River, which originates in Bandera county. It flows south across the eastern half of Medina county, changing to a more easterly course as it enters Bexar county. Several significant tributaries, including Elm Creek and Leon Creek, join the Medina River, which flows into the San Antonio River in the southeast corner of Bexar county. The most significant reservoir on the Medina River is Lake Medina, situated in the northeast corner of Medina county. Another man-made reservoir, Mitchell Lake, is located near the confluence of Leon Creek and the Medina River.

2.1.2 General Geology

The dominant geological feature of central Texas is the Balcones fault, which delineates the southern and eastern boundary of the Edwards Plateau (Figure 2-1). The upper layers of the Edwards Plateau consist of limestone rock of Cretaceous origin (shown in green). These rocks were deposited approximately 100 million years ago when the area was covered by a shallow sea. The porous limestone is a major source of water for the area and is replenished by surface runoff from the plateau. Where the limestone is exposed, springs and seeps provide the baseflow for streams that drain the Edwards Plateau.

The Edwards Plateau consists of rolling hill country at an elevation ranging from 1,000 feet MSL at the escarpment to 2,700 feet MSL at it northern limit. Edwards limestone covers most of the surface of the plateau except in portions of the Guadalupe and San Antonio River basins where it has been dissected by streams. At its southern and eastern edge, the limestone has been eroded exposing older material, primarily of the Glen Rose formation.

The Balcones fault zone runs east from the Del Rio area, through Kinney, Uvalde and Medina counties and across Bexar county, where it makes a sharp counterclockwise turn into Comal, Hays and Travis counties. The largest and most northerly fault within the San Antonio River basin has juxtaposed the approximately 500 foot-thick Edwards limestone and the older Glen Rose formation of the Edwards Plateau. Approximately 15 miles south of this fault, two significant faults within the City of San Antonio result in the abutment of Edwards limestone against less resistant chalk, clay and marl of younger Cretaceous age (Figure 2-2).

The Balcones fault zone consists of a highly fractured layer of Edwards limestone, divided into two regions. The northern and western section, where the Edwards limestone is exposed, is the recharge zone. To the south and east, separated by a significant fault, is the artesian zone. The former provides the major recharge area for the Edwards Underground Reservoir, particularly in Kinney, Uvalde and Medina counties. Water enters the fault zone from rivers and streams flowing across limestone outcrops that extend to the surface. It percolates downwards to lower layers of the Edwards and associated limestones through cracks and fissures. Underlying the limestone is the relatively impermeable Glen Rose formation, which acts as a barrier to further downward movement.

Within the study area, the recharge zone crosses the Medina River in the vicinity of Medina Diversion Lake. There are three significant faults in the area. The Medina Lake fault crosses the lake two miles north of Medina Dam. The Diversion Lake fault is 1.5 miles south of Medina Dam and the Haby Crossing fault is about 0.3 miles downstream of the Diversion Dam. The Haby Crossing fault has resulted in an offset of several hundred feet, with Edwards limestone on the north side being juxtaposed against Anacacho limestone on the south side. It appears to be the southern limit of the Edwards recharge zone.

The artesian (confined) section of the aquifer is covered by the clayey formations of the Gulf Coast Plains, which act as an impermeable barrier to the easterly and southerly flow of groundwater. In this region water is forced to flow in a northeasterly direction towards areas of natural discharge. Major springs, including Comal and San Marcos, provide the main points of discharge from the aquifer. However, this natural discharge is currently often exceeded by well pumpage in the San Antonio area. Historically, several other springs have been active in the San Antonio area. Most are no longer operating, either because of manmade structural changes to their system or alterations to the subsurface hydrology.

The Edwards underground reservoir recharges and discharges over a very short time frame, especially when compared with other underground water sources. It has been estimated that as much as 55 percent of the total Edwards recharge occurs in the Nueces Basin, with significant additional recharge updip of San Antonio in eastern Medina county and western Bexar county, (U.S.G.S., Bulletin 50, 91). The water rapidly flows underground, discharging at springs that provide much of the baseflow of the Guadalupe River.

The "bad-water line" roughly parallels the Balcones fault zone and separates the potable water of the Edwards Underground River from the highly saline water trapped in the downdip side. Within the study area the bad-water line roughly follows Interstate Highway (IH) 35. Groundwater below the Gulf Coast Plains is available only at considerable depth and is of poor quality. Total dissolved solids concentrations typically exceed 1,000 mg/L and often exceed 4,000 mg/L. Calcium and sulfate are the major ions, and hydrogen sulfide concentrations may exceed 50 mg/L. Sodium and chloride ions are also present in high concentrations and the water is saturated with respect to calcite and dolomite.

2.1.3 Climate

The regional climate of the study area is modified subtropical, predominantly continental during winter months and marine during the summer. Normal daily mean temperatures in San Antonio range from 50.7°F in January to a high of 84.7°F in July and August. While the summer daily maximum temperature exceeds 90°F over 80 percent of the time, it is typically less than 100°F. Winter temperatures are mild, with below-freezing conditions occurring on average about 20 days per year.

Average annual precipitation for the period 1943 to 1982 was 27.88 inches (Figure 2-3). It is fairly well distributed throughout the year, occurring in the form of thunderstorms during the April through September period. Heaviest rains occur in May and September and hail may be associated with springtime thunderstorms. Precipitation during winter months is typically in the form of light rain, with measurable snow occurring only once in 3 or 4 years.

Southeasterly winds prevail during the summer months and are frequent in the winter. However, cold weather during winter months is associated with northerly winds. Located only 140 miles from the Gulf, the San Antonio area is occasionally subject to tropical storms, which bring strong winds and heavy rains. For most of the year, southeasterly air causes low stratus clouds to develop during the latter part of the night and the relative humidity rises to 80 percent. The clouds usually dissipate by noon, and the humidity drops to 50 percent in the late afternoon.

2.2 Hydrology

2.2.1 Surface Water Hydrology

2.2.1.1 Medina River Basin

2.2.1.1.1 General Basin Description

The Medina River Basin is a sub-basin tributary to the San Antonio River Basin (Figure 2-4). The Medina River originates in Bandera County and flows in a southeasterly direction to its confluence with the San Antonio River, southeast of the City of San Antonio. The Medina River drains approximately 1,150 sq mi. The system has two major permanent impoundments (Medina Lake and Diversion Lake) that capture river flows, retaining them for agricultural use by the Bexar-Medina-Atascosa Water Control and Improvement District Number 1 (BMA). Medina Lake serves as the primary impoundment, releasing water as necessary to the much smaller Medina Diversion Lake where it is either diverted to the BMA Main Canal, stored for lake level maintenance or released downstream.

In the past as much as 30,000 acres of the 34,000 acres in BMA system were irrigated. Of this, 25,000 acres were irrigated with water from Lake Medina. As a result of urbanization, much of this land is no longer in agricultural use, and irrigated acreage has been reduced to 15,000 - 20,000 acres. The main crops are vegetables, sesame seed and corn.

2.2.1.1.2 Historical Flow Records

There are eight U.S. Geological Survey flow gauging stations on the Medina River and tributaries between its source and confluence with the San Antonio River (Table 2-1). Two active and one discontinued stations are located above Lake Medina; below the Lake there are nine active and one discontinued stations. Recorded hydrologic data from each of these stations is found in Appendix A.

2.2.1.1.3 Lake Medina and Medina Diversion Lake

Lake Medina and Medina Diversion Lake were constructed between 1911 and 1913 to supply irrigation water to farmers to the southwest of San Antonio. The Medina Dam is a concrete gravity dam located 14 miles upstream of Castroville. It is164 feet high with an overall length at the crest of 1,580 feet. The surface area of Medina Lake is estimated at 5,575 acres with an approximate volume of 254,000 ac-ft. Four miles downstream is the Diversion Dam. This dam, 50 feet high and 440 feet long, diverts water from Diversion Lake into the main irrigation canal through its outlet works. The elevation-area-capacity relationships for Medina Lake and Medina Diversion Lake are shown in Figures 2-5 and 2-6.

As described in Section 2.1.2, the area surrounding these reservoirs is underlain by the Glen Rose and related Walnut formations, as well as Edwards limestone. While Medina Reservoir is situated over all three of these rock formations, Medina Diversion Lake lies solely on Edwards limestone, overlain on the Glen Rose. Thus, considerable recharge to the Edwards Underground River occurs from both of these water bodies. Because the Glen Rose formation is relatively impermeable, leakage from Medina Lake occurs primarily at lake elevations exceeding 925.5 feet, where the Glen Rose is overlain by Edwards limestone. Additional loss of water from the reservoirs occurs through faults located beneath Medina Dam and in the vicinity of the Diversion Dam (EUWD 1989).

Inflows to Medina Lake for the period 1940 to 1986 have been calculated by Espey Huston and Assoc., Inc. (EH&A, 1989) using gauged flow data from USGS stations 08167000, 08179000, 08179100 and 08178880 and converting them to runoff per sq mi. Similar calculations were performed for Medina Diversion Lake. Average annual inflows were 131,183 ac-ft for Medina Lake and 3,413 ac-ft for Medina Diversion Lake. For the period 1954-56 and again in 1963 inflows were less than 15 percent of these amounts. In 1958, 1971, 1973, 1978 and 1981 inflows were more than twice the annual average.

However, because of evaporation, groundwater recharge and leakage, Medina Lake is considered, in the EH&A study, to have no firm yield. In the absence of diversions, Medina Lake would be drawn down below outlet levels for 17 consecutive months during the 1949-57 drought. Using a hydrologic model, EH&A calculated recharge and leakage losses from Medina Lake and Medina Diversion Lake for historical operating conditions for the period 1940 to 1986. Average recharge from Medina Lake for the period was 29,388 ac-ft/yr, with the lowest value, 2,075 ac-ft, occurring in 1956. For the period 1972-82, annual recharge was close to 35,000 ac-ft/yr. Leakage losses for Medina Lake averaged 22,710 ac-ft/yr, most of which is captured by Medina Diversion Dam. Recharge losses from Medina Diversion Lake are typically around 16,800 ac-ft/yr, although 1955 and 1956 had significantly less than this amount. Leakage losses at Medina Diversion Dam averaged 13,758 ac-ft/yr and it was estimated that correction of these leakages could result in a net gain in water availability of 4,500 ac-ft/yr when minimum flows are provided downstream (EH&A, 1989).

It should be noted that the EH&A analyses were performed under the assumption that all diversions would be from Medina Diversion Lake. Thus, the high Edwards losses in Medina Diversion Lake drive the firm yield calculations.

A more recent study by the Bureau of Reclamation (BuRec) came to somewhat different conclusions. Using its *Hydrologic River Operation Study System* computer model for the years 1924-90, the firm annual yield at Lake Medina Main Dam was estimated to be 27,500 ac-ft for agricultural demand and 29,700 ac-ft for municipal and industrial demand including amounts leaked into the Edwards and downstream releases.

The primary difference between the EH&A and BuRec studies is that the latter does not account for leakage into the Edwards Aquifer. Water supply availability for different levels of dependability are shown in Table 2-2. These figures assume evaporative losses of 15,000 ac-ft/yr and groundwater recharge of 60,000 ac-ft/yr. However, even with these estimates, given the amount of water already committed to senior permit holders (see Section 2.2.1.1.4) and allowing for seepage losses in Medina Diversion Lake and around the Diversion Dam, no excess water would be available during the driest year of the study period (U.S. Department of the Interior, 1992).

2.2.1.1.4 Downstream Water Rights

Accumulated water rights above Medina Dam total 67,765 ac-ft/yr, of which 66,000 ac-ft belong to the BMA (Table 2-3). This right dates from 1910 and is the most senior water right on the Medina River. Between the dam and the confluence of the Medina and San Antonio Rivers water rights total 76,110 ac-ft/yr. This water is supplied either from the Medina River or one of the following tributary creeks: San Geronimo, Medio, Elm or Leon. According to the Texas Natural Resource and Conservation Commission's definition, this drainage area forms Watershed Subbasin 3 of the San Antonio River Basin (see Figure 2-4). The majority of this water, 70,000 ac-ft computed on an annual average basis, is owned by the City of San Antonio for municipal use. However, this use is subject to minimum flow restrictions at downstream gauges, in order to protect senior and superior water rights of downstream users. Other uses include irrigation (4,704 ac-ft), mining (431 ac-ft) and recreation (14 ac-ft). An additional 961 ac-ft are under contract.

Other TNRCC designated watershed subbasins below Medina Lake that would be affected by water use from the lake are Subwatersheds 7, 8, 12, 13, 14 and 15. Subwatershed 7 extends from the confluence of the San Antonio and Medina Rivers to Falls City. The major use of water, 48,900 ac-ft, is for industrial purposes. Other uses include irrigation (4,476 ac-ft) and municipal (140 ac-ft). All of the water used below this point is for irrigation and includes 660 ac-ft in Subbasin 8, 180 ac-ft in Subbasin 12, 365 ac-ft in Subbasin 13, 3,884 ac-ft in Subbasin 14 and 246 ac-ft in Subbasin 15.

2.2.1.1.5 Proposed Projects in Medina Basin

The City of San Antonio has studied and proposed for the second time constructing a surface water reservoir (Applewhite) on the Medina River. The proposed Applewhite Reservoir would flood an area of approximately 2,500 acres and have a capacity of 45,251 ac-ft. The dam would be located at mile 11.6 of the Medina River, upstream of the confluence with Leon Creek. An additional component of the project involves a diversion dam on Leon Creek and the construction of a diversion canal to the reservoir. This reservoir was subject to a referendum by San Antonio voters, subsequently, a lawsuit, and has been stopped.

As originally conceived, Applewhite Reservoir would serve as a terminal storage impoundment. Major supplies from other reservoirs, Cuero or Lindenau, would be pumped to Applewhite where it would be stored for use by San Antonio. Only recently has Applewhite been considered as a stand-alone project. It was proposed as a stand alone project for permitting purposes because other associated projects were not developed.

The average annual yield of the Applewhite Reservoir would be approximately 53,000 ac-ft for municipal and industrial uses, with a maximum annual yield of 70,000 ac-ft with the Leon Creek diversion. However, this figure is predicated on the assumption that BMA, a senior water right holder upstream of Medina Dam, would continue to use only 35,000 ac-ft/yr of its 66,000 ac-ft annual allocation. Even under this scenario, the firm annual yield of Applewhite is only 14,500 ac-ft/yr; with 66,000 ac-ft withdrawn upstream, this figure drops to 7,500 ac-ft/yr. Presently San Antonio Water Systems (SAWS) is claiming a firm annual yield with upstream withdrawals of 8,000 ac-ft/yr.

Construction of Applewhite Reservoir was started in late 1989. In December 1990 the voters of San Antonio elected to discontinue the project at 14 percent completion. However, it remains a federally-authorized project by the U.S. Army Corps of Engineers and retains a valid water rights permit.

Upstream of the proposed Applewhite Reservoir is another potentially large user of water. The Living Waters Catfish Farm proposes to use 49,300 ac-ft/yr of groundwater. The discharge permit associated with this use was challenged at the Texas Natural Resource and Conservation Commission because of water quality concerns. The artesian wells from the Catfish Farm are now subject to a court order not to discharge until regulations under S.B. 1477 or its successor becomes effective.

2.2.1.2 San Antonio River Basin

2.2.1.2.1 General Basin Description

The San Antonio River Basin drains an area of approximately 4,180 sq mi. It is bounded on the north and east by the Guadalupe River Basin and on the south and west by the Nueces River Basin and the San Antonio-Nueces Coastal Basin. The drainage basins of its two major tributaries, the Medina River and Cibolo Creek, form, respectively, the western and eastern boundaries of the basin (see Figure 2-4).

Current water use in the basin is 319,088 ac-ft/yr, of which 242,041 ac-ft are for municipal purposes. Ground water provides all of the water supply for the City of San Antonio; there are no reservoirs providing municipal water supply. Two reservoirs, Braunig and Calaveras, provide cooling water for steam-electric generation, and Olmos Reservoir is used solely for flood protection. Both Braunig and Calaveras have been studied as potential conjunctive use projects.

2.2.1.2.2 Historical Flow Record

There are twelve USGS flow gauging stations on the San Antonio River and tributaries, not including those already listed for the Medina River (Table 2-4). Recorded hydrologic data from each of these stations is found in Appendix A.

2.2.1.2.3 Existing and Proposed Reservoirs

Victor Braunig and Calaveras Reservoirs are located in Bexar County on Arroyo Seco and Calaveras Creek, respectively. They supply cooling water for steam-electric power generating units operated by City Public Service Board. The main source of water is local runoff, supplemented by water pumped from the San Antonio River. The TNRCC has stipulated that pumpage from the river should not exceed the amount of sewage effluent discharged by the City upstream of its pumping station.

Another reservoir owned by the City of San Antonio is Olmos Reservoir located on Olmos Creek. It serves as a flood control structure, retaining flood water until it is safe to release it. The remainder of the time it is used as parkland. Formerly used as a source of irrigation water, Mitchell Lake is located south of the City of San Antonio. Its water supply is runoff and treated domestic sewage effluent. The City of San Antonio has recently established a bird refuge at Mitchell Lakes.

The City of San Antonio has been investigating the possibility of supplementing its groundwater supplies with surface water through the construction of one or more reservoirs. Within the San Antonio River Basin, three projects are under consideration by the City of San Antonio, San Antonio River Authority (SARA), the TWDB, and BuRec: Applewhite Reservoir (described above), Cibolo Lake on Cibolo Creek (Two possible locations have been investigated, one above IH-35 and one near the confluence with the San Antonio River.) and Goliad Reservoir. The upper site for Lake Cibolo, at 416.4 MSL, would impound 173,000 ac-ft and have a surface area of 9,200 acres. The lower site, at 416.0 MSL, would impound 404,000 ac-ft and have a surface area of 16,700 acres. The Goliad site is located on the San Antonio River in Goliad County. It would impound approximately 683,000 ac-ft and cover 27,800 acres.

2.2.2 Groundwater Hydrology

2.2.2.1 Groundwater Resources of the Edwards Aquifer

2.2.2.1.1 General Description of the Edwards Aquifer (Balcones Fault Zone)

The entire Edwards Aquifer (Balcones Fault Zone) extends from Salado, Texas, through Austin, San Marcos, New Braunfels, San Antonio, Hondo and Uvalde to Brackettville, Texas. The Edwards Aquifer is approximately 260 mi. long and varies in width from 5 to 40 mi. It crosses several streams in five major river basins, including the Nueces, San Antonio, Guadalupe, Colorado and Brazos. The Aquifer is segmented into three parts. The Northern segment of the Edwards Aquifer extends from Salado to the Colorado River in Austin. The Barton Springs segment of the Edwards Aquifer extends for the Colorado River to a ground water "high" located between the cities of Buda and Kyle. The San Antonio Region of the Edwards Aquifer (Figure 2-7) extends from this groundwater high to near Brackettville. Each segment of the Aquifer has major recharge sources and natural discharge points. For the most part, the segments act independently of one another, although there is technical evidence that limited quantities of water may flow between adjacent segments under certain hydrogeologic conditions.

2.2.2.1.2 Formation of the San Antonio Region of the Edwards Aquifer

The Edwards Limestone, formed in the Early Cretaceous age, is exposed throughout the Edwards Plateau. This limestone formation in the San Antonio Region consists of 400 to 600 ft of thin to massive-bedded carbonate rocks and is comprised of several stratigraphic zones containing permeable beds with well developed vuggy porosity. In some areas, these zones are vertically separated by beds of dense to chalky limestone with little to moderate permeability and porosity. At some locations, the permeable strata are hydraulically interconnected by open, inclined fractures. While at other locations, the lateral continuity of the permeable strata is made discontinuous by vertical/high angle faults that displace the entire thickness of the Edwards Limestone.

The Edwards Limestone was formed on the shores of ancient seas. Early Cretaceous barrier reefs, such as Stuart City Reef and Devils River Reef caused sediments comprising the Edwards Limestone to deposit, forming several limestone platforms (Figure 2-8). The Central Texas Platform and the San Marcos Platform developed to the north and west of the Stuart City Reef and the Maverick Basin (platform) developed as a result of the Devils River Reef. These platforms were created by cyclic deposition of materials behind (north and west) the reefs. The sediments comprising the carbonate Edwards Limestone were formed by the transgressing and regressing seas. After the seas resided, the platforms were propagated by tidal and subtidal sediments originating from the north and west. Evaporites were deposited on these vast low lying platforms, further contributing to their formation. During the late Edwards time era, erosion removed more than 100 ft of the deposits from the San Marcos platform resulting in extensive karstification of the limestones and dolomites. Porosity and karstification of the limestones was further developed by continual cycles of carbonate deposition and rainfall, which cemented and leached the sediments (USGS, 1986).

As a result of the deposition and erosion process, the Cretaceous stratigraphic units of the Edwards Limestone in the San Antonio Region were formed (Rose, 1972). These units, shown in Figure 2-8, include the Maverick Basin, Devils River Trend and San Marcos Platform. The geologic unit located below the Edwards limestone (aquifer) is the Glen Rose Formation. This formation consists of marl, shale and dolomite in the sections at higher elevations, and massive bedded limestone and dolomite at lower elevations. The upper sections of Glen Rose Formation, which has low to very low permeability, is the lower confining unit of the Edwards Aquifer. The top of the Edwards Aquifer is confined by the Del Rio Clay. This clay strata is relatively impermeable and prevents the vertical movement of water to and from the Edwards Aquifer within the artesian zone (see section 2.2.2.2.4).

The Edwards limestone of the San Antonio Region is extensively faulted as shown in Figure 2-2. These faults, generally downthrown to the south and southeast, and trending east-northeast (USGS, 1986), form a complex system of fault blocks that are differentially rotated and rise toward the San Marcos Platform. Along the strike of some major faults, the displacement across the fault plane is sufficient to disrupt the continuity of the Aquifer. Maximum fault displacement is reported to be 600 ft. at the Comal Springs fault, with fault displacement averaging 200 ft. to the west in Medina and Uvalde Counties (Klemt et al, 1979). Typical geologic cross-sections of the Edwards Aquifer illustrating these discontinuities are shown in Figure 2-9. Some cross faults intersect at acute angles. This complex system of faults includes barrier faults, which function as controls in the Aquifer, locally diverting the groundwater flow in the block updip from the barrier fault to a course parallel to the strike of the fault (Patterson, 1990). Where faults faces are contiguous, ground water can flow normal to the fault plane, if permeable conditions exist.

The San Antonio Region of the Edwards Aquifer is shown in Figure 2-7. Within this Region (referred to herein as the "Edwards Aquifer" or the "San Antonio Region"), the lower confining bed of the Edwards Aquifer is the upper member of the Glen Rose formation, and the upper confining bed is the Del Rio Clay. As stated above, these confining units typically have very low permeabilities, which effectively impede vertical leakage to or from overlying or underlying water sources. However, vertical fractures and faults are widespread and provide pathways for the movement of water between strata. The San Antonio Region of the Edwards Aquifer is bounded on the north by the updip limits of its surface outcrop; on the west in

Kinney County and in the east in Hays County by groundwater "highs"; and on the south by the "bad-water" line.

Both unconfined and confined aquifer conditions exist within the Edwards Aquifer. The unconfined portion is located in the northern area of the Aquifer, where the Edwards and associated limestones outcrop at the surface in the Recharge Zone (see Figure 2-7). Within this portion, ground water is under water table or free surface conditions. The confined portion of the Aquifer occurs downdip of the recharge zone and extends southward to the bad-water line (see Figure 2-7). With this area, groundwater is under artesian or "pressure" conditions, since it is confined underneath the Del Rio Clay.

2.2.2.1.3 Recharge Zone: San Antonio Region of the Edwards Aquifer

Recharge to the Edwards Aquifer occurs within the outcrop area (recharge zone) of the Edwards and associated limestones (see Figure 2-7), where water quickly seeps from overland flow, streams, creeks and rivers. All major watercourses in the region, except the Guadalupe River where the potentiometric head in the Edwards Aquifer is higher than the elevation of the river, lose water to the Edwards Aquifer as they traverse the recharge zone.

The recharge to the Edwards Aquifer is derived mainly from seepage and infiltration from streams that cross the outcrop of the Aquifer and from direct infiltration of precipitation (overland flow) on the outcrop. Approximately 85% of the recharge (USGS, 1986) is from the infiltration of streamflow where streams cross the outcrop area. Most of the remainder of the recharge is by precipitation on the outcrop. Additional recharge occurs to the Edwards Aquifer as cross-formational flow from the Glen Rose Formation, particularly where faulting has resulted in direct contact between this formation and the Edwards (USGS, 1986).

The western part of the recharge zone is comprised of the Frio-Sabinal, the Nueces and the Seco-Hondo-Medina River Basins, which collectively have about 60% of the total catchment area and supply about 70% of the total recharge to the Aquifer (about 2,950 sq. mi.). The remaining 30 percent of the recharge is derived from the eastern portion of the recharge zone, which includes the San Antonio and Guadalupe River basins, excluding the Guadalupe River (EUWD, 1988).

Recharge water, originating from surface sources, enters the unconfined zone of the Aquifer. Groundwater then flows (by gravity) downdip toward the confined portion of the Aquifer, where the water moves to the east and northeast through the artesian zone (confined zone) towards the areas of natural discharge. Major springs discharging water from the San Antonio Region of the Edwards Aquifer include Leona Springs near Uvalde, San Antonio and San Pedro Springs in San Antonio, Comal Springs at New

Braunfels, and San Marcos Springs at San Marcos. In addition, water is pumped from the Aquifer by thousands of wells located in Kinney, Uvalde, Medina, Bexar, Comal and Hays Counties.

2.2.2.1.4 Artesian Zone: San Antonio Region of the Edwards Aquifer

The confined or artesian portion of the Aquifer occurs downdip of the recharge zone and extends to the bad-water line. Groundwater moving from the unconfined recharge zone moves downgradient into the deeper or confined (artesian) zone of the Aquifer. The flow of groundwater within the Aquifer (unconfined and confined zones) is profoundly influenced by the presence of faults. Faults create extremely anisotropic conditions, acting both as barriers to flow and as conduits for lateral and vertical flow. Displacement of highly permeable beds opposite impermeable beds causes flow to be diverted laterally, parallel to the strike of the faults. Disruption of flow paths in the Aquifer by faulting results in fault blocks with flow systems that are separate from the main flow systems of the Aquifer (refer to Section 2.2.2.1.2).

The structural complexity of the San Antonio Region affects water movement in both the confined and unconfined portions of the Aquifer. Researchers (Maclay and Small, 1986) have found that in the artesian zone the hydraulic gradients are relatively flat and transmissivities are very large when compared to the unconfined (recharge) zone. Aquifer transmissivity values are difficult to quantify, because of the nature and regional characteristics (porosity and permeability) of the Aquifer. An estimate of transmissivities was calculated by Maclay and Small (1986) to be extremely high, ranging from 200,000 sq ft per day to 2 million sq ft per day. Specific yields and storage coefficients have also been estimated from previous work on the Edwards Aquifer. Maclay and Small (1986) estimated the storage coefficient to range from about 0.001 to 0.00001 within a specified yield of 3 percent. Klemt and others (1979) determined storage coefficients ranging from 0.0004 to 0.0008, with estimated specific yields of 6 percent.

The extremely high transmissivity of the artesian zone of the Edwards Aquifer is indicated by (1) very low hydraulic gradients, (2) excellent correlation of water levels among widely spaced wells, (3) large sustained springflows, and (4) uniform quality and temperature of water within the Aquifer (USGS, 1986). This tremendous capacity to transmit large quantities of water is indicated by the presence of hundreds of wells, some of which produce thousands of gallons of water per minute with a drawdown in water levels of only a few feet.

Researchers (Maclay, 1990; Knowles, 1990) have projected a wide variance in the estimated water storage capacity of the Aquifer, from 25 million ac-ft to 55 million ac-ft. Of this quantity, it is estimated that 1.5 million ac-ft of water can be stored in the Aquifer above the invert elevation (666 ft MSL) of Comal Springs. Also, it is estimated that each one foot of elevation represents an average of about 25,000 to 50,000 ac-ft of water storage (Maclay, 1990).

Storage in a saturated confined aquifer is defined as the volume of water that the Aquifer releases from storage per unit surface area of the Aquifer per unit decline in the hydraulic head. Hydrostatic pressure within the Aquifer partially supports the Aquifer rock framework. As the pressure in the Aquifer is reduced, such as by pumping water from a well and yielding water, changes in pressure in a confined aquifer produce only very small changes in the volume available for the storage of water. In the unconfined parts of the Aquifer, the level of saturation changes as the water table moves up and down. The amount of water that the unconfined aquifer yields is the amount of water that will drain from the pore spaces. There is no compression of the Aquifer framework and the volume of water yielded from a given volume of aquifer rock, under unconfined conditions, is as much as five orders of magnitude greater than for an equivalent volume of rock under confined conditions (Patterson, 1991).

As the water table drops in the unconfined part of the Aquifer, sections of the Aquifer in the recharge zone may be dewatered. Further declines in the water table could cause confined parts of the Aquifer to come under unconfined conditions, with a resulting change in storage capacity. The volume of the artesian zone represents 30-40 percent of the total volume of the Aquifer. Therefore, a very large amount of water released from the Aquifer comes from storage in the unconfined zone. The quantity of water retained in the artesian zone after a recharge event is affected strongly by the geologic structure of the Aquifer. Faults can act as barriers to reduce the flow of water moving from the unconfined zone to the artesian zone, thereby allowing a greater volume of water to remain in the unconfined zone for a longer period of time and with a slow lowering of water levels. Based on an analyses of the faulting system and water levels in the Aquifer, the TNRCC (1991) segmented or divided the San Antonio Region into three distinct areas or pools (Figure 2-10): Uvalde Pool, San Antonio Pool and San Marcos Pool.

2.2.2.1.5 Historical Recharge

Table 2-5 lists the estimated historical annual recharge to the Edwards Aquifer from 1934 to 1988, including that portion of the recharge attributable to Medina Lake and Medina Diversion Dam. Estimated annual historical recharge for the Aquifer varied from 43,700 ac-ft in 1956 to 2,003,600 ac-ft in 1987. The average annual historical recharge for this period was 635,500 ac-ft. Recharge attributable to Medina Lake and Diversion Lake varied from 6,300 ac-ft in 1956 to 104,000 ac-ft in 1960.

2.2.2.1.6 Historical Pumpage and Spring Flows

Also listed in Table 2-5 is the estimated total historical discharge from wells and springs in the Edwards Aquifer, including the portion corresponding to Bexar and Medina counties for the years 1934 through 1988. The annual historical pumpage from the Edwards Aquifer varied from 101,900 ac-ft in 1934 to 539,900 ac-ft in 1988. The average annual historical pumpage for this period was 273,700 ac-ft. The annual historical spring discharge varied from 69,800 ac-ft in 1956 to 580,300 ac-ft in 1977, with an average annual spring discharge of 359,500 ac-ft for the 55 years of record.

2.2.2.2 Other Groundwater Resources of the Study Area

The Edwards and associated limestones constitute the principal groundwater resources of the study area. However, other water bearing formations located within, or in the proximity of, the study area include the Leona formation, Glen Rose limestone, Travis Peak formation, Austin chalk, Hosston and Sligo formations, rocks of the Taylor and the Navarro group, and the Carrizo-Wilcox sands.

2.2.2.2.1 Leona Formation

The Leona formation outcrops along the Balcones fault zone within the study area and overlies the Edwards aquifer. This formation is composed of clay, silt, sand and gravel deposited by rivers in the form of terrace deposits. Gravel is generally present in the lower part of the formation. The Leona also contains much caliche, which is a calcium carbonate residue formed by the evaporation of ground and surface waters.

A maximum formation thickness of approximately 70 ft occurs in Uvalde County. The average thickness in of the formation, where present, in Bexar and Medina Counties is 30 ft. The Leona formation covers a fairly large area of Bexar and Medina Counties, but since the formation is relatively thin, well yields are only a few gallons per minute.

The surface of the Leona formation is relatively flat, facilitating infiltration of rainfall and runoff. In places, the Leona formation support dense growth of mesquite and other pheataphytes. The Leona provides temporary storage for water that is not lost by evapotranspiration. Where the Leona lies directly on the Edwards limestone, a considerable of water may vertically migrate into the Edwards and associated limestones.

Groundwater in the Leona formation generally occurs under water table conditions. However, locally, the water is confined by nearly impermeable lenses of silt or clay. Small bodies of water not connected to the main reservoir may be encountered along the flanks of the stream-terrace deposits. The water in these isolated reservoirs may be exhausted rapidly by pumping (TWDB, 1976)

Although the water of the Leona formation is generally very hard, it is satisfactory for most purposes. The nitrate content, high in some localized areas, ranges form about 2 ppm to 400 ppm. Water from the Leona formation is the principal supply for the communities of D'Hanis, Quihi and Lacoste.

2.2.2.2.2 Glen Rose Limestone

Glen Rose limestone underlies the Edwards and associated limes throughout the study area, outcropping in the northern part of the Balcones fault zones in Medina and Bexar Counties and the surrounding counties of Uvalde, Real, Bandera, Kerr and Kendall. Many researchers (TWDB, 1990; USGS, 1986) have found evidence for free movement of water out of the Glen Rose into the Edwards and associated limestones at places where faulting has put the two units in close proximity.

The Glen Rose as a whole is a poor aquifer, with respect to water supply within the study area (TWDB 1976). Groundwater development in this formation is limited to localized domestic and livestock uses. This water-bearing unit yields generally small quantities of water, few Glen Rose wells producing more than 50 gpm. Water in the Glen Rose occurs in thick beds of limestone and dolomite separated by beds of clay and marl. The formation contains extensive deposits of gypsum (hydrous calcium sulfate), which is more soluble than limestone. Because of its solubility, gypsum increases both the permeability of the formation and the sulfate content of the water. The Glen Rose yields water of poor quality, containing moderate to large amounts of total dissolved solids (from 200 ppm to over 4,000 ppm) and is very hard.

2.2.2.2.3 Rocks of Taylor Age and Navarro Group

In southern Bexar County the Austin chalk is buried under relatively impermeable non-water bearing clay and shale that are either of the Taylor age or belong to the Navarro group. West of Bexar County the Taylor marl grades into the Anacacho limestone, and the Escondido formation of the Navarro group becomes sandy in western Medina County. Both supply small amounts of water for domestic and livestock uses, but cannot be developed for regional supplies.

The Anacacho limestone locally yields water acceptable for domestic purposes, although it may be very hard. The Escondido formation yields water containing moderate to large amounts of dissolved solids, with observed ranges form 480 ppm to 3,330 ppm. The more highly mineralized waters are located near old oil and gas fields, which probably contaminate the water locally.

2.2.2.2.4 Austin Chalk

The Austin chalk is above or near the surface in much of the artesian area of the Edwards and associated limestones in the study area. In Bexar and Medina Counties the Grayson shale, Buda limestone and Eagle Ford shale lie between the Austin chalk and the Edwards limestones. These overlying formations, ranging in thickness from 100 ft to 300 ft, are relatively impervious, except along fault lines, and provide a "confining" cap to the Edwards Aquifer.

In general, the Austin chalk is a poor aquifer, yielding only small (less than 10 gpm) quantities of water to wells. In most places, Austin chalk water contains hydrogen sulfide gas and minerals that prohibit its use as a public water supply. However, in the San Antonio area chalk wells yield water similar in chemical quality to the water obtained from the Edwards aquifer. In addition, the rise and fall of water levels in chalk wells is related to that in Edwards wells, indicating a direct connection between the formations in Bexar County.

2.2.2.2.5 Travis Peak Formation

The Travis Peak formation underlies the Glen Rose limestone throughout the study area. This formation is divided into three members: the Hensell sand member at the top, the Cow Creek limestone member in the middle, and the Sycamore sand member at the base.

The formation is comprised of limestone, marl, sandstone and conglomerate. In Bexar and Medina Counties, the Travis Peak varies in thickness from 100 ft to over 400 ft. For the most part, well yields are small to moderate (less than 30 gpm) and water quality is poor with a high total dissolved solids content. This water bearing unit is used for localized domestic and livestock purposes.

2.2.2.2.6 Hosston and Sligo Formations

Situated below the Travis Peak formation are the Hosston and Sligo formations. The Hosston formations and the overlying Sligo formations are exposed at the surface in Mexico but do not outcrop in Texas. These formations in Bexar and Medina Counties are often associated with hydrocarbon production and are not recognized as an extensive potable water source. Within the study area, the Sligo formation is comprised of gray limestone with shale partings; the Hosston is mostly gray to red siltstone with a sandstone layer. Wells in Hosston and Sligo formations yield only small volumes of water and are not suitable as regional water supply sources.

2.2.2.2.7 Carrizo Sand

The Carrizo sand outcrops in the southern part of Medina and Bexar Counties in a belt extending from the Atascosa County line southwest to the Frio County line. The formation lies disconformably upon the underlying Indio formation and is 230 to 330 ft thick.

The Carrizo sand consists chiefly of friable light-gray to dark-red medium grained quartz sandstone. Clay or shale occurs near the middle of the formation as thin, lenticular beds or as lumps 2 to 3 inches in diameter. Locally the formation is limonitic and contains several thin beds of ferruginous sandstone. In many outcrop areas the formation is massive, with highly developed crossbedding.

The Carrizo sand supplies water to shallow wells in its outcrop area and to deeper wells southeast of the outcrop. These wells yield abundant supplies of water for domestic and livestock uses. The water is essentially under water-table conditions in the outcrop area, because the upper surface of the saturated part of the formation is a permeable sand. The formation dips south or southeast, necessitating an increase in depth of wells with distance from the outcrop. Southeast of the outcrop area the water is under artesian conditions.

Wells in the outcrop area of the Carrizo sand yield adequate supplies of water for municipal use and irrigation. Devine and Natalia obtain their public water supply from the lower section of the Carrizo sand. In addition, numerous Carrizo sand and Indio formation wells are used for irrigation within this area. The thinning of the Carrizo at the northern edge of the outcrop restricts the amount of storage and limits water availability.

Analyses of water samples from wells show that the water in the Carrizo sand is generally of good quality, although hard. Total dissolved solids are generally less than 500 ppm. The wells that supply the City of Devine yield water that has from 350 ppm to 500 ppm of total dissolved solids and less than 100 ppm each of sulfate and chloride. Manganese and iron have been found in water from the Carrizo sand, most notably in the Somerset area and the area served by Wendy's Water Works. Water treatment would be required for the water to acheive acceptable taste and odor control.

2.3 Ecological Features

2.3.1 General Ecological Structure

The northern portion of the study area, including the area surrounding Medina Lake, consists of the Glen Rose Hills. Because of the alternating layers of hard and soft rock, the hills have a terraced appearance. They support a considerable amount of vegetation, predominantly mountain cedar, small oak and other scrubby trees. They are easily distinguished from the Edwards limestone hills, which are exceedingly rough with a broken topography. The Edwards hills are covered with large boulders and support little vegetation.

Southeast of the escarpment the area is characterized by grassland or savanna-type climax vegetation, which has been replaced in many areas by brushy species as a result of overgrazing. The area consists of several distinct ecosystems resulting from its heterogeneous geological makeup. A variety of surface outcroppings result from both the downdipping of the rock layers and the displacement of various layers through faulting. Much of the plain has been covered by terrace gravel deposits, except where it has been eroded by streamflow. Where not influenced by gravel deposits, the soil is a deep black clay and very sticky when wet.

Upland areas that have not been cleared for farming and ranching are characterized by mesquite-brush habitat. Honey mesquite is the dominant species (*Prosopis glandulosa*). Other woody species include whitebrush (*Aloysia gratissima*), agarito (*Berberis trifoliolata*), huisache (*Acacia smallii*), yucca, Texas persimmon and bluewood condalia. Underbrush is most common on sloping areas adjacent to riparian forest. Herbaceous plants include silver bluestem, plains lovegrass, buffalograss, curly mesquite, purple three-awn and hooded windmill grass. This habitat is most common in the southwest portion of the study area and supports a diverse array of vertebrate species (U.S. Army Corps of Engineers, 1989).

Moving south and east across the study area, the clayey soils of the Wilcox group give way to more sandy soils and mesquite becomes less common. The central portion of the area is a mixture of low hills and level ground. The southern portion of Bexar and Medina counties consists of the Carrizo Sand Hills. The area is distinctly hilly with very sandy soils and the vegetation is chiefly deciduous oak.

Except for the urban areas, the dominant land use is farming and ranching. Major crops include oats, wheat and some improved hay pasture. Rangeland consists primarily of reclaimed mesquite-brush in native grasses. It can support a wide range of species, if it is in good condition. However, where it is overgrazed, its value as wildlife habitat is reduced.

2.3.2 Wetlands

Several karst features, including caves, sinkholes, faults and springs, occur in the vicinity of Lake Medina Dam and the Diversion Lake and Dam on the Medina River. Several endangered species are associated with the springs and seeps of the Balcones Canyonlands of the Edwards Plateau. Although not specifically identified within the study area, this region is potential habitat for endangered salamanders and blind catfish. Small wetland areas associated with these springs and seeps support a tree overstorey of bald cypress (*Taxodium distichum*), sycamore (*Platanus occidentalis*), cottonwood (*Populus deltoides*), black willow (*Salix nigra*) and pecan (*Carya illinoensis*). Understorey vegetation may include boxelder (*Acer negundo*), buttonbush (*Cephalanthus occidentalis*), Turk's cap (*Malvaviscus arboreus*), maidenhair fern (*Adiantum capillus*) and shield fern (*Thelypterus kunthii*). In addition, small pockets of deciduous woodlands are found in moist canyons. These areas provide potential habitat for the endangered black-capped vireo (*Vireo atreicapillus*) and the golden-cheeked warbler (*Dendroica chrysoparia*) (U.S. Department of the Interior, 1992).

The upper end of the Medina Canal passes through the edge of the Edwards Plateau and the Balcones Escarpment. It is associated with steep narrow canyons that drop toward the Medina River. Where seepage from the canal occurs, these canyons support small communities of riparian vegetation, such as black willow (*Salix nigra*), box elder (*Acer negundo*) and hackberry (*Celtis laevigata*), and communities of wetland emergent vegetation, including those dominated by sedge (*Carex* spp.), soft rush or cattails (*Typha* spp.). Adjacent upland vegetation is dominated by Ashe juniper (*Juniperus asherii*), cedar elm (*Ulmus crassifolia*), live oak (*Quercus fusiformis*) and mesquite (*Prosopsis glandulosa*) (U.S. Department of the Interior, 1992).

Figure 2-11 shows the irrigation canal system and its associated wetlands. These are shown in more detail in Figures 2-12a through 2-12d. U.S. Fish and Wildlife Service (USFWS) has defined five wetland systems (U.S. Department of the Interior, 1979). Of these, three, riverine, palustrine and lacustrine, are represented in the project area.

Riverine wetlands are contained within a channel, except for those dominated by trees, scrubs and emergent vegetation. They have salinity regimes of less than 0.05 percent. Two subsystems of riverine wetlands are present. Lower perennial wetlands are covered with slow-moving water, while intermittent wetlands consist of steambeds that are covered with flowing water for part of the year. Palustrine wetlands are all non-tidal wetlands with salinity regimes of less than 0.05 percent. They are less than 20 acres in size and less than 2 meters in depth. They include areas containing emergent vegetation adjacent to rivers and lakes, but not dependent on running water habitat. Lacustrine wetlands lack extensive vegetation cover and are more than 20 acres in size.

Wetlands are further subdivided into classes. Those areas with more than 30 percent vegetation cover are classified according to the predominant vegetation type. Within the study area, there are three types of palustrine wetlands that have extensive vegetation cover. Emergent wetlands, shown in green, are dominated by perennial plants. Scrub-shrub wetlands, shown in light blue, are characterized by woody vegetation. Where this vegetation is more than 6 m in height, it is classified as forested, shown in magenta.

The remaining wetlands in the area (including riverine, palustrine and lacustrine) have less than 30 percent vegetation cover, except for pioneering plants, and are classified according to the nature of the substrate. While bottoms are submerged most of the time, streambeds and shores are exposed most of the time. Shores are typically adjacent to bottoms, and in this area are characterized by unconsolidated substrate, that is, more than 25 percent of the area is covered with particles smaller than stones.

Figure 2-12a shows the areas of wetland habitat associated with the upper end of the Medina Canal. Immediately below the Diversion Dam, the canal is close to, and east of, the Medina River. In this area the predominant wetlands are in the river bed. For approximately one mile there is a continuous stretch of lower perennial riverine habitat. The terrain is unconsolidated and extends beyond the river bottom onto the shore. Both temporarily and permanently flooded areas are present.

For approximately 3 miles below the point where the canal crosses the Medina River, it is associated with widely scattered areas of palustrine wetlands with unconsolidated substrate. Most are flooded on a temporary or seasonal basis, but a few are saturated. Most are associated with dikes or impoundments. Of note is a permanently-flooded area with emergent vegetation, approximately one quarter of a mile south of the junction with the river.

The central portion of Figure 2-12a shows an abundance of wetlands, mostly associated with the tributaries of the Medina River. Wetlands associated with diked areas are mostly palustrine on unconsolidated terrain. Some are seasonally flooded, while others are permanently flooded. Riverine habitat found in stream beds is mostly intermittent, being either temporarily or seasonally flooded.

The lower portion of Figure 2-12a is dotted with small wetland areas. Two of these areas of more significant size are Gabe Lake and another small impoundment immediately north of it, situated between the canal and the Medina River. Most wetlands in this area are permanently flooded. The main canal supports small seepage wetlands, with emergent vegetation, including dominate sedge (*Carex* spp.) or cattail (*Typha* spp.) communities mixed with smartweed (*Polygonum* spp.), cocklebur (*Xanthium* spp.) and other herbaceous plants. These types of habitat are characteristic of the areas in and around the canal as it continues its southerly course (Figure 2-12a) (U.S. Department of the Interior, 1992).

Where the canal bifurcates, the terrain is not as steep and the wetland areas become larger and more numerous. To the west of the canal is a large number of small impoundments that have unconsolidated bottoms and are permanently flooded. Two larger impoundments are Ruby Lake to the north of the eastern fork of the canal and an area adjacent to the canal of palustrine emergent wetland that is surrounded on three sides by scrub/shrub vegetation.

The southeast quadrant of Figure 2-12b shows the irrigation canal system supplied by the eastern fork of the main canal. There are also two significant creeks, Chacon and Fort Ewell. Small wetland areas are abundant, especially along the creek beds. Smaller areas may also be associated with the irrigation canals. In general, these areas are palustrine wetlands with unconsolidated shores resulting from impoundments. They may be permanently flooded, but seasonal flooding is more common. Along the canal and stream beds intermittent riverine habitat is also represented. Also included in this area, and forming another source of water for the irrigation canals, is Chacon Reservoir. It includes both open water and areas with emergent vegetation. Surrounding areas that are temporarily-flooded contain deciduous woody vegetation, either trees or scrub/shrub. Forested areas are concentrated at the northwestern arm of the lake, where the major inflows from Chacon Creek occur.

Figure 2-12c shows the final section of the western arm of the main canal, which terminates in the D-2 canal. This canal extends from Chacon reservoir to the southerly tip of the irrigation system. On the eastern side of the figure is the Fort Ewell canal, which is supplied from the eastern main canal. The western arm supplies two irrigation canal systems, 33-K to the west and 33-B to the east. Both are surrounded by numerous small wetlands. All are associated with impoundments or dikes, and are temporarily or seasonally flooded.

The D-2 canal runs alongside Chacon Creek for approximately 2 miles. Most of the wetlands are associated with the creek, consisting of unconsolidated shores, with intermittent riverine habitat in the stream bed. Further south, both palustrine and riverine wetlands are clustered around the canal. Immediately east of the junction of the D-2 and main canal, a group of excavated areas are used to store water on a temporary basis.

The southern portion of the D-2 canal again runs close to Chacon Creek. Both are associated with palustrine wetlands, which are flooded on a temporary basis. Along the creek some of the areas are forested, typically with deciduous, broad-leaved trees. The terminal portion of the canal is in close proximity to the San Francisco Perez Creek and wetlands are common. Two stock tanks north of the canals are flooded, either temporarily or semi-permanently. Further north, a larger impoundment close to the creek is permanently flooded.

The Fort Ewell canal system is characterized by scattered palustrine wetlands, flooded on a temporary basis. Most are the result of small impoundments. Where the canal crosses Fort Ewell Creek there is a small wetland area, vegetated with deciduous shrubby plants. Also associated with the creek is an area of emergent vegetation including sedge (*Carex* spp.) and cattails (*Typha* spp.). The canal terminates in a permanently-flooded impoundment with an unconsolidated bottom.

Figure 2-12d shows the eastern half of the irrigation canal system. In the southwest corner of the map, Canal 9 and the Lytle Canal are both associated with wetland areas. However, the close proximity of natural creeks, tributaries of the Atascosa River, may be more significant. In both areas there are seasonally-flooded unconsolidated areas. The larger areas, three near Canal 9 and one near the Lytle Canal, are permanently flooded impoundments. The former are also associated with intermittent riverine habitat in the stream bed.

Moving north and east, a network of canals arises from the B-1 canal. There are many small wetlands in the area, mostly associated with stream beds or areas that facilitate drainage. Most are temporarily or seasonally flooded. A major stream and its tributary between the B-1-K and S canals each have a small permanently-flooded impoundment at their upper end and several areas of intermittent riverine habitat.

The S canal is one of two major canals that originate at the terminus of the eastern branch of the main canal. It is separated from the area served by the B canal by Elm Creek. Numerous wetlands are associated with tributaries of the creek, the canals and natural drainage areas. Most are temporarily flooded, but three larger impoundments north of the S canal near its origin are permanently flooded. Another large impoundment can be found at the junction of the S canal and the Randle lateral. A tributary of Elm Creek between the Wisdom and Randle laterals is rich in palustrine and intermittent riverine habitat. At its origin is a permanently-flooded impoundment supporting wetland habitat. Toward the western end of the wetland, where it is not always flooded, there is a clump of deciduous, broad-leaved trees.

The Randle lateral is in a relatively flat area between two creeks. The whole area has numerous small wetlands, which are flooded on a temporary basis. The more southerly creek, the Black Hill Branch, supports intermittent riverine habitat and, near its junction with Elm Creek, has larger, permanently flooded areas.

The northern and eastern portions of Figure 2-12d show the area served by the B canal. The B-35 and B-35-A canals serve the area between Elm Creek and Live Oak Creek. The whole area is rich in wetlands. Elm Creek supports intermittent riverine habitat and has many areas of palustrine wetlands. Towards its source these wetlands include areas with deciduous trees and scrubs. Most are flooded on a seasonal basis. East of the canal, on Live Oak Creek, there is a cluster of small impoundments, some of which are permanently flooded. The vegetation includes deciduous shrubs.

The remainder of the B canal service area is dotted with small wetlands. Some of the larger ones are permanently flooded, including one on the B canal. Another defined by an impoundment at Kenney Road supports both emergent and forested vegetation. One half mile to the southeast of this wetland is an open water area with several small associated wetlands. Moving south is an area of permanently and semi-permanently flooded areas, the largest of which is known as Lost Pond.

North of the B canal wetlands are less frequent and typically close to creeks. In the vicinity of the Devine Series a small creek has a series of seepage wetlands with emergent vegetation. The area between the B-4 and B-12 canals appears to be a natural drainage area and has many unconsolidated wetland areas, the two closest to the B canal being largest and semi-permanently flooded. Both of these water courses drain into Polecat Creek at the northern boundary of the irrigated area. The creek has many wetlands areas, some with emergent vegetation, as well as intermittent riverine habitat.

Corridors of riparian forest can be found along the Medina River, Elm Creek and Leon Creek. The overstorey vegetation consists of bald cypress (*Taxodium distichum*), sycamore (*Platanus occidentalis*), eastern cottonwood (*Populus deltoides*), black willow (*Salix nigra*), hackberry (*Celtis laevigata*), elm (*Ulmus* *crassifolia*), boxelder (*Acer negundo*) and pecan (*Carya illinoensis*). It is often thick and, together with occasional flooding, acts as a limit to the amount of understorey vegetation. The stream bank usually has a more diverse and dense cover and transitions to pecan groves on the adjacent flood plain terraces. Steeper slopes at the valley walls delineate the transition to upland mesquite-brush vegetation. Southwest Research Institute reports that this ecosystem provides habitat for approximately 170 birds, 36 mammals, 36 reptiles and 11 amphibians (U.S. Army Corps of Engineers, 1989).

Aquatic habitats on the Medina River and its tributaries within the study area are diverse with riffles, pools, runs and sand and gravel bars. Pool and eddy complexes are created by temporary to semi-permanent log-jams and undercut banks add to the diversity of habitat. Because many of the streams in the study area are intermittent, the associated wetlands are classified by the U.S. Fish and Wildlife Service as riverine, intermittent. Below the confluence of Leon Creek and the Medina River the diversity appears to be limited by a deterioration in water quality.

2.3.3 Threatened and Endangered Species

Threatened and endangered species have been identified in two portions of the study area. In the southern part of the study area, in Atascosa county, the sandyhill woolwhite and Parks' jointweed have been identified. In the vicinity of Lake Medina, several examples of both Buckley tridens and bracted twistflower have been seen. East of the lake and north of San Antonio, there have been several sitings of the Texas salamander (*Eurycea neotenes*). The golden-cheeked warbler (*Dendroica chrysoparia*) has also been spotted in the same general area. Slightly south of this area, within the recharge zone of the aquifer, two examples of the Comal blind salamander (*Eurycea tridentifera*) have been seen. These two salamanders are not within the immediate study area, but together with the San Marcos salamander (*Eurycea nana*), Cascade Cavern salamander (*E. latitans*), Texas blind salamander (*Typhlomolge rathbuni*), San Marcos gambusia (*Gambusia georgei*), fountain darter (*Ethiostoma fonticola*) and Texas wild rice (*Zizania texana*) are indirectly affected by water use in the area because they are critically dependent on the quantity and quality of water in the Edwards Underground River (U.S. Army Corps of Engineers, 1989).

A complete list of species within the study area considered by TPWD to be of concern is shown in Table 2-6. Other rare vertebrates found within a 4-county area are shown in Table 2-7.

3.0 CURRENT POPULATION AND HISTORICAL WATER DEMANDS

3.1 Existing Conditions Within the Primary Planning Area

3.1.1 Water Purveyors Located Within the Primary Planning Area

The primary planning area is located in the southern portion of Bexar County and is comprised of twenty-two (22) water purveyors, five of which are military bases. Of these water purveyors, only four lie outside of the contiguous boundary of the primary planning area. These outlying water purveyors are: Castle Hills, which is operated by the Bexar Metropolitan Water District and is centrally located within City of San Antonio; Brooks Air Force Base, which is located within the city limits of San Antonio and is just east of the primary planning area; Randolph Air Force Base, which is not within the city limits of San Antonio but is located in the Northeastern portion of Bexar County; and Fort Sam Houston Army Base, which is also located within the city limits of San Antonio.

Each non-military water purveyor operates under a Certificate of Convenience and Necessity (CCN), which licenses the water purveyor to sell water within a specified area. Figure 3-1 presents the primary planning area boundary and the water purveyors located within this area.

The majority of water supplies within the primary planning area are obtained from the San Antonio region of the Edwards Aquifer via water wells. Eight of the water purveyors, however, obtain water from other sources: three purveyors, Brooks Air Force Base, Silver Mountain Water Company and Waterwood Utilities, purchase water, as needed, to supplement their Edwards Aquifer water wells; two purveyors, City of Elmendorf and Twin Valley Water System, obtain water via water wells from the Trinity Aquifer; and two purveyors, Kings Point Water System and Windy's Water Works, obtain water via water wells from the Carrizo/Wilcox Aquifer. Table 3-1 lists the water purveyors located within the primary planning area, population served, number of connections and average daily use, as recorded by the Texas Department of Health (TDH). The BMWD - South San Antonio Water Supply System has the highest daily water use rate. All of the non-military water purveyors operating within the primary planning area have approximately three persons per tap, whereas the military bases range from one person per tap to ten persons per tap.

3.1.2 Current Population

The current estimated population of the primary planning area is approximately 215,845 persons based on 1990 Census data. In order to determine this population, some extrapolation of census data had to be performed. There are forty-seven census tracts located within the primary planning area boundary. Thirty-five of these tracts are wholly located within the planning area. Therefore, population figures for these tracts were easily derived by taking information directly from the census data. The other twelve tracts, however, fall partially within the primary planning area and partially without.

An estimation of the population in these twelve tracts was derived by determining the ratio of census tract area located within the primary planning area to the total census tract area. This ratio was then applied to the total population of the census tract to yield an estimation of the population of that portion of the census tract falling within the primary planning area. Table 3-2 lists the census tracts, their total area within each tract, the total area that falls within the primary planning area, and the estimated population within the primary planning area. Figure 3-2 graphically illustrates the tracts that fall within the primary planning area and Figure 3-3 shows an overlay of the census tracts and the water purveyors that are located within the primary planning area.

There has been much speculation that the 1990 Census has substantially under-counted the population, especially in areas that have a high migratory population. Therefore, in order to maintain the highest level of accuracy within this study, the census figures for the planning area were cross checked with Texas Department of Health Sanitary Survey information. TDH records show that the identified water purveyors located within the planning area currently provide service to an estimated 210,758 persons. Thus, the discrepancy between the census data and the sanitary survey data is of the order of 2%. In light of the conservative nature of this report, the higher census population of 215,845 persons will be used to reflect the current population throughout the remainder of this report.

3.1.3 Historical Uses

TWDB records were examined to establish historical use patterns for the primary planning area. Monthly data were used to establish such variables as: total water self-supplied; maximum and minimum use months; maximum to average month use ratios; and rates of consumption per service connection. These data will be important in the design phase of future growth planning within the identified planning area.

All water purveyors in the primary planning area obtain water from groundwater sources to provide service to their respective service areas. In addition, three purveyors,Brooks Air Force Base, Silver Mountain Water Company and Waterwood Utilities, purchase additional supplemental water from other sources. Table 3-3 provides a general description of all of the water purveyors within the planning area and includes total number of wells, pump and storage capacity, number of connections and pressure ranges. Appendix B contains a more detailed description for each purveyor.

TWDB records were obtained for 21 of the 22 water purveyors that exist within the planning area. These historical water use data have been grouped into three categories; Bexar Metropolitan Water District, Military Bases within the planning area, and all other non-military water purveyors within the planning area. A more detailed description of historical water uses within the planning area follows.

3.1.3.1 Historical Uses of the Bexar Metropolitan Water District

Tables 3-4 and 3-5, and Figure 3-4, show overall water usage for the combined BMWD system for the years 1980 through 1990. The BMWD system as a whole has remained fairly stable over the past ten years with slight offsetting negative and positive growth trends throughout the 1980s. These trends are highly correlated to total average rainfall for the area as shown in Figure 3-5. Of the total BMWD users, Castle Hills comprises only 14.8% of the total system usage.

3.1.3.2 Historical Uses of Military Bases

Historical water usage for the military bases located within Bexar County can be seen in Tables 3-6 and 3-7 and Figure 3-6. Historical data show that water usage for the military bases as a whole experienced a 28% decline in usage from 1980 to 1981. Thereafter, water usage began to increase until it peaked in 1989. By 1990, however, water usage for all military bases declined by 31% from the 1989 high. Individually, all of the military bases have exhibited either a leveling or declining water usage rate from 1987 to 1990. Randolph Air Force Base is the only military base to supplement its self-supplied groundwater. TWDB records show that water was purchased in 1980, 1982, 1983 and 1984.

3.1.3.3 Historical Uses of Other Purveyors Located Within the Primary Planning Area

Of the remaining water purveyors within the study area, five have exhibited dramatic growth spurts during the period of 1980 through 1990. Tables 3-8 and 3-9, and Figure 3-7, present the water usage for the non-military water purveyors located within the primary planning area. Windy's Waterworks increased its water usage 249% over the period of 1980 to 1990; Vos Water Company increased its water usage 182% from 1982 to 1990; Atascosa Rural Water Supply Corp. increased its water usage 140% from 1980 to 1988; Lackland City, now BMWD, increased its well water usage 48% from 1980 to 1990; And the City of Lytle increased its water usage 55% from 1980 to 1989, showing a decline of 18% thereafter. The remaining water purveyors showed little or no growth during the 1980s. As a whole, the combined water purveyors exhibited 2% growth from 1980 to 1990. Lackland City was the only purveyor to purchase additional water. They did so in the years 1980, 1982 and 1983.

3.2 Existing Sources and Distribution Infrastructure in Primary Planning Area

3.2.1 Bexar Metropolitan Water District

3.2.1.1 General Description

According to TDH records, Bexar Metropolitan Water District provides service to approximately 4,198 persons in Castle Hills and 82,257 persons in the BMWD-South Side service area through 2,728 and 27,419 connections respectively.

3.2.1.2 Facilities Description

Within its service area, BMWD owns and operates 22 well sites, located, five of which serve the Castle Hills area and 17 of which serve the South Side area. The five wells that serve the Castle Hills area have a combined rated capacity of 9,600 gpm, whereas, the 17 wells that serve the South Side area have a combined rated capacity of 42,000 gpm (Table 3-3). In addition to the well sites, the BMWD operates four high service booster pumps at Castle Hills and 19 high service booster pumps at BMWD-South Side, with a total rated capacity of 6,200 gpm and 32,100 respectively. There is one ground storage facility located in the Castle Hills area, with a capacity of 2.0 MG, and six ground storage facilities located in the BMWD-South Side service area, with a capacity of 10.05 MG. Pressure maintenance is provided through the use of elevated storage. Elevated storage in the system for Castle Hills is 1.25 MG and for South Side is 3.35 MG. Total system storage capacity is 3.25 MG and 12.4 MG, respectively.

A summary of the BMWD water system is presented in Appendix B and Figure 3-8 presents the existing and proposed transmission lines within the system, as well as current and proposed well locations. According to TDH records, the average daily usage within the system is approximately 1.805 million gallons for Castle Hills and 11.470 million gallons for BMWD-South Side. Maximum daily usage is reported to be 4.331 million gallons and 18.140 million gallons, respectively. System pressures range from 42 psi to 48 psi for Castle Hills and 55 psi to 100 psi for South Side.

3.2.1.3 System Evaluation

Based upon the results of the most recent sanitary survey conducted by TDH, dated April 17, 1991, for Castle Hills and April 30, 1992, for BMWD-South Side, the BMWD is a superior rated system and has adequate well capacity, ground and elevated storage and high service pump capacity.

3.2.2 Military Bases Located Within Bexar County

3.2.2.1 General Description

According to sanitary survey information, the combined military bases within Bexar County (Brooks Air Force Base, Ft. Sam Houston Army Base, Kelly Air Force Base, Lackland Air Force Base, and Randolph Air Force Base) provide service to approximately 54,378 persons through 8,725 connections. The military bases obtain all of their water from the San Antonio region of the Edwards Aquifer, with the exception of Brooks Air Force Base, which purchases some of its water from the San Antonio City Water Board (SAWS).

3.2.2.2 Facilities Description

Combined, the military bases own and operate 25 wells with a combined rated capacity of 29,905 gpm (Table 3-3). Only one of the military bases operates high service booster pumps. Lackland Air Force Base operates two high service booster pumps with a total capacity of 800 gpm. None of the military bases have ground storage facilities. Pressure maintenance is provided through the use of elevated storage. Combined elevated storage capacity for the military bases is 4.6 MG. Total system storage capacity is 7.5 MG.

A summary of the individual military bases and their system components is presented in Appendix B. According to TDH records, the combined average daily usage for the military bases is approximately 12 million gallons. Combined maximum daily usage is reported to be 22.9 million gallons.

3.2.2.3 System Evaluation

Based upon the results of the most recent sanitary survey conducted by TDH, all military bases meet or exceed State requirements for well capacity, ground and elevated storage, and high service pump capacity.

3.2.3 Other Local Water Purveyors Located Within the Primary Panning Area

Of the remaining non-military water supply systems that are located within the primary planning area, historical water use and sanitary survey information is available for all but one water purveyor, Oakland Utility Company. All of these purveyors obtain water from groundwater sources to supply their respective service areas. Table 3-3 provides a general description of all of the water supply systems within the planning area and includes total number of wells, pump and storage capacity, number of connections and pressure ranges. Appendix B contains a more detail description for each water purveyor.

3.2.3.1 General Description

According to TDH records, the remaining non-military water purveyors currently provide service to an estimated 69,925 persons through 22,849 connections within the planning area.

3.2.3.2 Facilities Description

The combined water purveyors own and operate 41 well sites within their respective service areas. The 41 wells have a combined rated capacity of 30,225 gpm (Table 3-3). In addition to the well sites, the non-military purveyors operate 57 high service booster pumps, with a total rated capacity of 17,480 gpm. All of these purveyors maintain ground or standpipe storage facilities and have a ground and standpipe storage capacity of 2.1 MG and 0.25 MG, respectively. Pressure maintenance is provided through the use of elevated and pressure storage tanks. Elevated storage in the system is 4.6 MG and pressure storage is 0.16 MG. Total system storage capacity is 6.9 MG.

Average daily usage, maximum daily usage, pressure ranges and date of most recent sanitary survey can be viewed on an individual basis in Appendix B.

3.3 Existing Sources and Distribution Infrastructure of BMA

3.3.1 Medina Project

The Medina Project (see Figure 3-9) includes Medina Dam, Medina Diversion Dam, Medina Canal, an extensive system of lateral canals, and Chacon Reservoir on Chacon Creek. Each of these project components are discussed in the following paragraphs.

3.3.1.1 Medina Dam and Medina Lake

Medina Dam and Medina Lake are owned by the Bexar-Medina-Atascosa Water Improvement District No. 1 (BMA). This reservoir was built by the Medina Irrigation Company under a Declaration of Appropriation filed on November 16, 1910, in Medina County by Mr. Thomas B. Palfrey. On June 17, 1911, Mr. Palfrey and his associates sold their rights in Medina Dam and Medina Lake to the Medina Irrigation Company. Subsequently, on March 21, 1912, the Medina Irrigation Company sold the project to the Medina Valley Irrigation Company, which built the Medina Project in 1912 and 1913. In 1917, the Medina Irrigation Company went into financial receivership and was reorganized as the Bexar-Medina-Atascosa Counties Water Control Improvement District No. 1.

Medina Dam, located on the Medina River about 30 mi northwest of San Antonio, is a gravity concrete structure, 1,580 ft in length and 164 ft high. The dam, containing 205,000 cu yd of concrete, is 128 ft thick at its base and 25 ft wide at the top. The top of the dam is at elevation 1,076.5 ft above mean sea level (ft MSL). Lake Medina has an uncontrolled spillway with a crest length of 880 ft at elevation 1,064.5 ft MSL. This spillway is cut through natural rock at the right end (looking downstream) of the dam. The spillway is unpaved, except for a 3.0 foot wide concrete cutoff wall with a crest elevation of 1064.5 ft MSL.

The dam impounds Medina Lake, which captures runoff from a 587 square mile (sq mi) drainage area (USBR, 1992). The original capacity of Lake Medina at elevation of 1,064.5 ft MSL was estimated to be 274,000 ac-ft. Based on sedimentation surveys performed on Medina Lake in 1925, 1937 and 1948 (USDA, 1925 and USSCS, 1937 and 1948), the reservoir has an average depletion in storage, due to siltation, of 0.09 percent per year. Using this storage depletion rate, it is estimated that the 1992 capacity of Lake Medina is 254,000 ac-ft.

3.3.1.2 Medina Diversion Dam and Lake

Water released through Medina Dam is diverted for irrigation at the Medina Diversion Dam, located 4 mi downstream. Three 60-inch-diameter steel pipes equipped with lift-type gates, at an invert elevation of 959.0 ft MSL, are used to release water into Medina Diversion Reservoir for irrigation purposes. Two 30-inch-diameter steel sluice pipes, equipped with lift-type gates at an invert elevation of 912.5 ft MSL, are used to drain the Medina Diversion Reservoir.

Medina Diversion Dam is used primarily for irrigation purposes with domestic, livestock and recreational uses being secondary. The dam is a concrete gravity structure 450 ft long and arched slightly upstream. The center 360 ft is an ogee section which serves as the spillway. The structure is 62 ft high and is 50.5 ft thick at its base. The storage capacity behind this dam is estimated to be 4,000 ac-ft. The dam is equipped with two low-flow outlet pipes used to drain the reservoir. There is a service outlet system located at the right abutment (looking downstream) of the dam to release water for irrigation purposes into the BMA Main Canal. This service outlet system has five inlet gates with trash guards and screens that release water into a forebay area, and five outlet gates that release water into the irrigation canal.

Both the Medina Dam and Medina Diversion Dam were classified as high hazard structures by the U.S. Army Corps of Engineers (1979). As a result of recent studies under BMA sponsorship, TNRCC has reviewed the dam safety and provided a letter of review and approval including requirements for continual monitoring of the dams. Since construction was completed, both dams have exhibited significant seepage under and around abutments. In addition, both dams and reservoirs are located either entirely or partially over the recharge zone of the Edwards Aquifer. Consequently, both reservoirs contribute significant quantities of recharge to the Edward Aquifer on a continual basis.

3.3.1.3 BMA Canal System

Water diverted from the Medina Diversion Reservoir enters the BMA Canal System. A schematic of the BMA Canal System is shown on Figure 3-10. This system has the capability of transporting water by gravity flow to over 34,000 ac of land. The canal system is comprised of six types or sizes of canals (see Figures 3-11 through 3-16), which total an estimated 266.1 mi in length. The right-of-way for these canals and laterals totals approximately 1,935 ac. At normal capacity, the canals and laterals have a storage capacity of about 427 ac-ft.

3.3.1.3.1 Main Canal

The Main Canal (Type VI), beginning at the head works behind Medina Diversion Dam, is approximately 24.0 mi long. The bed material of the canal is primarily earthen, except for an initial, concrete lined section of approximately 0.5 mi in length extending from Medina Diversion Reservoir. Its course roughly parallels that of the Medina River, primarily on its west side, for most of the way to the City of Pearson (see Figure 3-9). Two concrete siphons transports canal water under the Medina River to its east side, recrossing to the west side a few miles downstream. There are also 11 fumes located along the Main Canal, the longest one being approximately 1,700 ft in length. These are double semicircular, heavy galvanized metal flumes, each being 9.5 ft in diameter and supported on creosote trestles. The Main Canal terminates at Pearson, near the Southern Pacific Railroad, where it drops off 60 ft to the valley lands below to provide irrigation water to a series of BMA canals (Type I through Type V). Irrigation water usage along the Main Canal is minimal. It is estimated that a maximum of 300 ac of land are irrigated directly from the Main Canal. In addition, water from the Main Canal is used to provide supplemental water to three stock tanks, which have an estimated total capacity of less than 25 ac-ft.

The Main Canal requires a high level of continual maintenance by BMA. The canal levee frequently fails, causing significant water losses. In addition, there are frequent occurrences of land slides into the canal from the higher elevation hills from which the canal is cut. It is estimated that approximately 25 percent of BMA's annual operation and maintenance budget is dedicated to repair and maintenance of the Main Canal (personal communication with Mr. Kirk Decker, 1992).

3.3.1.3.2 Lateral Canals

At "Pearson Junction" near the community of Pearson, the Main Canal divides into two major branches: A-1 Canal and D-1 Canal. These canals supply water to irrigators and a complex series of lateral canal systems (see Figure 3-9).

The A-1 canal flows in an easterly direction for a distance of 5.8 mi where it provides water to an estimated 152.6 mi of canals and laterals. D-1 Canal flows in a southwesterly direction for a distance of 11.4 mi. This canal provides water to an additional 74.0 mi of canals and laterals (see Figure 3-9).

D-1 Canal also provides water to Chacon Reservoir, located on Chacon Creek about four mi north of Natalia. Chacon Reservoir has a storage capacity of about 2,000 ac-ft. This reservoir impounds a small amount of runoff from Chacon Creek, but is primarily used to store surplus water from the Main Canal and D-1 Canal. Stored water is released from Chacon Reservoir to downstream BMA irrigators.

Based on an inventory of the BMA Canal System, it is estimated that the A-1 Canal and D-1 Canal provide water to 375 and 797 irrigation turnouts, respectively, serving approximately 34,000 ac. An inventory of the BMA main and lateral canal system is presented in Table 3-10.

3.3.2 BMA Irrigation Land and Irrigators

For the period January 1, 1980 through December 31, 1990, BMA had an average of 34,336.45 ac on which a flat tax was levied (BMA Annual Audited Financial Statements Fiscal Years 1980 - 1990). During FY 1990, BMA assessed a flat tax on 34,312.78 ac. BMA does not routinely keep a compilation of land (number of acres) actually irrigated in any given year. However, with its adoption of the water conservation plans and passage of legislation in 1993 to include land from the district, BMA has commenced such record keeping. BMA did perform a compilation of lands actually irrigated for an investigation sponsored by the Edwards Underground Water District, San Antonio, Texas, for calendar year 1988. This special compilation yielded the following inventory for calendar year 1988:

Total Irrigated Acres on BMA Books as of January 1, 1988	34,386.50 ac
Total Number of Land Owners	1,950
Total Water Diverted Through BMA Main Canal at Medina Diversion Reservoir	59,810.00 ac-ft
Total Acres Irrigated One or More Times	16,689.00 ac
Total Acres Irrigated During 1988	32,095.50 ac

Based on the 1988 inventory, BMA assessed taxes on a total of 34,386.50 ac, owned by 1,950 land owners. This yields an average acreage per land owner of 17.63 ac. A listing (as of May 1992) of individual land owners who own more than 50 ac within the BMA service area and who irrigate from the BMA system is shown in Table 3-11. As can be seen from Table 3-11, 39 land owners own a total of 6,844.26 acres. This means that the remaining 1,911 (1,950 - 39) property owners have an average tract size of 14.41 ac

(27,542.24/1,911). Therefore, the BMA service area is comprised primarily of many small acreage tracts, which have access to irrigation water through the extensive BMA canal and lateral system.

Since BMA does not meter water sales to individual irrigators, BMA does not have records of water applied to the field. BMA sells water on the basis of acreage. Table 3-12 summarizes, on an annual basis, the total amount of acres for which water was sold. Based on annual water sales revenue for the 11 year period from 1980 through 1990, BMA sold water for application to an average of 26,491 ac per year. This ranged from a maximum of 43,545 ac in 1984 to a minimum of 12,287 ac in 1987. It should be noted that individual acreage or tracts of land are watered more than once during any given year. Based on the 1988 BMA inventory (shown above), the ratio of the area of land actually irrigated (16,689 ac) to the total acres for which payment for water has been made (32,095 ac) is 0.52 (some tracts being irrigated more than one time during the year). This ratio, (approximately 50%) of acreage actually irrigated to total acreage paid for, corresponds with the working experience of BMA personnel (personal communication with Ms. Evelyn Sollock, BMA accountant/bookkeeper and Mr. Kirk Decker, BMA Operations Manager, 1992).

In an effort to evaluate total water diverted and total BMA acres irrigated, a statistical correlation was performed for the 11 year period 1980 through 1990. Using linear regression procedures, total water diverted at Medina Diversion Reservoir was regressed against total acreage receiving water (Table 3-12) on an annual basis. As shown in Table 3-13, there is a strong positive correlation between these two variables, with a correlation coefficient (R-squared) of 0.80. The mathematical relationship for these variables is shown in the following equation:

$$TARW = 0.87 * TWD - 8,210.62 \quad \text{(Eq. 1)}$$

where; TARW is Total Acres Receiving Water and

TWD is Total Water Diverted as measured at the USGS gage in the Main Canal.

Using Equation 1, total acres irrigated (some tracts irrigated more than one time per year) for the period 1958 through 1979 can be estimated. Figure 3-17 shows total acres irrigated (projected and actual data) and water diverted into the BMA canal for the period 1959 - 1990. For this period total water diverted into the BMA Main Canal averaged 35,793 ac-ft per year. Total acres irrigated averaged 22,762 acres, based on actual (1980 - 1990) and projected (1958 - 1979) data. Using the ratio of 0.52 for acres actually irrigated to total acres paid to be irrigated (see BMA 1988 inventory above), yields an annual average number of acres actually irrigated of 11,836.

Table 3-14 gives a listing of the TWDB's irrigation inventory (TWDB, 1975) in Medina and Bexar Counties for entities using surface water sources. As shown in this table, Medina and Bexar Counties have an average irrigation application rate (surface water sources only) of 2.17 ac-ft per ac and 1.37 ac-ft per ac, respectively, or a combined average of 1.77 ac-ft per ac. Applying the combined average of 1.77 ac-ft per ac, since the BMA service area is situated almost equally in Medina and Bexar Counties (see Figure 3-9), to an annual average of 11,836 ac irrigated, results in an estimated average annual usage (irrigation water actually applied to the fields) in the BMA system of 20,950 ac-ft.

3.3.3 Projected Water Use

BMA's agricultural water requirements depend on the acreage currently in irrigated production, the extent of urbanization of farm/ranch lands, the current water usage per acre, water costs and water availability. As shown in Table 3-12, BMA's total acreage has not significantly changed over the last decade. BMA, due to its proximity to the City of San Antonio, will in the future experience increasing urbanization pressure. Larger agricultural tracts will be subdivided into smaller sections with an overall increase in population density and decrease in irrigation water use. BMA's irrigated lands, like all irrigated lands in Texas, will probably decline following the state-wide trend.

For purposes of projecting future irrigation water requirements, it is assumed that demand for irrigation water in BMA's service area will parallel statewide declines projected by the TWDB (1990) in their report titled "Water for Texas - Today and Tomorrow". In this report, the TWDB performed a low case and high case forecast for irrigated acreage in Texas. In estimating the future water needs of irrigated agricultural, the TWDB took into account: the total acreage suitable for irrigation; acreage currently in irrigated production; water use per acre; water costs; the economics of dryland versus irrigated production; and national and international demands for food and fiber. Based on these factors, the TWDB projected a decline in total farmland irrigated from 6.75 million ac in 1985 to 4.71 million ac for the low case and 5.82 million ac for the high case 2040 forecast.

Applying the TWDB low and high forecast trends to the BMA service area, yields a decrease in actual annual average acres irrigated from 11,836 ac in 1990 to 10,033 ac and 10,977 acre in the year 2020, respectively (Table 3-15). This decrease in average annual acres irrigated results in a corresponding decrease in average annual water diverted (without additional water conservation measures) from Medina Diversion Reservoir into the BMA Main Canal from 35,687 ac-ft in 1990 to 31,691 ac-ft in 2020[1] for the low case forecast, and 33,783 ac-ft in 2020 for the high case (see Table 3-15). As explained later in this report, the BMA could implement additional water conservation measures which could result in 20 percent water savings. Applying the 20 percent water conservation measures, at a rate of 1 percent per year for

[1]Total water diverted into the BMA Main Canal from Medina Diversion Lake is performed by applying Equation 1 and the ratio of 0.52 to for lands actually irrigated to acres total acres paid.

the first 20 years (see Table 3-15) results in a decrease in water diverted into the BMA Main Canal from 35,687 ac-ft in 1990 (low and high cases) to 25,352 ac-ft in 2020 for the low case and 27,026 ac-ft in 2020 for the high case. The low and high case forecast projections for BMA water requirements (with and without additional water conservation) are shown in Figure 3-18.

3.3.4 Types of Crops

The type of crops irrigated within the BMA system can be classified into six categories: Corn, Grain, Grass, Vegetable, Other and Farm Tank. Table 3-16 presents an inventory of the total acreage (some individual tracts irrigated more than once in a given year) irrigated for these six categories by month for the years 1980 through 1986.[2] The annual average acreage irrigated for the crop categories (excluding Farm Tank Category) for this seven year period is shown in Figure 3-19. These data show that, within the BMA system, corn and grasses represent about 62 percent of the irrigated land; while grain, vegetables and other represents approximately 38 percent of the irrigated land using water on an average annual basis. Also, for this seven year period, BMA supplied an average of about 1,445 ac-ft of water per year to farm tanks.

3.3.5 BMA Water Use Patterns

None of the water deliveries to individual irrigators is metered by BMA. Therefore, an analysis of water use at the field (point of application) cannot be performed. BMA has only one gauge to measure the total water diverted from the Medina Diversion Reservoir to the Main Canal. This gauge, maintained by the U.S. Geological Survey, is located on the Main Canal, approximately 0.25 mi downstream of the head gates at the Medina Diversion Reservoir.

Table 3-17 presents a tabulation of monthly and annual water diverted to the BMA Main Canal for the period 1958 through 1990. During this period, BMA diverted an average of 35,793 ac-ft per year from the Medina Diversion Reservoir. This ranged from a low of 16,616 ac-ft in 1973 to a high of 62,235 ac-ft in 1989. A plot of total annual diversions for this time period is shown in Figure 3-20. The maximum average daily diversion for this time period was 216 cfs.

Average monthly water diverted from the Medina Diversion Reservoir to the Main Canal for the 1958 through 1990 period is shown in Figure 3-21. As can be seen in this figure, monthly water diverted is almost normally distributed throughout the year, with peak diversions occurring during the months of June, July and August.

[2]BMA did not have monthly data for 1985, therefore only annual data for this years is shown on Table 3-3.

Since BMA does not meter water sales to individual irrigators, BMA does not have records of water applied to the field. BMA sells water based on acreage. Table 3-12 summarizes, on an annual basis, the total amount of acres for which water was sold. Based on annual water sales revenue for the 11 year period from 1980 through 1990, BMA sold water for application to an average of 26,491 ac per year. This ranged from a maximum of 43,545 ac in 1984 to a minimum of 12,287 ac in 1987. It should be noted that individual acres could have been watered more that once during any given year.

3.3.6 Water Rights

As of June 18, 1992, the TNRCC recognized water rights for the Medina River Basin (the Medina River upstream from its confluence with the San Antonio River) totaling 71,407 ac-ft per yr (Table 3-18). Of this amount, 67,146 ac-ft are located above the Medina Diversion Dam and 4,261 ac-ft are located below the Medina Diversion Dam.

The BMA holds two primary water rights in the Medina River Basin. BMA is recognized under Certified Filing (CF) No. 18, the right to impound 237,874 ac-ft and 4,500 ac-ft of water in Medina Lake and Medina Diversion Reservoir, respectively. Under CF No. 18, BMA has the right to divert from the Medina Diversion Reservoir 63,098 ac-ft per yr for the purpose of irrigating 31,549 ac within BMA's boundaries. In addition, BMA is recognized the right to divert from Lake Medina and/or Medina Diversion Reservoir 750 ac ft per yr for domestic and livestock purposes for use by inhabitants in BMA's boundaries. BMA may also under CF No. 18 perfect the diversion and use of an additional 2,902 ac-ft of water per year from Medina Lake and/or Medina Diversion Reservoir for irrigation of an additional 1,451 acres of land located within the BMA boundaries. In essence, BMA has water rights in Lake Medina and Medina Diversion Reservoir to store a total of 242,374 ac-ft of water, to divert a total of 66,750 ac-ft per year for irrigation, domestic and livestock purposes, and to irrigate a total of 33,000 acres located within BMA boundaries. With a priority date November 16, 1910, CF No. 18 is the most senior water right in the Medina River Basin.

Under Certified Filing No. 19, the BMA is recognized the right to impound 730 ac-ft of water in Chacon Reservoir and to annually divert and use, at a maximum diversion rate of 22.2 cfs, 2,000 ac-ft for the irrigation of 1,000 ac of land located within the BMA boundaries. CF No. 19 has a priority date of March 20, 1912.

Therefore, BMA's water rights (CF Nos. 18 and 19) within the Medina River Basin total an annual diversion rate of 68,750 ac-ft from a combined storage capacity (Lake Medina, Medina Diversion Reservoir and Chacon Reservoir) of 243,104 ac-ft.

The Medina Ranch, Inc. also holds a water right (Permit No. 1200) on Medina Diversion Reservoir. Under this right, Medina Ranch Inc. can use Medina Diversion Reservoir (4,500 ac-ft impoundment) for a game preserve, recreation and pleasure resort. This permit has a priority date of December 14, 1931 and is, therefore, junior to BMA's permitted rights (CF Nos. 18 and 19).

3.3.7 BMA Water Losses

As discussed above, the estimated actual average annual irrigation usage within the BMA system is 20,950 ac-ft. With an average annual diversion of 35,793 ac-ft into the BMA canal system, unaccounted for and/or water losses of approximately 14,843 ac-ft/yr (42 percent) are apparent. Some of this 14,843 ac-ft is in transient storage in the BMA canal system and in Chacon Reservoir.

The design storage capacity of the BMA canal system is estimated to be 427 ac-ft. Allowing for transient canal storage (427 ac-ft) and replenishing the storage in Chacon Reservoir of approximately 1,000 ac-ft per year[3], provides for a total estimated average yearly system storage capacity of 1,427 ac-ft. Adding the 1,427 ac-ft of annual canal system storage to the 20,950 ac-ft of average annual actual water use results is an estimated 22,377 ac-ft of "accounted for" water. This leaves 13,416 ac-ft per year (35,793 - 22,377) of "lost and unaccounted for" water (37.5 percent of total stored water).

Water losses in the BMA system occur in all components of the system: Medina Dam and Lake, Medina Diversion Dam and Impoundment, BMA Main Canal, and BMA Lateral System. These losses may be categorized as recharge to the Edwards Aquifer, leakage around and under structures, and conveyance losses (infiltration/seepage and evapotranspiration).

For the purposes of this report, recharge is defined as the water (quantity or volume) lost from the Medina Lake, Medina River, and/or the Medina Diversion Reservoir to the San Antonio Region of the Edwards Aquifer. Recharge represents the estimated volume of water permanently lost from permitted state surface water sources to the Aquifer. Seepage or leakage is defined as the estimated volume of water that flows around or underneath Medina Dam and/or Diversion Dam in the form of springs. This does not include spills or controlled releases that pass through these structures. Conveyance losses are those water losses associated with the transport of water through the BMA Main Canal and Lateral System. These losses include canal bank storage, evapotranspiration and infiltration from the sides and bottom of the canals to the surrounding geologic formations.

[3]This assumes that one-half of the storage in Chacon Reservoir (1,000 af) is replenished each year by water from the Medina Diversion Lake.

As discussed above, Medina Lake Dam and Medina Diversion Reservoir are constructed over the recharge zone of the San Antonio Region of the Edwards Aquifer. Consequently, both structures and impoundments have experienced significant water losses believed to include recharge to the Aquifer. Both dams have a history of leakage around and underneath the physical structures. Also, it has been documented that the 24 mi long BMA Main Canal experiences conveyance losses because of the type of construction materials and evapotranspiration.

Many public and private entities have evaluated losses (recharge, leakage and conveyance) for these projects, including the U.S. Geological Survey (1930, 1969), E.P. Arneson (1935), Terrell Bartlett Engineers (1948), Robert Lowery (1953), W.F. Guyton and Associates (1958), U.S. Army Corps of Engineers (1964, 1979), Ed Reed and Associates (1970), Freeze and Nichols (1971), Texas Natural Resource and Conservation Commission (1973, 1974, 1976), Texas Department of Water Resources (1977, 1979), Mason-Johnston and Associates, Inc. (1976, 1979), Espey Huston & Associates (1989), Texas Water Development Board (1992), and U.S. Bureau of Reclamation (1992). A brief summary of the findings and conclusions of these investigations for the elements of the BMA water supply and delivery system in presented in the following paragraphs.

3.3.7.1 Medina Dam and Lake and Diversion Dam and Lake

3.3.7.1.1 Structural Investigations

In 1935 E.P. Arneson described attempts by BMA and others to physically and structurally correct leakage around and underneath the Diversion Dam. Arneson did not quantify the quantity or rate of leakage, but concluded that efforts to reduce leakage prior to 1935 were successful in achieving 50 percent leakage reductions, but that leakage was increasing back to original levels.

Terrell Bartlett Engineers conducted an extensive grouting program for BMA in 1948, in an attempt to reduce or stop the leakage around the Medina Diversion Dam. This firm drilled a series of 15 holes at intervals of about 12 ft immediately upstream from the dam. Most of these holes were carried down to a level approximately 115 ft below the bottom of the original cutoff wall of the dam, approximately 140 ft below the low point in the bed of the Medina River. A total of 4,800 sacks of cement were pumped into the holes. The grouting was somewhat effective for a short period of time. However, springs re-appeared at approximately the same flow rates at other locations downstream of the dam.

In 1970 Ed L. Reed and Associates re-evaluated whether or not grouting at either the Medina Dam or the Diversion Dam would be economically and technically feasible. Reed concluded that grouting was not feasible at either structure.

Dam safety inspections performed by the U.S. Army Corps of Engineers (COE 1964, 1979), the Texas Natural Resource and Conservation Commission (TNRCC 1973, 1974, 1976) and the Texas Department of Water Resources (TWDR 1977, 1979), have identified the nature and extent of leakage and seepage around Medina Dam and Medina Diversion Dam. Medina Dam was also inspected by Mason-Johnston and Associates, Inc in 1976 and 1977 at the request of the BMA. More recently the dams were inspected in 1993 by Blackwell Environmental, Inc. As a result of these inspections the following conclusions were made:

- Substantial clear water leakage through the abutments of Medina Dam is occurring and has occurred for decades. No change in the volume of abutment seepage has been detected by visual observations of knowledgeable people in 1964 and 1977.

- The majority of the observed leakage in the abutments of Medina Dam occurs above the Glen Rose and within the Edwards and Comanche Peak limestone formations. The leakage appears to be occurring through the joint system of the massive crystalline rocks and there is no visual evidence of rock deterioration over the past several decades.

- With respect to Medina Dam, there are some major seepage areas along the left bluff area approximately 200 ft downstream. There are numerous seepage areas all along the right bluff area for a distance of approximately 500 feet downstream.

3.3.7.1.2 Hydrological Evaluations

Lowery (1953) performed a hydrological evaluation of seepage and recharge related to Medina Dam and Diversion Dam. In his report entitled "Hydrological Report, Medina River Above the Applewhite Dam Site", Lowery developed reservoir and channel loss rates (recharge and leakage) as a function of rising and falling reservoir levels in Medina Lake. A replot of Lowery's recharge and seepage curves is shown in Figure 3-22. Lowery concluded that recharge and leakage from Lake Medina average about 3,500 ac-ft per month on a rising stage when the lake contains 17,000 ac-ft, and recharge averages 7,000 ac-ft per month when the lake contains 223,000 ac-ft of storage. On the falling stage, Lowery projected that recharge from the lake is 1,000 ac-ft and 4,400 ac-ft at corresponding lake levels. For the 1913 through 1953 period of record, Lowery determined that the average annual recharge from Lake Medina and the Medina Diversion Reservoir was 41,000 ac-ft. In addition, Lowery found or assumed that leakage from the Medina Diversion Reservoir is about 25 cfs when the lake (Medina Diversion Reservoir) is at full capacity.

Lowery's 1953 work is probably the most cited and referenced work on reservoir losses by researchers of these projects. For example, W.F. Guyton and Associates (1958) relied extensively on Lowery's 1953 study in their report entitled "Leakage from Medina Lake, Medina County, Texas". In this research, Guyton concluded that there was no recharge to the Edwards Aquifer when the reservoir elevation was at or below 952.5 ft MSL, the elevation at which the Glen Rose formation starts in the vicinity of Lake Medina Dam. Guyton also concluded that the recharge from Lake Medina gradually increases to more than 100 cfs between lake elevations 952.5 ft MSL and 1064.5 ft MSL (spillway crest).

In 1971 Freeze and Nichols (formerly Freeze, Nichols and Endress) performed a study for political subdivisions located in Bexar County titled "San Antonio and Bexar County, Texas Report on Reclamation and Re-Use of Municipal Wastewater." As part of this effort, Freeze and Nichols (1971) extended Lowery's 1953 work to include the period 1937 through 1968. They concluded that the combined recharge from Lake Medina and Medina Diversion Reservoir during this period averaged 47,482 ac-ft per yr, assuming a steady BMA irrigation demand on Lake Medina of 35,000 ac-ft per yr. They also projected that the potential recharge from these projects, without irrigation demands placed on Lake Medina, would average 61,459 ac-ft per yr. In this study, Freeze and Nichols did not separate seepage or leakage around Medina Dam from inflows to the Medina Diversion Reservoir, but concluded that the average leakage below the Diversion Dam was around 22 cfs or about 16,000 ac-ft per yr.

In 1989 Espey, Huston & Associates, Inc. (EH&A) performed an evaluation for the Edwards Underground Water District, San Antonio, titled "Medina Lake Hydrology Study." In this effort, EH&A conducted an evaluation of the historical, natural recharge and leakage for Lake Medina and Medina Diversion Reservoir. EH&A made numerous attempts to reproduce Lowery's 1953 results, but were unsuccessful. As an alternative, EH&A performed various reservoir operation studies of Lake Medina and Medina Diversion Reservoir and projected recharge quantities (for Lowery's study period). These estimates were approximately 1,200 ac-ft per month less than the recharge calculated by Lowery when Lake Medina is at elevation 1040 ft, and 4,000 ac-ft per month than Lowery's calculations when Lake Medina's elevation is greater than 1040 ft. Based on EH&A's hydrologic model for these reservoirs, they projected an average annual recharge of 45,325 ac-ft for the period 1940 through 1986. Of this recharge quantity, EH&A calculated that 29,389 ac-ft per yr was attributed to Lake Medina and 15,936 ac-ft per yr was attributed to Medina Diversion Reservoir. EH&A projected an average leakage loss around Medina Dam and Medina Diversion Dam of 31 cfs and 19 cfs, respectively, for their 1940 through 1986 simulation period.

3.3.7.2 BMA Canal System

3.3.7.2.1 BMA Main Canal and Lateral System

3.3.7.2.1.1 BMA Main Canal

As discussed early in this report, the BMA is currently experiencing operation and maintenance problems with the Main Canal. These problems include levee and embankment failures and landslides. The BMA has not attempted to quantify the extent of water losses resulting from these recurring problems. However, water losses can be substantial, depending on the location of the failure(s) and time period required to determine the nature and location of the failure(s).

Other operational losses occur in the Main Canal and lateral system. Losses result from infiltration and seepage from the canals, as well as evaporation from the canal water surface. In addition, evapotranspiration can be significant, both from vegetation growing in the canals and from phreatophytes with root systems deriving water from or underneath the canals' soil water zone.

Two flow loss/gain investigations have been conducted primarily focused on the Main Canal. The U.S. Geological Survey (USGS) conducted a study in 1969 at the request of the BMA. The purpose of the USGS study was to determine water losses in the Medina Canal from the point of diversion from Medina River (Medina Diversion Reservoir) to a point 24 miles downstream at the first diversion lateral near Pearson, Texas ("Pearson Junction"). During the USGS study, the BMA maintained a constant discharge into the canal, while the USGS made current-meter measurements at specified points after a constant flow had been achieved throughout the study reach of the Main Canal. The results of the USGS study are presented in Table 3-19. The USGS found a total loss over the 24 mile reach of four cfs, less than four percent of the inflow to the canal.

A second gain/loss study was performed by the Texas Water Development Board (TWDB) in 1991. This effort was broader in scope than the 1969 USGS study, and included losses in Medina Diversion Reservoir, the 24 mi long Main Canal, and the 18.3 mi long D-1 Canal. The results of the TWDB investigation are presented in Table 3-20. The TWDB found that, based on the flow conditions existing at the time of their study (76.13 cfs immediately downstream of Medina Dam), 48 percent of the flow between Medina Dam and Medina Diversion Dam was lost to recharge and leakage below the diversion dam. Flow measurements on the 24 mi long Main Canal indicated a net loss of about 20 percent, with an inflow into the Main Canal of 36.03 cfs. For the 18.3 mi long D-1 Canal, the TWDB could not reliably determine water losses due to water storage behind check dams. However, the TWDB and BMA staff estimated that 33 percent of the water entering D-1 Canal at the Pearson Junction is lost within the 18.3 mile segment. Most of this loss is speculated to occur at the lower end of the D-1 Canal (TWDB 1991).

4.0 PROJECTED POPULATIONS AND WATER DEMANDS

4.1 Population Projections

The TWDB produces population projections for each county in the State of Texas and for all cities that have populations over 1,000. These estimates are used in water supply and wastewater disposal planning projects. Under the terms of the Texas Water Development Board/BMWD Planning Grant Contract, this study is to utilize TWDB population estimates in the planning process unless compelling reasons for using alternative estimates are presented. In this study, TWDB projected population and water demand methodologies are employed. However, because TWDB future population estimates and water demand scenarios are computed and presented within the context of political boundaries and are not geographically conducive to the defined planning area, it is necessary to calculate current study area populations based on other methodologies, as described in Section 3.1.2. TWDB projected population and water demand growth rates are then applied to the current planning area population, as described in detail in the methodologies of this report (Section 4.1.1).

4.1.1 Projection Methodology

In 1989, the Texas Water Development Board projected water use and population growth for the State of Texas in its publication entitled the "*1990 Texas Water Plan.*" Population projections were based on historical U.S. Census Bureau data. In April, 1992, The TWDB revised its population projections and water use estimates to reflect the 1990 U.S. Census data. Although it has been widely publicized that the 1990 Census has under counted the population, the 1992 Draft TWDB report data has been chosen for use in this study for two reasons: first, this study uses only the projected population and water use growth ***rates*** and not the actual population figures, and second, the TWDB has reevaluated its population and water use growth rates to reflect current social, political and economic conditions and, therefore, these revised rates reflect a more accurate picture of future water use.

The TWDB draft 1992 Water Plan uses a Cohort Component Method with a Net Migration Component to predict future populations. Simply put, the TWDB uses U.S. Census Bureau derived local rates of fertility and mortality to determine a rate for the naturally expanding population base. In addition, estimates of immigration into the area and emigration from the area are used to estimate a net migration.

The TWDB then constructs two models from these data. One model is calibrated to the 1950-1970 statistical period, it predicts a much slower rate of population growth in Texas than was observed in the late 1970s and early 1980s. Future population estimates using this model represent a conservative or "Low Population Series." A second model is constructed using growth rates developed for the 1970-1980 statistical period. Future population estimates using this model represent an optimistic or "High

Population Series." For each population series, water usage is projected for all cities and military installations with populations over 1,000. Cities with populations less than 1,000 are classified into the "Other" category. For the purposes of this report, the "Other" category has been labeled "Other Rural" and all city populations greater than 1,000 that do not fall within the primary planning area are grouped into a category called "Other Metropolitan"

A source of recent debate has been the effect of the North American Free Trade Agreement (NAFTA) on commerce and future population increases or decreases. A number of impact assessments of NAFTA have been initiated at all levels of government. The Office of the U.S. Trade Representative have described various possible scenarios ranging from increased development along the border, to a scenario where the development actually moves away from the border. Faced with this uncertainty the TWDB concluded that no substancial change to the TWDB's population projection methodology was appropriate (TWDB, 1992).

4.4.1.1 Low Series Population Estimates

Low series population estimates for the primary planning area through the year 2040 are shown in Table 4-1 and are graphically depicted in Figure 4-1. The TWDB-projected growth estimates show the greatest increase in growth in the Other Rural category. It is predicted that the rural areas within Bexar County will experience a population growth of 43% by the year 2000, with a continued increase in population of approximately 23% each decade thereafter until the year 2040. Both the City of San Antonio and the Other Metropolitan areas as a whole are expected to see an average increase in population of 17% per decade until the year 2040. With the exception the military bases within Bexar county are expected to decline in population, with the possibility of some bases being closed by the year 2040. Table 4-2 and Figure 4-2 present the projected growth rates as they apply to the primary planning area. BMWD-Castle Hills is expected to exhibit a slight increase in population (approximately 14%) by the year 2000, with the population stabilizing by the year 2040 as they reach geographical constraints. BMWD-South Side, which falls into the other rural category, is expected to increase its current population of 82,257 people to 117, 674 people by the year 2000, ultimately reaching a population of 273,778 by the year 2040. The military population is predicted to decrease from 54,378 to 53,686 people by the year 2040, assuming no base closures. Collectively, the other water purveyors are expected to see an increase in their respective service areas from 69,925 people to over 232,733 people by the year 2040. The aggregate population for the primary planning area, which is approximately 211,028 persons at this time, is expected to reach 565,726 people by the year 2040 using low population series estimates.

4.4.1.2 High Series Population Estimates

TWDB High Series population estimates for Bexar County are presented in Table 4-1 and Figure 4-3. High series population estimates are only slightly different from the low series estimates, with the rural areas expected to show a 43% increase by the year 2000 and a growth rate of 25% per year thereafter. The City of San Antonio and other metropolitan areas are expected to experience a growth rate of 18% per decade. High population series projections for the Primary Planning Area through the year 2040 are shown in Table 4-2 and Figure 4-4. Using high population series estimates, BMWD-Castle Hills is expected to exhibit the same slight increase in population (approximately 14%) by the year 2000, and to stabilize by the year 2040, as projected with the low population series estimates. High series estimates show BMWD-South Side ultimately reaching a population of 288,681 persons by the year 2040. The military population is predicted to maintain a population of 56,611 people from the year 2000 to 2040 under the high series estimate, again assuming no base closures. And, the other water purveyors collectively are expected to serve 245,402 people by the year 2040. The aggregate population for the primary planning area, utilizing the high population series estimates, is expected to reach 596,524 people by the year 2040.

4.1.2 Population Projection Results

The primary planning area is expected to exhibit a dramatic increase in population by the year 2040. While other areas of Bexar County are expected to have a moderate or declining growth rate, this trend is not demonstrated in the projections for the primary planning area. This high growth trend can be attributed in part to geographical limitations being reached by the larger cites and the limited water availability within urban areas. TWDB has predicted that urban sprawl will continue into the rural areas of Bexar County and that new businesses will choose to locate in those areas where water is readily available. The High Series population estimates most adequately reflect the steady growth of the primary planning area and are used throughout the remainder of this report.

4.2 Water Demand Projections

4.2.1 Water Demand Projection Methodology

The TWDB applies historical per capita water use factors to its high and low series future population estimates to determine future water demands. These water demands are based on high per capita and average per capita use rates. The high per capita use rates are based on the highest annual use during 1978-1989, which is reflective of demand during periods of below average rainfall. The average per capita use rate is based on the average for the same time frame, reflecting average rainfall conditions.

In addition to the average and high per capita use rates, the TWDB applies water conservation reduction factors to each historical use rate to obtain future demands with and without implementation of water conservation measures. Conservation savings are computed differently for urban and rural settings; however, both are non-linear functions that assume an increasing rate of savings until some ultimate reduction limit is achieved. From that point on, annual water conservation savings are assumed constant. For rural areas, the TWDB water conservation savings begin at 2% for the first year and increases to a maximum of 15% in 2020. Thence, conservation savings remain constant at 15%.

There are eight possible combinations of future water demand that will be explored in detail in the following sections:

Low Population Series	High Population Series
Average Per Capita Use	Average Per Capita Use
(1) With Water Conservation	(3) With Water Conservation
(2) Without Water Conservation	(4) Without Water Conservation
High Per Capita Use	High Per Capita Use
(5) With Water Conservation	(7) With Water Conservation
(6) Without Water Conservation	(8) Without Water Conservation

4.2.2 Water Demand Projection Results

Projected water use figures are extremely valuable in calculating future treatment capacity and distribution infrastructure. The future water demand projections for the primary planning area are categorized into the following groups: Bexar Metropolitan Water District (Castle Hills and South Side); Military Bases within Bexar County; and other water purveyors located within the primary planning area.

4.2.2.1 BMWD Projected Water Demand

Aggregate BMWD future water demand projections are shown in Table 4-3 and Figure 4-5. Depending on the population series, per capita use rate and water conservation scenario chosen, the total projected BMWD 2040 water demand ranges from 51,448 acre-feet/year (high population series - average demand - with conservation) to 84,562 acre-feet/year (high population series - high demand - without conservation).

4.2.2.2 Other Local Purveyor Projected Water Demand

Aggregate future water demand projections for other non-military water purveyors in the primary planning area are shown in Table 4-3 and Figure 4-6. The total projected 2040 water demands for the aggregate purveyors within the planning area range from 42,503 acre-feet/year (high population series - average demand - with conservation) to 70,125 acre-feet/year (high population series - high demand - without conservation).

4.2.2.3 Projected Water Demand for Military Bases Within Bexar County

Aggregate Military Base future water demand projections are presented in Table 4-3 and Figure 4-7. Military 2040 water demands are projected to range from 15,153 acre-feet/year (high population series - average demand - with conservation) to 24,274 acre-feet/year (high population series - high demand - without conservation).

4.3 Selection of Future Development Planning Scenarios

Planning for future water supply acquisition and future treatment plant and distribution infrastructure designs require different uses of the same information. If in planning for the acquisition of firm future water supplies, future demands are over or under-estimated, adjustment can usually be made to either liquidate excess capacity or obtain additional supplies from alternative sources. However, if future water treatment or distribution capacities are underestimated, the results can be costly. Additional capacity, at some future date, may be considerably more expensive than the initial cost of over-sizing distribution system lines. Maintaining excess or unused treatment and distribution capacity can be equally expensive. Therefore, it is important to choose the most appropriate population series, water use rate scenario and conservation plan to insure that future growth will not be under or over-estimated.

The following future water demand estimates will be used in the remainder of this study, as they are deemed most appropriate to the projected growth of the primary planning area:

- **High Population Series**
- **High Per Capita Use Rate**
- **With Water Conservation**

To minimize the possible economic impacts of over- or under-estimation of future populations and water demands, all water supply and infrastructure development scenarios examined will be phased.

A detailed water conservation and emergency water demand management plan is required under the TWDB Water and Wastewater Planning Grant Program. Detailed plans have been prepared for both the

BMWD and BMA and are contained in Appendices C and D, respectively. These two appendices are designed to be stand-alone documents to be submitted to the TWDB for review under separate cover. As such, portions of these appendices, principally those sections describing the project and study area, have been duplicated from portions of the main document.

5.0 IDENTIFICATION OF FUTURE SUPPLY DEVELOPMENT OPTIONS

Identification and development of the most appropriate future water supply, treatment, and distribution options for the BMA and BMWD service areas first requires examination of all potential regional supply options. This section identifies many future development options which appear, on the surface, to be insignificant. However, prudent planning requires that all feasible options be considered and ranked in order of engineering difficulty and institutional and legal acceptability. Those few options identified through this ranking as the most promising are then subjected to a more rigorous analysis, which includes costs, to select those options which will be presented to the boards of the BMA and BMWD for further consideration. During this ranking process some options which may appear initially attractive will be eliminated, and some initially unattractive options may become attractive when subjected to a side-by-side comparison.

5.1 Future Demand Conditions

Future populations and water demand projections in the BMWD service area and remainder of the study area were developed in Section 4.0 of this study (Figure 5-1). The future water supply demands of the BMA and BMWD service areas are separate and distinct. The BMA's water demands are related only to agricultural use, and presently do not have a municipal component; the BMWD future demands are for municipal use, and do not have an agricultural component.

5.2 Preliminary BMA System Modification Options

There are four primary and numerous secondary options available for modification and improvement of the BMA irrigation canal system (Table 5-1 and Figure 5-2). Those options range from a "no-action alternative", which essentially means doing nothing, to substitution of Lake Medina water for water from another source. All of the options are discussed in detail in the following sections. A detailed analysis of each alternative, including advantages and disadvantages is presented in Section 6.0.

5.2.1 Limited/No-Action Alternative

The first BMA Canal System option considered is the "limited/no-action" alternative. The limited/no action alternative serves as a baseline for comparison with other proposed options. Two subsets of the limited or no-action alternative are:

- Continue the implementation of the historical BMA maintenance program, which will essentially perpetuate the current water loss and other operational problems into the future, or

- Continue the upgrade, at least on a limited basis, of the existing BMA maintenance program, i.e., perform only those tasks absolutely necessary to reduce future system losses.

If the BMA is to continue with its contractual agreement with the BMWD for the purchase of excess Lake Medina yields, as defined as those waters above the needs of the BMA users, it is imperative that the BMA continue to husband its resources, minimize canal system losses, and maximize the water available at Lake Medina for sale to the BMWD.

5.2.2 BMA Canal System Improvements

Two main types of the canal system improvements are proposed for the BMA: (1) main canal system improvements and (2) lateral canal system improvements. An obvious option available to the BMA is relocation of the existing diversion point from the Diversion Reservoir or location of an additional source of water for use in the irrigation system. This option includes moving the BMA diversion point to Lake Medina, thereby avoiding the estimated large losses occurred by routing the Medina releases through the Diversion Reservoir. Another option is moving the diversion point for the BMA system to a point downstream of the Diversion Reservoir nearer the existing lateral canal system. This would also eliminate the estimated large losses currently incurring in the main canal system.

5.2.2.1 Main Canal System Improvements

5.2.2.1.1 Line Main Canal

The BMA main canal system is approximately 24 miles long from its point of diversion at the Diversion Reservoir Dam to Pearson Junction, where the water is distributed to the lateral canal system. In this 24 miles, the BMA main canal crosses the Medina River twice, using concrete inverted siphons. In addition, there are 11 elevated aqueduct crossings of other streams or canyons. These aqueducts are constructed of double-wall galvanized steel and supported by wooden tressels. The main canal is constructed on the Balcones Escarpment and uses the difference in elevation at the escarpment between the higher western side and the lower eastern side as a fall-line for gravity transport of the water from the Diversion Reservoir to Pearson Junction. This stretch of the main canal system is subject to breaching of the canal levees by erosion and overflow from the canal system caused by blockages resulting from slides from the higher west bank of the main canal system. One possible means to reduce losses from the main canal losses would be to line the main canal with concrete, plastic, clay, or some other impervious material. This could greatly reduce losses from leakage and would reduce losses from levee erosion and failure. This would not, however, eliminate all potential losses resulting from levy over-banking caused by blockages of debris from landslides.

Another option would be to enclose the main canal. An enclosed pipe, either standard concrete cylindrical pipe or box culvert, could be laid right in the existing canal. In addition to losses from seepage, either option would eliminate erosion and slide induced losses. It would be the option to BMA to either line the entire main canal or simply line those portions of the Main canal which have a history of being problem sections.

5.2.2.1.2 Improve Maintenance of Main Canal

An alternative to actually lining the main canal would be to continue the rigorous pro-active canal maintenance program initiated by BMA in 1992. BMA levee riders would routinely inspect, through visual and mechanical means, the entire main canal to identify potential trouble spots. And then, repairs would be performed at those locations before they become a real problem. Slides that reoccur at specific location could be regraded or covered with rip-rap materials to minimize the possibility of a slide.

5.2.2.1.3 Lateral Canal System Improvements

There are over 250 miles of lateral canals in the BMA irrigation system. Most of the canals are constructed of earthen levees, with unlined bottoms. There are four simple alternatives to reduce losses in the BMA lateral canal system: (1) line or enclose the lateral canals, (2) improve maintenance of the lateral canals, (3) install metering capabilities at all turn-outs, and (4) establish a rigorous mandatory water conservation program for all BMA water users.

5.2.2.2. Lateral Canal System

5.2.2.2.1 Line Lateral Canals

Lining or covering all of the BMA lateral canals would be a very ambitious and expensive alternative. However, the primary lateral conveyance canals and some secondary canals (Type III-V canals) could be lined, and in some cases covered. The most obvious candidate lateral canals for lining are A3, B, S-Canal, D1, and D2. These canals represent the primary irrigation water carriers in the lateral canal system.

5.2.2.2.2 Improved Maintenance of Lateral Canals

Continuation of the improved pro-active maintenance program will continue to greatly reduce the losses from the BMA lateral canal system. Historically, the majority of losses occured from levee failure, resulting from infrequent maintenance. This improved maintenance program would require considerably more personnel, equipment, and a considerably higher capital expenditure by the BMA. However, the savings resulting from improved maintenance could be substantial. Information generated by twelve metering guages installed along the main canal by BMA between Diversion Reservoir and the Bexar County Line will be used to identify portions of the canal experiencing the greatest water losses.

5.2.2.2.3 Flow Metering at All Lateral Canal Turnouts

Currently, BMA irrigation water users call for diversions of their water rights based on time rather than a specific quantity of water. This is an imprecise way to measure the amount of the diversion. The amount of water diverted to a field during a certain amount of time is dependent upon the elevation of water in the lateral canal system at the point and time of diversion and the elevation of the land to be irrigated. If the canal system is at a particularly high level, a user can divert a lot more water during a given time than if the canal system is at a low level.

Metering all diversions, combined with rates based upon the volume of water diverted, would reduce tail-water pond formation and encourage the more efficient use of water. If users are charged on a per gallon or per ac-ft basis, they are likely to be more attentive to irrigation application rates and frequencies. This will significantly reduce the amount of water wasted to tail water ponds. In addition, some irrigators may switch to less water intensive crops or dry-land farming.

5.2.2.2.4 Enforced Water Conservation

Voluntary water conservation programs seldom result in greater than a 2% reduction in usage. Mandatory conservation measures with enforcement and penalties can result in reductions of 10-20%. The BMA currently has developed and instituted a water conservation program and is working to implement enhanced conservation measures for all of its users through its rate structure. If it is very expensive to waste water, people will not do it.

5.2.3 BMA Diversion Point Relocation

5.2.3.1 Medina Lake Diversion

One means to avoid the high losses to the Edwards Aquifer from the Diversion Reservoir is to move the BMA diversion point to Lake Medina, and eliminate the use of the Diversion Reservoir as an impoundment. The BMA diversion point could be moved to Lake Medina in two ways.

- BMA could construct a new diversion structure at Lake Medina and pump the water over the ridge on the southwest side of the Lake to the existing main canal (Figure 5-2, Option A), or
- BMA could take water through one of the existing Medina Dam release ports and pump the water to the existing main canal through a pipe layed in the existing Diversion Reservoir bed (Figure 5-2, Option B).

Either option obviates the need for the Diversion Reservoir for BMA withdrawals.

5.2.3.2 Medina River Downstream of the Diversion Reservoir

There are several convenient locations downstream of the Diversion Reservoir where the BMA could divert dedicated Lake Medina releases (Figure 5-2, Option C). Moving the diversion point to well downstream of the Diversion Reservoir would, however be trading main canal losses for high Medina River losses.

5.2.3.3 Edwards Aquifer Wells

The 73rd Texas Legislature (1993) passed Senate Bill 1477 (SB 1477) which relates to the management of the Edwards Aquifer. However, the implementation of SB 1477 has been blocked by the United States Department of Justice's failure to grant "pre-closure," under the Voting Rights Act, to the creation of the Edwards Aquifer Authority. Three provisions of that bill are important to the BMA and BMWD.

- SB 1477 provides for the creation of the Edwards Aquifer Authority (EAA), and abolishes the Edwards Underground Water District (EUWD) as the management entity for the Edwards,
- All new wells drilled into the Edwards Aquifer must be permitted by the EAA,
- Entities which construct or maintain a recharge structure to the Edwards Aquifer are allowed to recover their recharge with two constraints:

  (1) Recovery is limited to the actual amount of demonstrated recharge and

  (2) Recovery must be completed within the subsequent twelve months.

A feasible future development option available to the BMA, and the BMWD through water sales contracts, is the recovery of Edwards losses from the Lake Medina and Diversion Reservoir (LM/DR) System, through the development of new wells (Figure 5-2, Option D). Several arguments can be made in support of these wells as simply recovering an asset which technically belongs to the BMA.

While no "real-time" collection of data has ever been undertaken to actually measure the losses in the LM/DR system to the Edwards Aquifer, some theoretical studies have estimated that the LM/DR System contributes between 40 and 80,000 ac-ft/yr to the Edwards, through uncontrolled recharge (the average is approximately 60,000 ac-ft/yr). The breakdown is approximately 18,000 ac-ft/yr from the constant level Diversion Reservoir and 22-60,000 ac-ft/yr from Lake Medina. It is technically feasible to substantially reduce or eliminate some of this recharge. Elimination of the use of the Diversion Reservoir for BMA withdrawals (diversions could be taken directly from Lake Medina or through a pipeline layed on the current Diversion Reservoir bed) could save at least 18,000 ac-ft/yr. Structural and operational changes to Lake Medina could, conceivably, save another 10-15,000 ac-ft/yr. BMA, as the sole owner of both Lake Medina and the Diversion Reservoir, would benefit from the reduced losses, which would be the property of the BMA.

Additional benefits would accrue through BMA canal system loss reductions. The LM/DR system would operate at a higher annual level of storage, which would reduce the available capacity and/or need to capture flood flows. These flows would pass through the LM/DR System, and recharge the Edwards Aquifer downstream or contribute to Guadalupe Bay freshwater inflows.

Thus, the BMA should be entitled to divert and use, as a minimum, up to 66,000 ac-ft/yr from the LM/DR-Edwards Aquifer (LM/DR-EA) System. Diversions could be from either surface or recharged groundwater sources, or both. As with surface water diversions, groundwater diversions would be limited by inflows (recharge). But the BMA and/or BMWD could withdraw up to 66,000 ac-ft/yr from the system.

5.2.4 Use of Living Water Catfish Farm Effluent

The Living Waters Catfish Farm (LWCF) is located on the Medina River adjacent to the eastern extremity of the BMA lateral canal system in Bexar County. The LWCF intends to withdraw approximately 50 MGD from the Edwards Aquifer for use in the commercial production of catfish. Effluent from the LWCF will be discharged to the Medina River near the upper end of the former Applewhite Reservoir site.

Direct use of the LWCF effluent as irrigation water by the BMA, with discharge to the Medina River during non-irrigation months, would obviate the use of the LM/DR System as a BMA source of supply and would eliminate all losses associated with the main canal (Figure 5-2, Option E). The LWCF effluent could be pumped to Pearson Junction where it would feed the A, B, and D lateral canal systems. This would free the total LM/DR system yield for use for non-irrigation purposes including municipal use.

During maximum irrigation months, however, the BMA demand exceeds 50 MGD. To satisfy maximum monthly demands, the BMA would need to either provide for off-channel storage of LWCF effluent or maintain an alternative source of supply, such as LM/DR water or Edwards recharge wells to supplement irrigation demands.

5.2.5 Reuse of BMWD/SAWS Wastewater Effluent

The City of San Antonio currently discharges a portion of its treated wastewater effluent to the Medina River near the BMA lateral canal system in Bexar County. A portion of this effluent could be diverted for use as irrigation water by the BMA (Figure 5-2, Option F). This option would also free the LM/DR system yield for municipal use.

5.3 BMWD System Modification Options

Twelve potential future development options have been identified for the current and proposed BMWD service areas. Those options are listed in Table 5-2 and graphically presented in Figure 5-3. Each alternative will be discussed individually in the following sections. A detailed analysis of each option, including advantages and disadvantages will presented in Section 6.0.

5.3.1 Limited/No-Action Alternative

As a baseline against which all other future BMWD supply development options will be measured is the "limited or no-action" alternative. Generally, this is the least cost alternative and is the alternative which, in terms of engineering feasibility, is generally the simplest. In addition, this option generally does not have undue negative institutional or legal ramifications. However, this is the alternative that offers the least firm future water supply.

There are three limited or no-action alternatives available to the BMWD.

- Continue on existing Edwards Aquifer wells. This would not necessarily mean drilling new wells into the Edwards Aquifer but would emphasize maintaining and utilizing existing excess well capacity. In 1990, TDH sanitary surveys indicated that the BMWD maintains approximately 42,000 gpm of well capacity; of which, approximately 25,000 gpm is excess. At least for some time, future BMWD demands could be satisfied from existing wells; provided that the EAA would issue the necessary permits.
- Develop new wells in South Bexar County area or Northern Atascosa or Wilson Counties into the Corrizo Sands or Corrizo-Wilcox Aquifer.
- Development of new wells into local shallow formations that may offer reasonable amounts of treatable water.

5.3.1.1 Continue Existing Wells

The BMWD currently gets its total water supply from the Edwards Aquifer, and conceivably could continue to do so. There are currently no rules which would preclude the BMWD from continuing to rely on the Edwards as a sole source of supply. SB 1477 does, however, provide for future mandatory withdrawal reductions as a means to reduce overall Edwards Aquifer pumpage. The exact procedures for those reductions have not been developed, but they do require an overall pumping reduction to 450,000 ac-ft/yr by December 31, 2007 and to 400,000 ac-ft/yr thereafter.

The Edwards Aquifer Authority, if implemented, will in the future require permitting of all existing and new wells. Thus, some entity other than the BMWD may control the future water supplies available in South Bexar County. Provisions are underway to develop regional surface water supplies, including Lindenau and Goliad Reservoirs and the Trans-Texas Pipeline. However, the minimum lead-time for major reservoir projects is typically 15-20 years and the BMWD users could suffer considerably in this period.

5.3.1.2 New Wells to Corrizo Formation

The Corrizo Sands in Southern Bexar County are known to contain reasonable quantities of water. That water, however, often has problems with hydrogen sulfide (H_2S) and elevated levels of chlorides (Cl^-) and sulfates ($SO_4^=$) which impart undesirable tastes and odor to water. Removal of Cl^- and $SO_4^=$ from drinking water and oxidation of H_2S are technically feasible and common treatment practices. Blending of treated lesser quality Corrizo formation water with the high quality Edwards water will result in larger supplies of acceptable quality water.

5.3.1.3 Drill New Wells to Other Formations

Other formations in South Bexar County and Northern Atascosa and Wilson Counties are known to contain treatable water of varying quantities and qualities. These sources could be developed individually or as a group and their waters either treated for direct use by the BMWD or blended with the Edwards Aquifer water prior to distribution.

5.3.2 Development of Lake Medina/Diversion Reservoir System

5.3.2.1 Lake Medina/Diversion Reservoir

A major focus of this study is an evaluation of the LM/DR System as a possible future source of water for the BMWD. The two primary diversion points from Lake Medina examined are: BMWD direct diversions from Lake Medina itself and BMWD diversions from the existing Diversion Reservoir at the point where the BMA currently diverts its supply (Figure 5-3, options A_1 and A_2). BMWD is also considering withdrawing water from the main canal at Pearson Junction. That location is being studied as a potential site for a surface water treatment plant to service municipal demands in Medina and western Bexar counties.

Surface water treatment facilities could be located either at Lake Medina, which would allow easy service to the western portions of the study area, or near the center of the study area, which would allow for the development of an efficient "hub-and-spoke" type distribution system.

The distance between Lake Medina and the current BMWD service area is approximately 32 miles. The difference in elevation between Lake Medina and the BMWD is a net negative; however, the intervening topography undulates, which precludes gravity flow from the source of supply to the study area demand centers.

5.3.2.2 Living Waters Catfish Farm Pump-back to Lake Medina

The availability of effluent from the LWCF further enhances the possibility of development of firm supplies from the LM/DR System. Thus, two additional LM/DR development options are: diversion of BMWD sources from Lake Medina, with and without pump-back of LWCF effluent, and BMWD diversion from existing Diversion Reservoir, with and without pump-back of LWCF effluent (Figure 5-3, Option B).

Under full operation the LWCF will produce approximately 60,000 ac-ft/yr of good quality effluent. Unless reused, that effluent will be discharged to the Medina River near the middle of the proposed BMWD service area. In addition to direct use by the BMA as a primary source of irrigation water, the LWCF effluent could be treated and used directly by the BMWD or pumped back to Lake Medina where it will enhance the LM/DR supplies available to both the BMWD and BMA.

This option would require construction of a second pipeline, from the LWCF to Lake Medina. The effluent could be pumped to the upper reaches of the impoundment or to a remote cove.

5.3.3 Medina River Below Diversion Reservoir

The proposed BMWD service area straddles the Medina River in South Bexar County. A possible option for the BMWD is to pick up future supplies, which have been released form LM/DR, from the Medina River in closer proximity the BMWD service area (Figure 5-3, Option C). Supplies purchased from the BMA could be simply released from the Diversion Reservoir and withdrawn nearest the point(s) of demand. However, demand releases from the LM/DR would need to be far in excess of supplies actually required, as this stretch of the Medina River is known to incur large hydrologic losses.

5.3.4 Medina /Applewhite Reservoir Combination

In 1990 the Applewhite Reservoir was narrowly rejected by San Antonio voters as a stand-alone water supply reservoir project. The rational for that rejection was that, as a stand-alone project, Applewhite could not economically develop a sustainable firm yield. However, in combination and consort with Lake Medina, Applewhite Reservoir could develop a reasonably firm 35,000 ac-ft/yr yield of surface water (Figure 5-3, Option D). The Applewhite project could be resurrected and operated as a system with LM/DR. System operation generally results in a higher yield than the sum of the reservoir yields when operated individually.

5.3.5 Medina/Cibolo Reservoir Combination

Cibolo Reservoir located on Cibolo Creek east of San Antonio is an authorized federal project which could be developed and used in a scalping operation with the existing LM/DR System. (Figure 5-3, Option E) This operation would require the construction of diversion and pumping facilities in the San Antonio River capable of scalping flood flows that are released as uncontrolled spills from Medina Lake. Scalped flood flows would be stored in Cibolo Reservoir where they would commingle with natural Cibolo Creek inflows. Stored waters could then be pumped back to the BMWD for treatment and distribution. Such a system operation could yield considerably more water than available when evaluating either Medina or Cibolo as stand-alone projects.

Also due to its strategic location, Cibolo Reservoir could serve as a supply source for both the BMWD and CRWA, and could store waters derived from either the San Antonio or Guadalupe Rivers.

5.3.6 Edwards Underground Aquifer (New Permits)

The Edwards Aquifer currently serves as the sole supply of water to all users in BMWD service area. It is an option to the BMWD to approach the, once implemented, EAA and request new permits (Figure 5-3, Option H). Those permits would cover all existing wells into the Edwards within the existing and projected BMWD service area and projected service areas.

In Section 5.2.2.3 arguments were presented why the BMA has rights to up to 66,000 ac-ft/yr which could be recovered from a combination of the LM/DR System and wells drilled into the Edwards Formation. The same arguments apply to the BMWD pumping of water from the Edwards under a contractual relationship with the BMA. Rather than attempting to drill new wells to the Edwards, the BMWD could purchase or lease the BMA's right to up to a total of 66,000 ac-ft/yr under the Edwards Aquifer (SB1477) recharge or Supplementary Recharge Augmentation (SRA) (water-banking) arguments.

5.3.7 Living Water Catfish Farm

The Living Waters Catfish Farm is located adjacent to the Medina River immediately south of the current BMWD service area, and near the center of the proposed BMWD service area. The LWCF is expected to produce between 50 and 60 MGD of water from the Edwards Aquifer under artesian pressure. The proximity and constant flow of the supply makes use of the LWCF effluent a very attractive option to the BMWD. Development of that supply option could be done with or without off-channel storage facilities. If Applewhite Reservoir is to be investigated as a feasible option, the 50 to 60 MGD of effluent from the Living Waters Catfish Farm would flow directly into the proposed Applewhite Reservoir site. Otherwise, the consistent flow could serve as a base load to the proposed BMWD treatment facilities and peaking supplies could be obtained from more expensive sources such as pumped Edwards water from existing wells. At the time of this report printing, the fate of the LWCF permit is still in the regulatory and permitting arena.

5.3.8 Purchase or Leasing, and Conversion of BMA Irrigation Rights

An option available to the BMWD is to simply purchase or lease the irrigation rights currently held by the BMA or other irrigators, develop the LM/DR System to the maximum extent possible under the limits of existing permits, and then divert the total permitted yield from LM/DR System for use by BMWD. However, BMA has made it clear that it has no present interest in selling its water rights in the LM/DR System.

5.3.9 Develop Cibolo Reservoir As a Stand Alone Project

Cibolo Reservoir was previously identified as a possible supply option in conjunction with the LM/DR system (Figure 5-3, Option E_1 and E_2). Cibolo Reservoir is an authorized federal project, and could be developed as a stand-alone reservoir, in conjunction with Medina Lake or as a storage impoundment for the effluent from the LWCF or the City of San Antonio. A particular advantage of the Cibolo site is its strategic location between the BMWD and CRWA service areas. Thus, this source could serve both entities.

Development of Cibolo Reservoir can only be considered a long-term option due to the lengthy development process associated with a large reservoir project.

5.3.10 Wastewater Reuse

Wastewater reuse has become a popular option for reducing water supply demands. Municipal wastewater reused in the San Antonio area has been studied, and planned for by the City through the placement and construction of their new "water factories." Wastewater reuse options available to the BMWD include: reuse of wastewater generated within the BMWD service area and regionally generated wastewater or wastewater treated by SAWS (Figure 5-3, Option I). BMWD wastewater is currently collected and treated by the City of San Antonio. BMWD could modify those agreements and collect and treat their own wastewater for reuse within their service area.

5.3.11 Purchase New Supplies from Other Entities

Three potential future regional supply projects should be considered for participation by the BMWD:

- Trans-Texas Pipeline- The Trans-Texas Pipeline is envisioned as an enclosed conduit delivery system from the water rich basins of East Teas (Sabine and Neches) to Houston and then on the San Antonio and/or Corpus Christi using Lake Texana for intermediate storage and supply augmentation. The exact configuration and alignment of the pipeline is still under study. However, the project appears to be a viable option for Central Texas.

- Lindenau Reservoir- The TWBD is currently studying construction of Lindenau Reservoir in the Guadalupe Basin as a primary site. SB 1477 is likely to increase the spring fed base flow in the Guadalupe River. Lindenau is envisioned as a off-main channel scalping operation which would capture all flows in excess of those necessary for satisfaction in-stream and bay and estuary minimum flow requirement and protection of downstream water rights.

  Lindenau could function independently, or in conjunction with the Trans-Texas Project. Early estimates place the unit of water from Lindenau well in excess of $200/ac-ft. In addition, due to the long lead-time of large reservoir projects (10-15 years), Lindenau can only be considered a long-term option.

- Goliad Reservoir- Goliad Reservoir, located in the San Antonio Basin near its confluence with the Guadalupe Basin, is another project under study by the TWDB. Goliad is most likely to function as a source of supply for the City of Corpus Christi, in conjunction with the Trans-Texas pipeline. However, investigations are still in an embryonic stage.

  Again, Goliad can only be considered as a long-term option due to long major project study and permitting times.

5.3.12 Supplementary Recharge Augmentation (SRA)

Groundwater recharge enhancement or Supplementary Recharge Augmentation (SRA) has become a popular concept at both the TWDB and the TNRCC. The secret is to find relatively confined formation or a large pool underground aquifer and use it as a storage reservoir for surface water. Surface water is encouraged to recharge the aquifer, naturally or through mechanical means, with the intent to recover that resource for later use. Such storage is not subjected to typical surface reservoir losses such as evaporation. However, if the formation is not sufficiently large or confined, there can be infiltration or exfiltration which could adversely affect both the quantity and quality of recharged water.

6.0 EVALUATION OF FUTURE POTENTIAL WATER SUPPLY OPTIONS

6.1 Matrix Evaluation Techniques

Matrix methods have long served in planning as a means to reduce a large number of potential future development options to a few of the most promising options. These options are then examined in more detail. Matrix evaluation techniques attempt, in a semi-rigorous manner, to identify and assign positive or negative numerical weighting factors to each potential future development option. Those options which exhibit a positive impact, or are advantageous, are assigned a positive integer weighting factor; while those options which are either negative or disadvantageous are assigned negative factors. Summation of the positive and negative weighting factors associated with each development option will readily identify those options worthy of detailed consideration and those options which should be eliminated from further consideration. This technique reduces the option evaluation labor by eliminating those future development alternatives which are obviously infeasible, or for some other reason not advantageous or attractive. A fatal flaw analysis is, by definition, built into a matrix evaluation through application of the maximum negative weighting factor to those options which contain a fatal flaw.

6.1.1 Evaluation Criteria

Before weighting factors can be applied to each potential future BMWD and BMA supply option, a set of evaluation criteria are established and a numerical weighting scale applied to each criteria. For the purposes of this study, we have chosen to separate evaluation criteria for engineering/technical considerations from those associated with institutional/legal considerations. Examples of the BMA and BMWD water supply evaluation matrices with source options and supply evaluation weighting criteria are shown in Tables 6-1 and 6-2.

6.1.2.1 Engineering/Technical Criteria

Four engineering/technical criteria were selected for evaluation with respect to each of the potential supply options for the BMA/BMWD study area. Those criteria are: engineering feasibility, reliability of the supply, flexibility of implementation, and environmental impacts.

6.1.2.1.1 Engineering Feasibility

Engineering feasibility attempts to measure the technical reality of a potential supply option. If an option requires very little engineering to design and construct, or if the engineering associated with that option is very simple and straight forward, the project would receive a relatively high positive weighting factor. Because engineering feasibility tends to be one of the principal drivers of the supply development process, we have chosen to use a weighting factor range of -10 to +10.

6.1.2.1.2 Reliability of Supply

Second only to engineering feasibility in importance in evaluation of potential water supply projects is reliability as a source. The true measure of a supply source reliability is the Firm Annual Yield (FAY), which is that amount of water that can be diverted continuously throughout the worst drought of the period of record. Sources with a FAY less than the projected demand can still be favorably considered; however, an alternative source of supply is generally necessary to insure adequate supplies through drought periods. The evaluation criteria placed on the reliability of supply ranges from -10 to +10.

6.1.2.1.3 Flexibility

In developing future water supplies, it is desirable that they be compatible with existing supplies, treatment processes and distribution system infrastructure. Often times the flexibility of a potential supply source and its compatibility with existing treatment and distribution systems can be a limiting factor in the selection of that source. However, flexibility is far less important than either engineering feasibility or reliability of supply. Flexibility has been given an evaluation criteria ranging from -6 to +6.

6.1.2.1.4 Environmental Impacts

Environmental impacts of proposed projects can be glaring or very subtle. Large negative environmental impacts tend to be obvious. Positive impacts, however, are generally less discernible and often apparent only in a relative sense when compared to the impacts of competing options. While adverse environmental impacts can often present a fatal flaw for a particular option, most impacts can be mitigated. Therefore environmental impacts were given an evaluation range of -10 to +10.

6.1.2.2 Institutional and Legal Criteria

Institutional and legal considerations encompass those softer issues such as governmental entity interaction, contractual relationships, conformance with legal and/or regulatory requirements, and public acceptance. With the exception of strict legality, these are not issues that will generally make or break a project. However, ignoring any one of them can make completion of a project exceedingly difficult, time consuming or expensive.

6.1.2.2.1 Legal Considerations

Legal considerations that could affect a potential supply option would include requirements for legal formation of a type of political entity or subdivision prior to development of a particular supply option, legal prohibitions on development of a supply option or other regulatory restrictions. Legal considerations rarely have positive impacts on a project, and generally only negatively impact feasibility. Therefore, a range of -10 to zero is assigned to this criteria.

6.1.2.2.2 Institutional Considerations

Advantageous or disadvantageous contractual arrangements, intergovernmental agreements or regulatory agency restrictions can often make a project appear very good, or very bad. An evaluation criteria range of -8 to +8 is applied to institutional considerations.

6.1.2.2.3 Public Acceptance

Public acceptance of a project is a difficult thing to judge prior to selection of a desired alternative and exposure to public scrutiny. Public acceptance of a proposed project generally assures political support and a favorable review by regulatory entities. Strong negative public opinion surrounding a project can certainly slow a project down, rob the project of political support and in some cases, insure failure of a particular development option. Generally, in water resource development projects, however, public acceptance ranges from strong opposition to strong support. An evaluation criteria range of -8 to +8 was assigned to public acceptance.

6.2 Supply Option-Detailed Evaluation

6.2.1 BMA Future Development Option Evaluation

The future BMA water development options were introduced and briefly described in Section 5.0. Each option is discussed in detail in the following sections.

6.2.1.1 Limited or No-Action Alternative

6.2.1.1.1 Continue Existing Canal Maintenance Program

The limited or no-action alternative (i.e., continuing historical maintenance programs on the BMA main and lateral canal systems) obviously offers the lowest short-term cost alternative to the BMA. Continuing the historical maintenance program will require minimal additional short-term cost to the BMA.

The disadvantage to the continuation of historical maintenance is that in the future, the maintenance costs for the system will escalate because the canal levees will continue to deteriorate. In addition, the supply of water available from the LM/DR System for use as irrigation water or for sale to the BMWD will, in fact, diminish because as the delivery system deteriorates, losses will increase for a given rate of diversion. As losses increase in the main canal and upper portion of the lateral system due to deterioration, there will be less water available for irrigation use and maintenance of wetlands in the lower portion of the system.

6.2.1.1.2 Limited Upgrade of Canal Maintenance System

A limited upgrade of the existing BMA canal maintenance program will have a limited impact on losses sustained in the main and lateral canal system. A limited upgrade should target chronic problem areas and be used pro-actively to prevent future problems.

6.2.1.2 BMA Canal System and System Operation Improvements

6.2.1.2.1 Main Canal System Improvements

Lining the Main Canals

The main canal system operation can be improved through the continuation of the enhanced canal maintenance program, coupled with a program of lining of all channels. Lining the main canal will reduce or eliminate most normal operation losses in the 24 mile system between the Diversion Lake and Pearson Junction, the point where the BMA starts to distribute water to the lateral canal system. A loss reduction will, in effect, increase the yield of the LM/DR System because less water will be needed for BMA irrigation, leaving more water in Lake Medina available for BMWD or another beneficial use. Lining the canal will also decrease future maintenance costs because trees and vegetation growth cannot occur.

The high cost of initial canal lining construction will be offset by enhanced water availability and a reduction in future operation and maintenance costs. There may, however, be some engineering difficulties involved with lining the canals because access is difficult in some portions of the system. There will also need to be some improvements made to the inverted siphons and some of the existing overhead aqueducts.

All losses in the main canal can be eliminated by substituting enclosed pipe for the open canal. Two types of enclosed systems could be used, pressure pipe or oversized box culvert. With pressure pipe the system would function as a force main rather than a gravity system, but would require pumping. If over-sized box culverts are used, the system could remain a gravity conduit. Either option could be placed in the existing main canal which would eliminate the need for right-of-way acquisition.

Improved Maintenance on Main Canals

The continuation of BMA's improved maintenance program on the main canal system will also decrease channel losses. And, like lining the canals, improved canal maintenance will increase the LM/DR System yield by decreasing the amount of losses in the main canal system, and thereby decreasing the amount of water necessary for diversion. An improved maintenance program will, however, require addition of BMA staff members to perform the maintenance activities, and may increase the future cost of water to the BMA users. Increased maintenance costs can be offset by increased system yield and resultant water sales.

6.2.1.2.2 Lateral Canal System Improvements

Lining Lateral Canals

The improvement options applicable to the lateral canal system are similar to those identified for the main canal. The lateral canals can also be lined or enclosed. Lining or enclosing these canals would greatly reduce, or eliminate, channel losses and would increase LM/DR System yield through diminished diversion demands. Lining the lateral canals would decrease future maintenance cost. However, lining or enclosing the more than 240+ miles of lateral canals would be extremely expensive, difficult to engineer, and would add pumping costs. Some of the canals are relatively remote and undefined which compounds the problems associated with this option.

Improved Lateral Canal Maintenance

The continuation of BMA's improved canal maintenance program will also decrease channel losses and will increase the LM/DR System yield. However, a rigorous lateral canal maintenance system would require the addition of substantial BMA staff and equipment. Maintaining the old canal system may be more expensive in the future as the system grows older and continues to deteriorate.

Metering Turnouts

Metering turnouts, or individual customer use metering, would be the most cost effective of the lateral canal system improvement options. Turn-out metering would allow the compilation of accurate usage records which could be used to modify the existing BMA flat rate structure. Charging customers for the amount of water they actually use would promote conservation and may, in fact, encourage some users to develop alternative methods for crop irrigation or crop selection. Metering turn-outs would be relatively expensive because of the large number of users in the BMA service area. A large scale meter maintenance program would, also, be necessary. However, it appears that the overall advantages of turn-out metering may far outweigh the cost associated with the implementation of such a program.

Water Conservation

Conservation measures appear to be the simplest form of BMA system canal improvement. Through reduced consumption, the effective yield of Lake Medina available for sale to BMWD and other municipal users is increased. Implementation of water conservation measures is relatively inexpensive and involves education and an effective enforcement program. The enforcement program is necessary because traditionally, on a voluntary basis, there has been a low level of conservation compliance of water users and it will require a monitoring program. BMA has adopted and implemented a water conservation plan. The continued development of the plan and its enforcement should be encouraged.

6.2.1.3 Relocation of BMA Diversion Point

6.2.1.3.1 Medina Lake Diversion Point Reservoir

The BMA currently diverts all of its water from the Diversion Reservoir located just downstream from Lake Medina. The Diversion Reservoir is believed to be located directly over the Edwards Aquifer recharge zone and underlain by very pervious limestone. Estimated losses to the Edwards Aquifer from the Diversion Reservoir average 1,500 ac-ft/mo (18,000 ac-ft/yr). This water is unavailable for diversion and use by BMA, BMWD or other users. One possible option to eliminate those losses would be to change the BMA diversion point. Direct diversion from Medina Lake would reduce losses to the Edwards Aquifer from the Diversion Reservoir. A Lake Medina diversion point would require construction of pumping facilities and a pipeline from the lake to the existing BMA canal system. Such a project would be expensive; however, it would eliminate the evaporative and any ground water losses associated with the Diversion Reservoir.

Relocation of the BMA diversion point to Lake Medina would be difficult to engineer and construct because of the severe terrain. In addition, there may be some legal complications with the modified operation of the Diversion Reservoir which might, at times, become nearly dry.

6.2.1.3.2 Medina River Diversion Point

Moving the BMA diversion point to a location downstream of the Diversion Reservoir, nearer to the BMA lateral canal, and eliminating the main canal system, potentially would be a relatively low cost alternative. Implementation would require construction of diversion facilities on the Medina river and a pipeline to Pearson Junction, where the BMA lateral system splits into its various lateral canal system components. Such a diversion would, however, suffer the increased loss in yield from the LM/DR System by adding in the large losses incurred in the Medina River downstream of the Diversion Reservoir. Additionally, putting a diversion structure in the Medina River would require both the modification of BMA's certificate of adjudication from the TNRCC and a U.S. Army Corps of Engineers (USCOE) Section 404 permit, which could be a lengthy and expensive process.

6.2.1.3.3 Drill New Wells to Edwards and Recover LM/DR Recharge

Relocation of the BMA diversion point to the Edwards Aquifer for recovery of the estimated LM/DR System recharge would be a relatively inexpensive alternative to implement. This option would require development of a well field, pumping and transmission capacity and possibly some off-channel storage. Eliminating or substantially reducing diversions from the LM/DR System, however, could result in destruction of the wetlands associated with the main canal system and tailwater ponding. New wells to the Edwards could require permits from the Edwards Aquifer Authority, created by the 73rd Texas Legislature (1993). However, as a result of the development of the Department of Justice's failure to grant pre-clearance to the implementation of the EAA, the feasibility of recharge recovery appears to be limited at the present time.

6.2.1.3.4 Use Living Waters Catfish Farm Effluent

Without off-channel storage, the LWCF effluent offers a firm and consistent supply. However, the constant flow rate of 50-60 MGD may be insufficient to totally satisfy existing BMA demands during peak irrigation seasons. Thus, without off-channel storage, BMA may need to supplement supplies from other sources.

Use of the LWCF effluent would allow the elimination of the main canal losses and would obviate the otherwise need for modification of the operation of the Diversion Dam and Diversion Reservoir. It would increase the Lake Medina yield through elimination of diversions from the lake and would be relatively inexpensive, due to the close proximity of the LWCF to Pearson Junction (approximately 3.8 miles), which is the main distribution point for the A, B and D lateral canal systems. Disadvantages associated with this option are pumping costs, right-of-way acquisition, pipeline construction and maintenance requirements, potential loss of wetlands associated with the main canal system, and possible public health problems associated with the use of the untreated LWCF effluent as a food crop irrigation source.

With off-channel storage of the LWCF effluent for use by BMA, there would be a very firm consistent supply of water. Again, main canal system losses could be eliminated and the Lake Medina firm yield would be increased for municipal purposes. The main canal maintenance costs would be eliminated. However, this option would require the construction of a new reservoir, or modification of the Pearson Junction diversion point, to allow for some local off-channel storage. It may be an expensive option to implement, and construction of any sort of storage facility or impoundment, sufficient to accommodate the needs of the BMA, would require permits from the TNRCC and the USCOE.

6.2.1.4 Recommended BMA Future Development Option(s)

The relative advantages and disadvantages of the proposed BMA future development options are shown in Table 6-3. The option evaluation matrix, which attempts to apply numerical ratings to the arguments, shown in Table 6-3, is presented in Table 6-4.

Based on the matrix application, two options for improvement of the BMA system stand out.

- Implementation of a rigorous water conservation plan for all users which includes education and enforcement measures, and
- Flow metering at all turn-out and actual usage billing.

The next highest scoring option is lining the main and lateral system canals which would be considerably more expensive.

6.2.2 BMWD Future Water Supply Development Options

Future potential BMWD water development were introduced and briefly described in Section 5.0. Each of the options is discussed individually and in detail and advantages and disadvantages to each described in the following sections.

6.2.2.1 Limited/ No-Action Alternative

6.2.2.1.1 Continue on Existing Wells

If the BMWD chooses to remain on its existing wells as a sole source of water supply, in the short-term, this is a viable least-cost option available to the Board. No new construction would be required, and existing system maintenance practices would be adequate. However, continued use of existing wells as a long-term sole source alternative is not feasible for the BMWD, or other water purveyors within the planning area. This is because future populations and water demand are expected to increase markedly in the current and proposed BMWD service areas.

As a limited action alternative, the BMWD could develop some new wells, or increase the pumping capacity of existing wells. This would be a relatively inexpensive option. The LM/DR System currently recharges an estimated average of 60,000 ac-ft/yr to the Edwards Aquifer. Conceivably through non-control or enhanced recharge, the BMA and BMWD could claim that continued recharge is, in fact, an ARS project, and that the BMWD is entitled to recover water intentionally or unintentionally recharged.

6.2.2.1.2 Drill New Wells in Corrizo Sands

The BMWD could develop new well fields in the Corrizo Sands. The Corrizo Sands in South Bexar and Northern Atascosa Counties contain reasonable quantities of marginal water. Wells in northern Atascosa County, near IH-35, have been estimated to yield over 600 gpm. A well field in Northern Atascosa County could be reasonably expected to produce up to 10 MGD.

Corrizo Sand water is relatively saline (has high concentrations of chlorides, Cl^- and sulfates, $SO_4^{=}$)and in most locations has elevated sulfides (H_2S), iron (Fe) and manganese (Mn). Sulfides can be oxidized through aeration, and iron and manganese can be removed by coagulation-flocculation and precipitation. These processes are typically incorporated in the design of surface water treatment plants, which will be required to treat other option surface supplies. The salinity issue can be easily resolved by blending Corrizo water with surface or Edwards Aquifer source water prior to distribution.

To keep the cost of well field development low, the Corrizo wells could be considered in the base load to the treatment plant; obviating the need for peak demand oversizing of the wells. Peak flows could be more easily secured from the Edwards Aquifer through existing or recharge recovery wells.

6.2.2.1.3 Drill New Wells in Other Formations

Other local formations, such as shallow perched water, could yield reasonable supplies. However, shallow supplies are undependable because they are recharged from local runoff and, thus, are quickly depleted during prolonged droughts. In addition, shallow formations, because of their local runoff recharge and short hydraulic retention time, are subjected to frequent pollution.

6.2.2.2 Develop Lake Medina/Diversion Reservoir Sources

6.2.2.2.1 Lake Medina Diversion

<u>Without Pump-back of Living Waters Catfish Farm Effluent</u>

The BMWD currently has a contract with the BMA for the purchase of excess yield from Lake Medina, above that necessary to satisfy the irrigation demands of the BMA. Development of that option can include direct diversion from Medina Lake, direct diversion from the Diversion Reservoir, or diversion from either Lake Medina or the Diversion Lake with pump-back of the LWCF effluent to Lake Medina. The Lake Medina diversion option, with or without pump-back of LWCF effluent would have the effect of reducing the BMWD's dependence on the Edward's Aquifer as a sole supply. It also would increase the total water supply available to BMWD for sale in the proposed service area. The supply from Medina Lake without pump-back of LWCF effluent would, however, be relatively firm. Yield studies performed by the

Bureau of Reclamation (BuRec) and the Edwards Underground Water District (EUWD) have determined the firm annual yield of the (LM/DR) System to be between zero and 29,000 ac-ft/yr, depending on operational conditions and model application assumptions. This is less than the BMA currently diverts for irrigation use, on an annual average basis. If the BMWD intends to use Medina Lake water as a primary supply, it will require the maintenance of existing well fields as a supplemental source during prolonged drought periods. Diversion from the lake will require construction of pumping facilities on the lake and a large diameter (60 in) relatively long (140,000 ft) pipeline to deliver the water to the BMWD for treatment and distribution. The BMWD will need to construct and operate a surface water treatment plant and there will have to be a major right-of-way acquisition program.

With Pump-back of Living Waters Catfish Farm Effluent

If the effluent from the LWCF is pumped back up to Lake Medina, this would create a very firm supply of surface water from the lake. Pump-back essentially eliminates the critical period on which the original system yield estimates are predicted. The source would be sufficiently firm to allow total conversion from ground water to surface water sources for all existing BMWD customers. In addition, pumping the LWCF effluent water back up to Lake Medina would assuage local user perceptions of drinking wastewater effluent.

This option would require a second major pipeline (approximately 52 in) to transport the LWCF effluent to Lake Medina, approximately 23 miles upstream. This option would have all the same right of way problems as the Lake Medina diversion option without LWCF effluent, plus those associated with the additional pipelines and pumping costs.

6.2.2.2.2 Diversion Reservoir

Without Pump-back of Living Waters Catfish Farm Effluent

Diversions for BMWD from Diversion Reservoir could also be made with or without pump-back of LWCF effluent. Like diversion from Lake Medina, withdrawal from the Diversion Reservoir without LWCF effluent pump-back would reduce dependence on the Edwards Aquifer as a sole supply of water and would increase the total surface water supply to the BMWD. It also allows a convenient source of water for expansion of the BMWD service area on the western side of San Antonio. Again, this option is a relatively infirm supply which means the BMWD would have to maintain existing well fields for use during prolonged or severe droughts.

There is an additional problem with the BMWD taking water from the existing Diversion Reservoir. The Diversion Reservoir is relatively inaccessible from the north and west. It would be difficult for the BMWD to construct a diversion point on either side of the lake. However, it appears that the best location would be at the BMA take-out point. This would require modification of the BMA diversion structure plus an inverted siphon to get the BMWD water to the north side of the Medina River.

With Pump-back of Living Waters Catfish Farm Effluent

With pump-back of Living Waters Catfish Farm effluent to the Diversion Lake, this may, in effect, be a waste of a resource. The estimated recharge from the Diversion Lake is so high that pump-back could exacerbate or contribute to the estimated losses from the system.

6.2.2.2.3 Conditional Probability Methods for Determination of Lake Medina/Diversion Reservoir Useable yield

Model Description

Conditional Probability Analysis (CPA), as it is applied to reservoir design and operation, is a mechanism for determining a "useable yield" from a reservoir or reservoir system, that is independent of long-string historical hydrologic sequences. Traditional reservoir operations (RESOP) type firm yield analyses and models assume that the historical hydrologic sequence will reoccur in the future exactly as recorded in the past. Implicit in this assumption is that historical droughts, which define the critical period used for firm yield estimation, will occur in exactly the same sequence and with precisely the same severity and duration. This is arguably a bold assumption. But, in the absence of alternative methods, this has become the prevalent method of firm yield analyses.

In the 1950s, Australian researchers began developing a mechanism for determining the safe or useable yield from their reservoirs using methods that do not rely on long-string historical hydrologic sequences. That method is Conditional Probability Analysis. Australia's climate is dominated by frequent long-term droughts. The severity and duration of those droughts varies widely. Most reservoirs in Australia are managed on a fill-and-draw type operation. Impoundments are filled as a result of one of the relatively infrequent intense storms which produce large quantities of runoff. The users of the stored water draw on the system over the long rainless drought which usually follows. Conditional Probability Analysis has served well in the design and operation of this type of system and is particularly suited to the Medina River Basin, which is also subjected to relatively frequent droughts of varying severity and duration, and periodic large rainfall events, which can result from normal weather patterns or hurricanes.

Underlying Model Assumption

Conditional Probability Analysis does not completely alleviate the dependence on historical hydrologic sequences. Indeed, it has been demonstrated that there exists intra-year serial correlation in most hydrologic records throughout the state. Rainfall fluctuations tend to follow the same monthly patterns, with major variations in amounts, from year to year. Most records do not, however, demonstrate annual serial correlation, i.e., each year's hydrology is relatively independent of every other year's hydrology. Thus, each year of historical hydrology has the same statistical probability of occurrence as every other year. This hydrologic annual independence forms a basis for CPA.

Model Segmentation

Conditional Probability Analysis starts with a reservoir, or reservoir system, and divides the impoundment(s) into vertical segments of equal volume (Figure 6-1). In the case of the LM/DR System, the total system storage is divided into 20 vertical slices (called Zones), with each zone containing 12,700 ac-ft of available storage. Note that the zones are thicker near the bottom of the reservoir. This is because there is less horizontal area and more depth is required to contain the same volume of storage. In the case of Diversion Reservoir, water stored in Zone 1 is diverted to the BMA irrigation system without causing the Diversion Reservoir to be totally drained. Therefore, Zone 1, for present condition analysis is assumed unavailable for diversion.

Behavioral Routing

Behavioral routing includes taking all inflows to an impoundment (usually river flows), all outflows from the impoundment (usually operational releases and uncontrolled spills), plus direct rainfall and evaporation, and performing a water balance to determine a change in storage. Monthly sequential application of these procedures using the end-of-month storage from one month as the start-of-month storage for the next month is called behavioral routing.

In the case of the LM/DR System, inflows to Lake Medina come from the Medina River. Outflows from the Diversion Reservoir can result from operational releases prescribed by an established operation procedure or uncontrolled spills, which occur when inflows exceed the available storage. Direct rainfall contributions and evaporative losses are a function of the surface area of the impoundment at a particular level of storage.

Inflows to Diversion Reservoir come only from Lake Medina operational or uncontrolled releases. Outflows from the Diversion Reservoir include permitted downstream irrigation right releases, uncontrolled spills, designated BMA irrigation system diversions, and the proposed municipal and industrial diversions (from the BMWD and others).

Model Operation

As described in Section the previous sections, CPA attempts to disaggregate historical flow sequences into independent annual strings of monthly flows, each with the same probability of occurrence in any given year. In the case of the LM/DR System, historical hydrologic sequences demonstrated a serial correlation slightly greater than twelve months. Therefore, to be conservative, bi-annual hydrologic sequences were used in all CPA investigations. Starting with the first zone, Zone 1, each running bi-annual sequence of hydrodynamic data is individually behaviorally routed through the system, obeying all operational rules and constraints with withdrawals of prescribed (desired) quantities for BMWD municipal uses and BMA irrigation requirements, if any (Figure 6-2). Because the bi-annual sequences of hydrology are linearly independent, the order that the years are routed through the system is immaterial.

With each 2-year sequence of routing, two statistics are noted; first, the end-of-year storage zone (i.e., the zone in which the reservoir water surface resides at the end of the year) and second, the number of times (months) during the simulation period that the system was unable to deliver both the full requested municipal demand and required irrigation diversions. The inability of the system to supply both of these demands is called a "failure." The model algorithms assume that as much of the municipal and irrigation demands will be met as possible with available stored water. Because of daily operational uncertainties, deficits are split equally between municipal and irrigation.

The system is then moved to beginning-of-year starting Zone 2 and again each bi-annual sequence of hydrologic data is routed through the system and the end-of-year storage zone and failures are recorded. This procedure is repeated for each starting zone until a system-full condition is reached.

The sequential application of this CPA procedure produces two matrices. One matrix is an array of end-of-year storage zone frequencies as a function of start-of-year zone. The other matrix is an array of the number of failures as a function of starting zone (also shown in Figure 6-2). Each element of the Start Zone/End Zone [S/E] Matrix, $E_{a,b}$, is the number of times that the behavioral routing resulted in a particular end-of-year storage (b), as a function of start-of-year storage (a). Each element of the Failure [Failure] Matrix is the number of months during the entire period of record (POR) routed through the system that there was insufficient storage to meet both the BMWD municipal demands and BMA irrigation diversion requirements, $\mathbf{F_a}$, as a function of starting zone (a).

As constructed, the [S/E] and [Failure] matrices merely describe the response of the system to a given application number of hydrologic sequences, desired BMWD municipal demands and BMA irrigation requirements. They are of little use as a management or design tool. Dividing each of the elements of the [S/E] Matrix by the number of years routed through the system results in the probability that any given year will end in a particular storage zone as a function of each start-of-year storage zone. This new matrix is referred to as a Transition Matrix, [T]. But, this information is also only of anecdotal value. Dividing each element of the [Failure] Matrix by the number of months routed through the system yields the "probability of a failure" in any given month of any given year if that year is started in a particular storage zone. This information is of significant value as a management tool (Figure 6-3).

However, if the [T] Matrix is multiplied by itself a number of times (usually five) using matrix algebra (called powering-up), a curious thing happens, the columns of the [T] Matrix become identical. Each column of the new matrix, called the Steady-State Matrix [S], is the probability that any given year will be started in a particular storage zone. If the probability of starting any year in a particular storage zone is known and the probability of failure during any given month if a year is started in that zone is known, this information can be combined to form a valuable management tool for the system.

The arithmetic product of each of the [S] Matrix elements times each element of the [Failure] Matrix results in the conditional probability of failure (CPF) for each zone, and the sum of the conditional probabilities for each zone is the CPF for the reservoir system (Figure 6-4).

The "condition" is starting a year in a particular storage zone. The probability of that condition is derived by the [S] matrix. With each condition there is an associated probability of failure. The product of those probabilities is the conditional probability of failure associated with starting any given year in that zone.

Three curves are developed by the CPA which serve as important tools to reservoir system planners and operators. The first gives a measure of how the reservoir volume responds through time with proposed demand diversions. Figure 6-5 (an example) shows the probability of starting any year at or above a specified capacity. For the example shown, the median (50th percentile) percent capacity is approximately 65% of capacity and the system will start any given year at or above 90% full, 20% of the time.

Figure 6-6 (an example) shows the total usable system yield as a function of start of year capacity. Figure 6-7 (also an example) shows the probability of failure (failure being the inability of the system to satisfy the designated demand) as a function of start of year capacity.

Used together, Figures 6-5 through 6-7 give the system operator sufficient information necessary for tight system management. The following example illustrates the usefulness of this information:

Assume that a system manager finds their reservoir capacity at 75 % of total capacity. Then,

- from Figure 6-5, the manager knows that 40% of the time the system will start the year greater than or equal to 75% capacity;
- from Figure 6-6, the manager knows that the total usable yield for any year that starts at 75% capacity is approximately 79,000 ac-ft/yr; and
- from Figure 6-7, the manager knows that the probability of failure in the next year if they divert and use 79,000 ac-ft/yr is essentially zero.

Use of these three curves (though the above is only an example) frees the system manager from the constraints of operating under only one yield option, the firm annual yield (FAY). For the LM/DR System, the BuRec estimated the firm annual yield at approximately 27,000 ac-ft/yr. However, this yield is predicted on the sequential drought of record and includes Edwards Aquifer Recharge. All managers know that during "the good times" there is a usable yield above the FAY. What CPA gives the manager is (1) a means to quantify what the usable yield of the system is, (2) the probability of occurrence of those storage conditions and (3) the probability of failure if the usable yield is actually diverted.

6.2.2.2.4 Conditional Probability Assessment Simulation Scenarios

Four simulation cases have been developed which encompass the proposed operational scenarios for the LM/DR System, including relocation of the BMA diversion point the Lake Medina, which will eliminate use of the Diversion Reservoir, and pump-back of LWCF effluent to Lake Medina.

Simulation Case I

Simulation Case I, as depicted in Figure 6-8, assumes that the BMA continues to withdraw all of its water from the Diversion Reservoir at the rate of 35,000 ac-ft/yr; downstream water rights are satisfied by releases from the Diversion Reservoir, at the rate of 4,300 ac-ft/yr; recharge to the Edward's Aquifer from the Diversion Reservoir is a constant 1,500 ac-ft/mo (18,000 ac-ft/yr); and that the BMWD diversions will be from Lake Medina based on available supplies and probability of failure. In addition, this scenario assumes that the BMWD either does not use LWCF effluent or will directly use the effluent at the rate of 60,000 ac-ft/yr without pump-back to Medina Lake.

Simulation Case II

Simulation Case II, as shown in 6-9, assumes that the BMA diverts all of its water form the Diversion Reservoir, Edwards Aquifer recharge is maintained at 1,500 ac-ft/mo (18,000 ac-ft/yr), and the BMWD will divert water in variable quantities from Lake Medina. However, Simulation Case II assumes that 60,000 ac-ft/yr (approximately 50 MGD) of effluent from the LWCF is pumped-back to Lake Medina.

Simulation Case III

Simulation Case III, as shown in figure 6-10, assumes that the Diversion Reservoir has been eliminated as a storage impoundment, and that BMA withdrawals are taken either directly from Lake Medina or through a conduit from Medina Dam directly to the BMA diversion canal; downstream water rights are satisfied through Lake Medina direct releases which are passed directly through the Diversion Reservoir; and BMWD diversion will be variable from Lake Medina as a function of availability of stored water and the probability of failure. This scenario also assumes either no use or direct use of LWCF effluent by BMWD.

Simulation Case IV

Simulation Case IV, as shown in figure 6-11, assumes that the Diversion Reservoir has been eliminated as a storage impoundment and that BMA withdrawals are taken either directly from Lake Medina or through a conduit from Medina Dam directly to the BMA diversion canal; downstream water rights are satisfied through Lake Medina direct releases; LWCF effluent is pumped back to Lake Medina at the rate of 60,000 ac-ft/yr (approximately 50 MGD); and BMWD diversion will be variable from Lake Medina as a function of availability of stored water and the probability of failure.

6.2.2.2.5 Conditional Probability Analysis Results

The total useable yield from the LM/DR System for simulation cases I-IV varies from zero for Simulation Case I at all start-of-year capacities less than 50% to 140,000 ac-ft/yr for Simulation Case IV which moves the BMA diversion to Lake Medina and pumps back 60,000 ac-ft/yr of effluent from LWCF (Figure 6-12). The BMWD useable yield from the LM/DR System for Simulation Cases I-IV are shown in Figure 6-13. The BMWD useable yield are a maximum of approximately 100,000 ac-ft/yr. The difference between Figures 6-12 and 6-13 is that Figure 6-13 assumes that the total BMA irrigation demand is satisfied prior to any withdrawals by the BMA.

The probability of starting any year at or above a specified percent of capacity and the total usable yield and BMWD usable annual yields of that capacity for Simulation Case I are shown in Figure 6-14. The shape of the start of year probability curve indicates that there is little yield buffering capacity of the LM/DR System. As the percent of capacity increases, the probability of starting any year at or above that level drops rapidly. Accordingly, at a start-of-year capacity less than 40%, there is essentially no usable yield of the LM/DR System. The LM/DR System starts a year at or above 40% capacity approximately 76% of the time. So, in most years there is some usable yield from the system.

The BMA irrigation demand of 35,000 ac-ft/yr is not fully satisfied until the start of year capacity reaches approximately 75%, and this capacity is exceeded between 39 and 40% of the years. Thus, there is some yield from the LM/DR System available for BMWD use at least 40% of the time under conditions of Simulation Case I. The maximum total usable yield of the LM/DR System is estimated 61,000 ac-ft/yr; the BMWD maximum usable yield is 22,000 ac-ft/yr. The LM/DR System will produce approximately half of the maximum BMWD yield (11,000 ac-ft/yr) in any year which starts with Lake Medina greater than or equal to 90%; this start of year condition occurs at least 10% of the time.

Pump-back of 60,000 ac-ft/yr of LWCF effluent to Lake Medina drastically changes the shapes of both the condition and yield curves (Figure 6-15). For Simulation Case II, which differs from Case I only in the pump-back of LWCF effluent to Lake Medina, there is nearly a 100% chance that the lake will start any year at least 75% full. Pump-back also changes the total and BMWD usable annual yield curves.

Pump-back of LWCF effluent essentially eliminates the critical period upon which traditional yield analyses are predicted. In the case of the LM/DR System, the minimum total usable yield is increases from zero to nearly 30,000 ac-ft/yr and the maximum total yield increases to over 120,000 ac-ft/yr.

The BMWD usable yield for Simulation Case II varies from zero to 82,000 ac-ft/yr. The BMA irrigation demand is automatically satisfied for all years with a starting capacity of at least 15%, and it was previously stated that the minimum start year capacity is approximately 50%. This results in a revised minimum total usable yield of over 75,000 ac-ft/yr and a minimum BMWD usable yield of approximately 35,000 ac-ft/yr. So, the BMWD usable yield will vary between 35,000 and 82,000 ac-ft/yr, depending on start of year LM/DR System percent of capacity. At a start of year capacity of 75%, which is exceeded at least 85% of the time, the BMWD usable yield would be nearly 60,000 ac-ft/yr.

Moving the BMA diversion point to Lake Medina or some other mechanism for transfer from the lake to the main canal, without continued reliance on the Diversion Reservoir, adds approximately 20,000 ac-ft/yr to the maximum total and BMWD usable yields (Simulation Case III, Figure 6-16). Comparison of Simulation Cases I and II (Figures 6-14 and 6-16) indicates that the condition probability curve is also higher. This means that, not only does moving the diversion point (or the abandonment of the Diversion Reservoir) make more total and BMWD usable supplies available, it increases the frequency that they would be available. The following comparison illustrates this point:

	Simulation Case I		Simulation Case III	
Percent of Capacity	BMWD Usable Yield (ac-ft/yr)	Percent of Years Available	BMWD Usable Yield (ac-ft/yr)	Percent of Years Available
60	0	-	2,000	75
70	0	-	12,000	55
80	2,000	35	21,000	45
90	12,000	10	33,000	23
100	21,000	≈ 0	42,000	≈ 0

Thus, there is more to be gained by moving the BMA diversion point to Lake Medina than the simple recovery of the Diversion Reservoir recharge losses.

The highest total and BMWD usable yields plus the highest frequencies of occurrence were produced by Simulation Case IV (Figure 6-17). With the BMA diversion point moved to Lake Medina, plus the pump-back of 60,000 ac-ft/yr of LWCF effluent, Lake Medina rarely starts a year at less than 65% capacity. This results in an effective minimum total usable yield of 100,000 ac-ft/yr, and a BMWD usable yield of 65,000 ac-ft/yr; the maximum yield for both cases is 140,000 and 100,000 ac-ft/yr, respectively. Lake Medina will start the year at 80% capacity at least 85% of the time, and at 90% capacity at least 70% of the time. Thus, total usable yields of 100,000 ac-ft/yr and BMWD usable yields of 65,000 ac-ft/yr are relatively firm.

Based on the preceding analysis of Simulation Case I-IV results, it appears that optimum operation of the LM/DR System would be: the relocation of the BMA diversion point to Lake Medina, abandonment of the Diversion Reservoir as an impound structure and pump-back of 60,000 ac-ft/yr of the LWCF effluent to Lake Medina. However, this may not be the case.

Construction of a pipeline from the LWCF to Lake Medina will require approximately 32 miles of 56 in concrete cylinder pipe at an estimated initial cost of $28,000,000. In addition, there will be a substantial annual energy cost to pump the LWCF effluent 32 miles. The maximum firm yield for BMWD from this operation is 65,000 ac-ft/yr. However, direct use of the LWCF effluent will provide a BMWD firm yield of 60,000 ac-ft/yr (only 5,000 ac-ft/yr less than Simulation Case IV, without moving the BMA diversion point). Simulation Case II has a firm BMWD yield of 35,000 ac-ft/yr, or approximately 25,000 ac-ft/yr less than direct use of the LWCF effluent. In addition, the BMWD will not need to build or operate an additional pipeline to Lake Medina. Thus, the annual cost savings will be substantial.

6.2.2.3 Diversion of Lake Medina Releases from the Medina River Below the Diversion Reservoir

Development of the LM/DR System as a future supply option could include diversion from the Medina River below the Diversion Reservoir, at a point near the BMWD service area. The relative advantages to this option would be that it would require a short pumping distance (<20,000 ft) and does not require construction of a major diversion point and pipeline. The disadvantage is that there are well documented high channel losses below the Diversion Reservoir which would severely limit the availability of supplies during even minor drought periods. This would result in a relatively infirm yield, as the only water available for withdrawal would be run of the river water. Again, this option would require construction of a surface water treatment plant in accordance with the standards and requirements of the Texas Natural Resources and Conservation Commission.

6.2.2.4 Medina/ Applewhite Reservoir Combination

Construction and operation of Applewhite Reservoir in conjunction with LM/DR System would allow recapture of Lake Medina uncontrolled flood spills and some under flows which escape from the Diversion Reservoir dam and resurfaces downstream in the Medina River. This could increase the availability of water for BMWD. It would also allow a system operation of the Lake Medina/Applewhite System, which would result in maximum utilization of a resource. Construction of Applewhite would allow development of a convenient take-out point and would require short pumping distances to the BMWD service area.

The BMWD would, however, have to purchase or lease the existing permit from the City of San Antonio and it would require completion of the relatively expensive Applewhite Reservoir dam and impoundment facilities. In addition, there is the possibility of significant public opposition to this project. The project was narrowly defeated by the electorate in the City of San Antonio. This option would require construction of a surface water treatment plant.

Applewhite Reservoir may be revived as part of the Trans-Texas Project or as terminal storage for either the Lindenau or Goliad Reservoir Projects. In either case, it would be unavailable for use by the BMWD. The City of San Antonio would also benefit through capture of intervening runoff between Lake Medina and Applewhite.

6.2.2.5 Medina/Cibolo Reservoir Combination

Cibolo Reservoir is a federally authorized but unconstructed reservoir project located on the Cibolo Creek in the San Antonio River Basin east of the City of San Antonio. Cibolo Reservoir could be constructed and operated independently as a surface water supply for the BMWD or in conjunction with the LM/DR System. If operated independently, Cibolo Reservoir would be a relatively low yield project. However, if operated in conjunction with the LM/DR System, flood flows which pass through Medina Lake, plus flows from the San Antonio River could be pumped to Cibolo Reservoir where they would join natural inflows to the impoundments from Cibolo Creek. This flood flow scalping operation would result in a higher yield than either Lake Medina or Cibolo Reservoir operated individually. Because of its location, Cibolo Reservoir could serve as a future supply for both the BMWD and the CRWA which would enhance the regional nature of the option. This project, however, is not on the current TWDB list of priority projects; and therefore, could draw some opposition from the TWDB during the permitting process. There may also be some public opposition to the development of Cibolo Reservoir as it would be a significant impoundment, which would require the taking and inundation of a large area of currently private land. Permits must also be obtained from the USCOE which will require preparation of a formal Environmental Impact Statement (EIS).

6.2.2.6 Development of New Wells Into the Edwards Aquifer

Production of new wells within the BMWD existing or proposed service area to the Edwards Aquifer is a relatively inexpensive option. This option would be totally compatible with the existing BMWD distribution system and does not require the construction of a surface water treatment plant.

The 73rd Texas Legislature (1993) passed SB 1477 which, in part, provided for the recovery of water recharged to the Edward Aquifer. The entity which builds or maintains a recharge structure can apply to the EAA for a permit to recover recharged water. Recovery is limited to the amount of actual recharge and must be completed in the subsequent twelve months.

The LM/DR System recharges an average 60,000 ac-ft/yr to the Edwards; approximately 40,000 ac-ft/yr from Lake Medina and 20,000 ac-ft/yr from the Diversion Reservoir. During severe droughts the LM/DR System recharge approaches zero; when full, the LM/DR system can recharge up to 80,000 ac-ft/yr.

The BMA has a TNRCC permit to divert and use up to 66,000 ac-ft/yr from the LM/DR System. Approximately 35,000 ac-ft/yr is currently diverted and used by the BMA; an additional 9,000-10,000 ac-ft/yr could be diverted from Lake Medina by the BMWD during most years (the range is from zero to 22,000 ac-ft, depending on start-of-year storage). Thus, there is approximately 22,000-24,000 ac-ft/yr (approximately 22 MGD) of Edwards Aquifer recharge available for recovery by the BMWD within the limits of the existing permit. The remainder of the LM/DR system may be available for recovery under SB 1477; however, this will be subject to interpretation by the EAA, and is conditioned on implementation of SB 1477.

For planning purposes, it can be assumed that approximately 25,000 ac-ft/yr (22 MGD) of LM/DR System recharge is available for recovery by the BMA or BMWD.

6.2.2.7 Direct use of Living Waters Catfish Farm Effluent

Direct use of the Living Waters Catfish Farm effluent as a water supply for the BMWD could be developed two ways, (1) without off-channel storage, and (2) with off-channel storage.

6.2.2.7.1 Without Off-channel Storage

Without off-channel storage, effluent from the LWCF could be pumped directly across the San Antonio River to the BMWD service area. Direct use of the effluent from the catfish farm would allow a major reduction in dependence of the BMWD on the Edwards Aquifer as a sole source. The yield from the LWCF would be a relatively firm 50 to 60 MGD, and its proximity to the BMWD service area would require only a short pumping distance. This option would be relatively flexible in that the location of the treatment plant distribution hub could be located at any number of locations.

Use of the LWCF effluent would require additional water treatment plant unit process to handle the effluent. The plant could be either biological or physio-chemical, and would be a two-step process. The first step would be to treat the wastewater; the second step would involve "polishing" the water to state and federal drinking water standards.

There may be, however, significant public opposition to this option from BMWD's users. There may be a large negative perception of using wastewater effluent as a drinking water source.

6.2.2.7.2 With Off-channel Storage

Use of the LWCF effluent with off-channel storage would have all of the same advantages as direct use without storage, in that it would give the BMWD a very firm yield of 50-60 MGD. However, off-channel storage would require TNRCC and USCOE permits, and would necessitate the purchase or condemnation of significant amounts of privately held land. An off-channel reservoir would increase the yield, however, such an off-channel reservoir could be used in conjunction with a scalping operation which takes flows from the San Antonio River below the Diversion Reservoir and diverts them to the off-channel storage reservoir.

6.2.2.8 Purchase (or Lease) and Conversion of BMA Irrigation Rights

The BMWD or other water providers in South Bexar county have the option to purchase or lease and convert irrigation waters rights to municipal uses. In the case of the BMA and BMWD these purchases/leases and conversions would obviate the necessity to improve and or maintain the BMA canal system or move its diversion point to Lake Medina. It would allow the BMWD to develop a relatively firm yield of 35, 000 ac-ft/yr from the LM/DR system; plus, additional yield which could be developed during periods of higher inflow. This option would require TNRCC approval. The demand distribution of agricultural uses is limited to the summer irrigation season, while municipal demands tend to be more evenly distributed throughout the year. However, purchase/lease and conversion of BMA rights would have a significant negative impact on the perpetual wetlands which dot the BMA service area, as a result of tail water ponding. If the BMA and BMWD negotiate an action which severely reduces irrigation in South Bexar and Northern Atascosa Counties, the US Fish and Wildlife Service and/or USCOE are likely to force on Environmental Impact Assessment (EIA) or EIS. The goal of the BMWD, in developing the LM//DR System, is the reduced dependence on the Edward Aquifer as a sole source of supply. The USFWS encourages this activity because it will ultimately have a positive impact on future flows at Comal and San Marcos Springs. However, diversion of BMA irrigation water for BMWD municipal use would eliminate the BMA canal system and adversely impact the numerous perpetual wetlands which have developed from tail water ponds. Arguments can be made that the wetlands impact could be mitigated; however, mitigation is expensive. The BMWD has been willing to accept the higher costs associated with surface waters supplies, such as supply purchase, relatively long pumping distances and surface water treatment plant requirements. However, the addition of mitigation cost may simply make the LM/DR System costs too expensive. This could create an interesting dilemma which may need to be ultimately resolved in the courts. However, these rights are not presently being marketed for sale or lease. Even in the future, there may be opposition from some of the BMA members to the sale or lease of their irrigation rights, additionally, such purchases/leases would be relatively expensive.

6.2.2.9 Wastewater Reuse

6.2.2.9.1 BMWD Service Area Wastewater

The reuse of municipal and industrial wastewater effluent is currently being encouraged by the TNRCC, TWDB, TNRCC, TML, and other entities. Wastewater reuse is a logical step in the minimization of new source requirements and is considered pivotal to prudent water planning. Successful reuse projects have matched effluent water quality with secondary user water quality requirements. Generally speaking, wastewater treatment plant effluent is not a good source for development of a potable supply. However, wastewater use can be applied to a number of activities which do not require a potable supply such as cooling water for hydroelectric power plants, industrial processes, crop irrigation, landscaping, servicing car washes, and other such activities.

The BMWD currently contracts with the City of San Antonio to treat and dispose of its wastewater. A recycling program within the BMWD service area would require abrogation of that agreement with SAWS. Local wastewater reuse would eliminate the cost of treatment by the City of San Antonio, would reduce the raw water demands for non-potable purposes within the BMWD service area, and would be a relatively firm supply. However, to utilize this resource the BMWD would have to construct and operate its own wastewater treatment plant or reuses factory, and construct a gray water distribution system, separate from their potable water distribution system, to transport the treated wastewater to potential users. Potential users of this wastewater would be large scale irrigators or water intensive industries; neither of which are currently available in south Bexar County.

There may be some public opposition within the BMWD to the perceived use of wastewater for possible contact activities, and there may be institutional and legal problems associated with dissolution of the BMWD/SAWS agreement.

6.2.2.9.2 Regional Wastewater

A second wastewater reuse option is on the regional level. The advantages of a regional wastewater reuse are a larger pool of wastewater generators to draw from, and the supply is considerably more consistent or firm. An additional advantage is that the pool of potential gray water users is also increased.

The disadvantages of such a program are (1) a regional collection system must be constructed, (2) the BMWD would have to construct a water/wastewater treatment facility prior to introduction of this water into a gray water system and (3) the wastewater of other entities would need to be purchased or secured by agreements.

6.2.2.10 Purchase Water From Other Entities

The most obvious entities which may have water available for sale to the BMWD are SAWS, the CRWA, the proposed Lindenau or Goliad Reservoirs, or the Trans-Texas Pipeline Project. The purchase of water from the City of San Antonio obviates the development of other supply options for the BMWD and eliminates the necessity for construction of pipelines and treatment facilities. However, purchase of water from the City of San Antonio would insure continued reliance on the Edwards Aquifer as a principal source for the BMWD users. It would not allow the BMWD to operate as an independent system, but would rather as an appendage of SAWS. This could result in opposition from the residents of South Bexar County who depend on the BMWD for high quality, low cost water. In addition, the City of San Antonio may be precluded from adding new large scale users to their current system because of their single source reliance on the Edwards Aquifer.

There may be other entities in the South Bexar County which would be willing to sell water to the BMWD; however, most of those entities do not have an independent supply and, thus, their supplies are less than firm.

The CRWA purchases its supplies from the GBRA. Increased supplies may be available from Canyon Reservoir because of increased spring flows resulting from implementation of SB 1477. Those flows may be available to CRWA for diversion to BMWD. However, the issue of interbasin transfer may need to be resolved.

6.2.2.11 Aquifer Recharge Supplementation (ARS)

Aquifer Recharge Supplementation is currently being encouraged by the TNRCC, TWDB, and EUWD. ARS is essentially a form of water-banking. Through constructed or natural recharge structures surface water from natural runoff is allowed to or encouraged to recharge to natural formations where it is stored for later recovery. The major advantage of ARS, or water-banking, is that recharged waters are not subjected to the typically high evaporation and groundwater losses which plague surface reservoirs. However, there are losses in the ground water system if the formation recharged is not totally confined. In addition, there is a possibility of contamination of recharged water from a lower quality formation, and total recovery of recharged water may not be feasible. The recharging entity must essentially control all of the surface area above the formation being recharged or other water purveyors can drill into the same formation and essentially recover your deposits into the water bank.

6.2.2.12 Inter-aquifer Transfer

Inter-aquifer transfer is essentially encouragement of the blending of water from one formation with the water of another formation. Inter-aquifer transfer is typically used to increase the firm supply in a lower recharge aquifer. However, such inter-aquifer transfers can be dangerous in that groundwater formations may not be compatible, which could result in serious deterioration of water quality.

6.2.2.13 Recommended BMWD Future Supply Development Options

The relative advantages and disadvantages of the thirteen future BMWD water supply development options evaluated are summarized Table 6-5. That table was used, in part, to develop weighting factors shown in Table 6-6. The matrix analysis indicates that the following are the best options for the BMWD:

- Continue to use existing well to satisfy as much of the existing and future demand as possible,
- Use current excess capacity in existing wells to recover LM/DR Edwards Aquifer Recharge;
- Direct or indirect use of the LWCF effluent;
- Develop new well into the Corrizo Sands; and
- Develop to the maximum extent practicable, the LM/DR System with and without pump-back of LWCF effluent, including consideration of moving the BMA diversion point to Lake Medina, and purchase/lease and conversion of the BMA irrigation rights;

6.3 Phased Development Options

Currently, BMWD supplies are adequate to meet demands. However, the combination of increased projected demand and possible reductions in maximum allowable pumping rates as proscribed by SB 1477, will quickly render current supplies inadequate. Figure 6-18 shows projected future study area water demands; current supplies, adjusted for possible pumpage restrictions, and total study area deficit. It is clear that by 2005, the deficit could approach 50 MGD. Thus, all short-term supply alternatives must be readily and nearly immediately implementable. Comparison of projected demands with the quantities of water available from the most promising future supply options, shows that no single option will be sufficient to satisfy the projected study area demands (Figure 6-19). As an individual option, recovery of

LM/DR Edwards Aquifer recharge through existing excess well capacity appears to create the least deficit. In addition, this option could be implemented nearly immediately. The second largest impact comes from direct use of the LWCF effluent; which is also implementable in the near-term.

Coupling existing Edwards Aquifer well supplies with one other option shows similar results (Figure 6-20). Recovery of LM/DR System recharge in conjunction with continued use of existing Edwards Aquifer supplies offers the best short-term alternative; followed closely by direct use of LWCF effluent. Recharge recovery does not, however require construction and operation of a treatment facility.

Coupling the existing supplies with a 10 MGD well field drilled into the Corrizo Sands and then looking for the most effective next alternative shows that even with total utilization of the LM/DR System yield (limited to the permitted yield of 66,000 ac-ft/yr without LWCF pump-back) still results in a 2040 deficit of nearly 35 MGD (Figure 6-21). However, coupling the existing supplies with direct use of the LWCF effluent plus total utilization of the LM/DR System yield of 66,000 ac-ft/yr will be sufficient to satisfy total system demands through 2040 (Figure 6-22).

Figure 6-23 lists the future study area supply alternative combinations available to the BMWD and the year to which that supply alternative combination is sufficient to meet study area needs. Only use of current supplies plus direct use of LWCF effluent and full development of the LM/DR System permitted yield is sufficient to meet year 2040 demands.

Seven phased development options were selected for additional analysis and cost evaluation. Three of the options assume that direct use of the LWCF effluent is <u>not</u> a viable option, and three options assume that direct use is an option. The last alternative assumes that the LWCF effluent is pumped to Lake Medina for storage and recovery by the BMWD. Each phased development option is described in detail in Tables 6-7 through 6-9, and the ability of each phase development option to satisfy future projected demand is demonstrated in Figure 6-24 through 6-30.

Options 1-3, which do not assume any use of LWCF effluent, all begin with the continued use of existing wells and recovery of LM/DR recharge. They then vary with the development of other alternatives and treatment plant size and upgrade scheduling. All three options assume that in year 2025, the BMWD will need to purchase additional supplies from Lindenau, Goliad or the Trans-Texas project.

Options 4-6, which all assume direct use of LWCF effluent, do not require purchase of additional sources.

7.0 COST EVALUATION OF SELECTED OPTIONS

7.1 Supply Options

7.1.1 Short-term Options

In the near term, there are two principle options the will ensure adequate supplies of water for the BMWD, other users in the study area and the military bases in and around San Antonio: (1) continue use of existing Edwards Aquifer wells as a principle source of supply and (2) use existing excess well capacity of the BMWD and local Air Force bases to recover Edwards Aquifer recharge from the Lake Medina/Diversion Reservoir (LM/DR) System, assuming SB 1477 is implemented.

7.1.1.1 Continued Use of Existing Edwards Aquifer Wells

Under SB 1477, passed during the 1993 Legislative Session but not yet implemented, the BMWD will be required to apply to the newly created Edwards Aquifer Authority (EAA) for a permit to withdraw, for beneficial use, water from the Edwards Aquifer. There will be costs associated with the permit application process (both administrative and legal); however, those costs are anticipated to be minuscule, when compared with the costs associated with development of alternative water supplies.

7.1.1.2 Use Existing Excess Well Capacity to Recover Edwards Aquifer Recharge

Use of existing excess well capacity of the BMWD (approximately 37 MGD) and local Air Force Bases (approximately 24 MGD) to recover Edwards Aquifer recharge from the LM/DR System will also require acquisition of a permit from the EAA (Table 7-1). As the demand in the BMWD Study Area increase, the capacity of some wells may need to be expanded. In addition, peak demand and fire protection storage requirements may also be necessary. However, these system upgrades and expansions would be a normal part of the future BMWD operating expenses, independent of water source, and are, therefore, not specifically considered in this study.

7.1.2 Long-term Options

7.1.2.1 Types of Cost Analyses

The phased future water supply development options described in Section 6.0 were subjected to a rigorous cost analysis and evaluation. The following costs were developed for each option.

- Present Worth of each option, including:
  - well field development costs (if any)
  - lake or river raw water diversion structure (if any)
  - pump stations

- raw water transmission lines
- water treatment plants, including the following components:

  raw water meter vault
  rapid mix basin(s)
  flocculation basin(s)
  sedimentation basin(s)
  filters
  chemical feed facilities
  administration and maintenance building
  wash water recovery tank(s)
  clearwell
  yard piping
  site work
  sludge handling
  electrical equipment
  miscellaneous

- operation costs, including the following components:

  raw water pumping electrical costs
  treatment process electrical costs
  chemical costs

- Unit Cost of water production of each option ($/1,000 gal)

7.1.2.2 Cost Evaluation Assumptions

7.1.2.2.1 Wells Developed into the Corrizo Sands

The following assumptions were used in the development of present worth costs for development of wells into the Corrizo Sands, exclusive of pump station and raw water pipeline costs, which were computed separately.

- Average Day Demand - The average day demand was assumed at a maximum 10 MGD for the entire field. Due to the relatively long potential pumping distances (≥ 100,000 ft), it was assumed that the Corrizo system wells would be used to form part of the base load for the treatment facilities. Thus, the average day demand equals the maximum day demand.
- Well Capacity Required - Based upon the Texas Health Department requirement of 0.6 gallons per minute per connection.
- Number of Existing Wells - None
- Number of Wells Required - This was calculated as the Well Capacity Required divided by an average well yield of 0.54 MGD/well (600 gpm pumping rate).
- Number of Wells to be Developed - This value is equal to the Number of Wells Required less Number of Existing Wells.
- Estimated Well Level - Water level elevations shown were taken from Wind's Water Works' TDH Sanitary Survey and personal communications with local well drillers.
- Pumping Head - This was calculated using an estimated land surface elevation of 100 feet and the Estimated Well Level.

- Annual Electricity Consumption - Calculated value based upon the Average Day Demand and Pumping Head.

- Annual Electric Cost - Calculated based upon Annual Electricity Consumption and electrical unit cost of $0.07/kw-hr.

- Capital Cost for New Wells Required - The Capital Cost for New Wells uses the number of wells required and a unit cost per well of $650,000.

- Annual Cost of New Wells - It is assumed that the wells are financed with 20-year bonds with a seven percent interest rate.

- Total Annual Operating and Capital Cost - This value is the sum of the electrical, chlorine dioxide, phosphate, chlorine and new well annual costs.

- Water Production Cost - This value is the Total Annual Operating and Capital Cost divided by the Annual Demand (based upon Average Day Demand).

7.1.2.2.2 Water Treatment Plants

The following assumptions were used to estimate the construction and operation costs of water treatment facilities capable of treating surface water, Corrizo Sands well water and effluent from the Living Water Catfish Farm.

- Average Day Demand - The average day demand is assumed to be the total study area average day demand minus that portion of the demand currently served by existing well and that portion of the future demand that is likely to be served by additional Edwards Aquifer recharge recovery.

- Treatment Plant Capacity Required - This value is based upon Texas Health Department requirement of 0.6 gallons per minute per connection.

- Treatment Plant Capacity Provided - The initial treatment capacity required varies according to the phased development option constraints. Subsequent capacity expansions are in logical units.

- Capital Cost of Initial Treatment Plant - This cost includes the cost of a new treatment plant as shown in Tables 7-2 through 7-4, the cost of a raw water pump station and transmission main as shown in Table 7-5

- Annual Cost of Initial Treatment Plant - This value is the financing cost of the treatment plant and related improvements, assuming they are financed over 20 years at an interest rate of seven percent.

- Capital Cost of Treatment Plant Expansion(s) - Assumed at 85% of initial cost, pro-rated on expansion capacity.

- Annual Cost Treatment Plant Expansion(s) - Financing cost for the treatment plant expansion(s), assuming a 20-year term and a seven percent interest rate.

- Annual Raw Water Pumping Electrical Consumption - This value is calculated based on Average Day Demand and a pumping head of 50 feet.

- Annual Raw Water Pumping Electric Cost - This cost is computed using the Annual Raw Water Pumping Electrical Consumption and a -unit cost of $56/ac-ft.

- Annual Electric Cost for Treatment This value is computed using the Annual Electrical Consumption for Treatment and a unit cost for electricity of $0.07/kw-hr.
- Annual Coagulant Aid Consumption - It is assumed that alum is added as a coagulant to assist in the removal of turbidity from the surface waters. The amount consumed is based on the Average Day Demand and an alum feed rate of 15 mg/L.
- Annual Coagulant Aid Cost - This value is computed based on the Annual Coagulant Aid Consumption and a unit cost for alum of $200/ton.
- Annual Chlorine Consumption - It is assumed that chlorine would be added as the final disinfectant. The amount consumed is calculated based upon the Average Day Demand and a chlorine feed rate of 2 mg/L.
- Annual Chlorine Cost - This value is computed based upon the Annual Chlorine Consumption and a unit cost for phosphate of $1.83/pound.
- Annual Phosphate Consumption - It is assumed that phosphate would be added to stabilize the treated surface water. The amount consumed is based upon the Average Day Demand and a feed rate of 2 mg/L.
- Annual Phosphate Cost - This value is calculated based upon Annual Phosphate Consumption and a unit cost for phosphates of $1.83/pound.
- Total Annual Operating and Capital Cost - This number is the sum of electrical costs for pumping and treatment, cost for alum, chlorine and phosphates, and financing costs for an initial water treatment plant and expansion(s).
- Water Production Cost - This value is the Total Annual Operating and Capital Cost divided by the Annual Demand (based on the Average Day Demand).

7.1.2.3 Estimated Cost of Wells Drilled into Corrizo Sands

The estimated costs of wells drilled into the Corrizo sands in support of phased development Options 1 through 6 are shown in Tables 7-6 through 7-10. The wells associated with those options would be developed in approximately year 2000 and would thus have a relatively high present worth, $10,600,000. Well costs for phased development Option 2 would not begin until approximately 2015. The present worth of that option would be only $3,710,000. Phased development Options 4 and 5 do not schedule development of Corrizo Sand wells until at least year 2025. Thus, the present worth option costs are $1,560,000 and $633,000, respectively. Option 5 does not begin well development until 2040, which only covers one year of operation. Comparative estimates assume the same present worth as Option 4. The present worth of Option 6 is $5,300,000.

7.1.2.4 Estimated Cost of Surface Water and Corrizo Sands Groundwater Treatment Facilities

The present worth and unit production costs of water treatment for phased development Options 1 - 7 are shown in Table 7-11 through 7-17 and are summarized in Table 7-18. Direct comparison of the present worth of the proposed phased development options (Figure 7-1) indicates that Options 1 and 5 have the lowest present worth (Option 1 at approximately $107,703,000 and Option 5 at approximately $108,369,000). However, comparison of unit production cost of water (Figure 7-2) shows that, with the exception of the first year, Option 5 is less than Option 1. The average production rate of Option 1 is $1.66/1,000 gal while the production rate of Option 5 is only $1.33/1,000 gal (Figure 7-3). Direct comparison of Options 1 and 5 shows that production costs are consistently lower for Option 5 (Figure 7-4).

8.0 INSTITUTIONAL, LEGAL AND FINANCIAL CONSIDERATIONS

This section will catalog institutional, legal, financial, and permit requirements of the various water supply options available to the BMWD and the other water entities of the South Bexar County study area. The chapter is summarized in Table 8-1.

8.1 Continue on Existing Wells

Continued use of existing Edwards Aquifer wells is the simplest alternative from the standpoint of institutional, legal and financial considerations. Existing entities would continue to supply their customers with water from either existing or new wells. No new entities need be created, nor do inter-local agreements have to be executed.

The biggest constraint to the continuation of existing wells is the pumping limitations imposed by SB 1477 passed by the recent 73rd regular session of the Texas Legislature (1993). At the present time the U.S. Department of Justice has refused to "pre-clear" the creation of the new Edwards Aquifer Authority (EAA) under the Voting Rights Act. The effect of this action is to effectively stop implementation of SB 1477 at the present time. This report examines the substantive provisions of SB 1477, because they reflect the current political consensus regarding regulation of the Edwards Aquifer. As such, the substantive provisions of SB 1477 indicate the type, manner and levels of restrictions likely to be adopted by any new authority in the near future. As noted in the introduction of this report, every effort has been made to make this report as up to date as possible. Events regarding regulation of the Edwards are fast moving and may have overtaken the printing of this document.

SB 1477 imposes pumping limits on the Edward Aquifer users. The bill creates a new Edwards Aquifer Authority (EAA or Authority) and dictates that from September 1, 1993 until December 31, 2007 the Authority is responsible for reducing water pumped from the Edwards Aquifer to a maximum of 450,000 ac-ft/yr. After January 1, 2008, the Authority must limit pumping to 400,000 ac-ft/yr. The BMWD cannot rely on wells drilled between the present time and September 1, 1993 because the legislation provides that the EAA may not allow withdrawals from the aquifer to wells drilled after June 1, 1993, unless additional hydrological studies show that the maximum aquifer limits can be increased. Permits for amounts above the stated pumping limits will be on an interuptable basis only. Water purveyors using the Edwards Aquifer as the source of drinking water must apply for an initial regular permit by March 1, 1994. This is done by filing a declaration of historical use of underground water withdrawn from the aquifer during the period from June 1, 1970 through May 1, 1993. To the extent that water is available, the authority shall issue the existing user a permit for withdrawal of the amount of water equal to the user's maximum beneficial use of water, without waste, during any one calendar year of the historical period. If water is not available, the authority shall adjust the amount of water authorized by the user proportionally to meet the amount available for permitting. Since the water utilities in the San Antonio area are currently drawing more than 450,000 ac-ft/yr, it should be anticipated that all users will be proportionally limited on their withdrawals from the Edwards Aquifer to meet the pumping limits of the bill.

8.1.2 New Wells to the Edwards Aquifer

The legal constraint on drilling new wells to the Edwards Aquifer is the same as that for continuation of existing wells. The EAA will regulate pumping and withdrawals from the Edwards Aquifer. A pumping permit will be required from the EAA. If the Authority issues such a permit for a new well, it should be anticipated that the pumping will only be permitted when the aquifer has a large amount of water available. Because of the pumping limits, it should be anticipated that lenders, either the private bond market or the TWDB, will hesitate to issue revenue bonds to water districts for new wells to the Edwards Aquifer.

8.1.3 New Wells to the Carrizo Sands

New wells to the Carrizo Sands do not carry the legal constraints that new wells to the Edwards Aquifer do. SB 1477 was clearly limited to the Edwards Aquifer. While all of Bexar County is included in and subject to the jurisdiction of the EAA, under SB 1477, the Authority is only given the power to regulate the Edwards Aquifer. New wells to the Carrizo Sands would require land acquisition at the well head and possible acquisition of some right-of-way. Environmental assessments would be needed to determine if there were any environmental constraints or permits necessary. In addition, there are currently no restrictions on other users against tapping the same formation; provided that their cone(s) of depression do not infringe on the BMWD's ability to pump.

8.1.4 New Wells to Other Formations

The option of drilling new wells to other local formations has the same constraints and considerations as the option of new wells to the Carrizo Sands.

8.2 Medina River Sources

8.2.1 Medina River Surface Water Source From Medina Lake Without Living Waters Catfish Farm

The business arrangement between the BMA and BMWD, for the use of Medina Lake, could be handled between the various water entities by inter-local agreements, a form of contract. Another option is for one of the entities to finance and build the pipeline and become the wholesale supplier of water to the other entities.

This option would require conversion of the existing TNRCC irrigation right to a municipal right plus application for additional rights. This permit could either be for an appropriative right subject to water necessary for any downstream users, or it could be a change in the diversion point for existing surface water rights holders. In either case, the permitting agency is the TNRCC. If the water rights permit is for over 66,000 ac-ft, the permit will be a conditional permit for yields from the Medina Lake above 66,000 ac-ft/yr. An environmental impact assessment for the land to be acquired as right-of-way may also be necessary.

This option results in a relatively small amount of water for the cost. The water that is available will be on an interuptible basis. The interruptable nature of the water source means that the water entities will not be able to rely on this water all the time.

8.2.2 Medina River Surface Water From Medina Lake With Living Waters Catfish Farm

The BMWD have a couple of options on how to arrange for the purchase of LWCF. The entities could simply purchase the wastewater from the LWCF: the BMWD may choose to purchase the permitted well at the LWCF and use the water directly from the well or they might choose to purchase the LWCF, lease the farm back to the operator, and use the wastewater. These are options that the BMWD or other water entities will have to decide should they choose to use LWCF as a source of drinking water. If this option is pursued, they will have to negotiate the purchase or lease of the catfish farm.

An environmental assessment may have to be performed for the transmission line right-of-way to move water between the LWCF and Lake Medina. This option would also require an amendment to the discharge permit from the TNRCC. The water supply would have to comply with the standards of the Safe Drinking Water Act regarding potability of the water.

8.2.3 Medina River Surface Water From Diversion Lake Without Living Waters Catfish Farm

A BMWD withdrawal form the Diversion Lake would require some acquisition of right-of-way. An environmental assessment on the right-of-way property may have to be performed to determine what impact or permits are necessary. If the total BMA plus BMWD diversion exceeds 66,000 ac-ft/yr it would require a TNRCC Water Rights Permit. As with other options involving new water from the Medina River, the interuptible nature of the water supply adds risk to the transaction that could result in a slightly higher interest rate from a lender.

8.2.4 Medina River Surface Water From Diversion Lake With Living Waters Catfish Farm

As with the use of the LWCF water into Lake Medina, the entities would have a decision to make as to how they wish to acquire the LWCF. Their options include purchasing the wastewater, purchasing the permitted well, or purchasing the catfish farm and leasing it back to the catfish operator. The required permits are similar to those associated with the Medina River surface water from Lake Medina with LWCF.

8.3 Medina River Surface Water Below Diversion Lake

This option would not require any changes to the existing water entities. It would require only minimal right-of-way acquisition. If the total BMA plus BMWD diversion exceeds 66,000 ac-ft/yr a water rights permit would be required from the TNRCC. Otherwise it would require consent from the TNRCC to move the diversion point. In either case, the TNRCC would need to upgrade that portion of the supply from the agricultural use category to municipal. An environmental impact assessment on the right-of-way property would be required.

8.4 Medina River/Applewhite Reservoir Combination

The entities have several options on how to arrange the business aspects of a potential Lake Medina/Applewhite water source. San Antonio Water System (SAWS) could (1) build Applewhite Reservoir and BMWD would lease storage capacity in the reservoir, (2) BMWD could buy raw water from Applewhite Reservoir and SAWS, or (3) BMWD could purchase the permit for Applewhite Reservoir and build the reservoir. If BMWD exercises the last option it would have to increase its staff and train that staff in the operation of the reservoir, a new business for BMWD. Exercising this option would require the negotiation of contracts or purchase of the Applewhite permit with the SAWS. The SAWS currently holds a TNRCC permit for Applewhite Reservoir, and SAWS has obtained the necessary environmental permits.

8.5 Lake Medina/Cibolo Reservoir Combination

A Lake Medina/Cibolo Reservoir option has the advantage that BMWD would not have to increase its staff and get into a new business with which it is unfamiliar, that of operating a reservoir. The Bureau of Reclamation is currently scheduled to operate Cibolo Reservoir when, and if, it is constructed. This option would require major land acquisition. It would require TNRCC permits for construction and diversion of water for Cibolo. Since federal money would be involved, it would require a major environmental impact study and NEPA compliance. It would also require a U.S. Army Corps of Engineers Section 404 permit.

While Cibolo Reservoir is an authorized federal project, this does not assure that federal funds will be available for construction. Federal funds would have to be budgeted and appropriated. Because of increasing pressure on the federal budget this will be increasingly difficult. To actually get hard dollars budgeted and appropriated for the construction of the Cibolo Reservoir would require a multi-year congressional lobbying effort.

8.6 Edwards Underground Aquifer-New Wells for Recharge Recovery

Assuming the implementation of SB 1477, construction of new wells to the Edwards Aquifer for recharge recovery has similar legal constraints as other supply options that rely on the Edwards Aquifer. Historical users will most likely be required to cut back their use in proportional amounts. SB 1477 does, however, provide the theoretical possibility of new wells to the Edwards Aquifer. The EAA is granted the power to issue interuptible term permits for withdrawal for a period of up to ten years. The statute provides, however, that the holder of a term permit may not draw water from the San Antonio pool unless it is above 665 ft MSL at well J-17 and the Uvalde pool unless it is above 865 ft MSL. The EAA is still charged with keeping the overall withdrawal down to a maximum of 450,000 ac-ft between September 1, 1993 and December 31, 2007 and 400,000 ac-ft thereafter. Therefore, it is extremely unlikely that substantial amounts of new withdrawals from the Edwards will be permitted in the future. Because of the pumping limitations and the interuptible nature of the water supply, this project carries more than the normal amount of risk that the benefit of the project would not be there.

SB 1477 does, however, allow for the recovery of Edwards Aquifer recharge from existing or proposed dams or recharge structures. Recharge recovery is limited to the amount actually recharged and recovery must be completed within the next twelve months.

8.7.1 LWCF Effluent Direct Use Without Off-channel Storage

Because of the controversial nature of the LWCF, even reuse of the effluent should be viewed as requiring a major permit hearing. In addition to the TNRCC permit, the U.S. Army Corps of Engineers Section 404 Permit would be necessary as well as an environmental assessment.

8.7.2 LWCF Effluent Direct Use With Off-channel Storage

This option is similar to the previous one, but it has the additional legal constraint that the off-channel storage facility would be a major land acquisition requiring more legal work for negotiation and possible condemnation action. The environmental assessment could be much more involved for this project than with the LWCF effluent without off-channel storage.

8.8 Purchase and Conversion of BMA Irrigation Rights

BMA has made it clear that it has no present interest in selling its water rights in the LM/DR System. Because of this position, this is not a feasible option at this time.

Aside from this constraint, the purchase/lease of irrigation rights by BMWD could be handled by contract with the BMA. This could either be for an outright purchase of the irrigation rights or a lease of water. The contractual release would have to be negotiated. The conversion of agricultural rights to municipal rights would necessitate a water rights hearing at the TNRCC. As Lake Medina is changed from a lake predominately to serve agricultural users to a lake that is predominately serving municipal users, the operating rules for the reservoir should be changed to optimize the use of the water. The change in the operation rules of the reservoir would require a separate hearing and approval by the TNRCC. The purchase of water rights can be financed through the TWDB.

8.9.1 Develop Cibolo Reservoir Without Living Waters Catfish Farm

Cibolo Reservoir a federal project sponsored by the Bureau of Reclamation. The Bureau of Reclamation (BuRec) would own the reservoir and be in charge of its operation. The BuRec has a long history of construction operation and maintenance of large reservoir projects. The development of the reservoir would require a major land acquisition. This would involve all the associated negotiation of contracts for purchase of land and possible condemnation actions with recalcitrant sellers. Because it is a federal project, the federal environmental NEPA process would have to be followed, as well as obtaining a USCOE 404 permit. In addition, the TNRCC would also require a permit for the reservoir.

While Cibolo Reservoir is an approved federal project, in this era of federal budget cutbacks, the federal government cannot be counted on to actually have funds available for the construction of the reservoir. This option would require a major multi-year federal lobbying effort, in an attempt to budget and appropriate federal funds for the reservoir.

8.9.2 Develop Cibolo Reservoir With Living Waters Catfish Farm

The legal, institutional and financial considerations of this option are similar to the option without the LWCF. Adding the catfish farm to the Cibolo Reservoir project would require the negotiation of the purchase of the LWCF. As with other options with the LWCF, the legal entities have the choice of either purchasing only the wastewater, purchasing the catfish farms permitted well, or purchasing the catfish farm and leasing it back to its operator. Additional right-of-way will be required.

8.10 Wastewater Reuse

Wastewater reuse would require BMWD to expand its business operations into the wastewater treatment business. The staff would have to be acquired and trained and licensed to operate wastewater treatment facilities. The legal constraints include having BMWD acquire the wastewater certificate of convenience and necessity (CCN) for the area that they intend to serve. The contract between BMWD and the SAWS to purchase the present San Antonio Water Authority wastewater treatment plants would have to be negotiated. SB 1477 requires the EAA to give credit for any wastewater reuse; (See SB 1477 Section 1.13). However, the legal effect of this section is unclear. This option would require some right-of-way acquisition. BMWD would have to obtain TNRCC and NPDES discharge permits.

8.11 Purchase Supplies From Other Entities

8.11.1 Purchase Supplies From San Antonio Water System

The business arrangement for this option would be handled by wholesale water contracts to be negotiated between the SAWS and the BMWD. The legal constraint on this option is that previously described regarding permitting and pumping limitations on the Edwards Aquifer. SAWS is currently relying on the Edwards Aquifer as a sole supply of San Antonio water. SAWS would be subject to the same limitations on pumping Edwards as previously described.

8.11.2 Purchase Supplies From Canyon Regional Water Authority

BMWD is currently part of Canyon Regional Water Authority (CRWA). Additional contracts would have to be negotiated between BMWD and CRWA. The contracts should provide for each entity to be a seller and each to be a buyer of water. When BMWD has excess water, it could sell the excess to CRWA who would then distribute it to its water short members or hold it in its reservoirs. When BMWD is short of water, it could purchase water from CRWA, if the water is available.

Since most of CRWA and its reservoirs are in a different basin than the BMWD, and inter-basin transfer permit from the TNRCC would have to be acquired. Currently the TNRCC handles its inter-basin transfer permits similar to its water rights permits. At the permit hearing, the issues that the TNRCC would consider include whether or not the transfer would impair existing water rights, particularly downstream water users. They would also be concerned as to whether or not the inter-basin transfer was the most efficient way of providing water supplies to the BMWD service area. They would also be concerned about whether BMWD was avoiding wasting of water and that they would implement a stringent water conservation plan. The TNRCC will also be concerned about any adverse environmental, social or economic impacts. This should be considered a major permit hearing.

8.11.3 Purchase Supplies From Other Entities

Most other entities in the South Bexar area are currently relying on groundwater. If purchasing supplies from another entity involved use of Edwards Aquifer water, then this option would be subject to the same legal constraints as purchasing supplies from the SAWS.

Three unconstructed projects hold some long-term potential for the BMWD study area. Lindenau and Goliad Reservoir projects are currently under study by the TWDB. Either or both of these reservoirs could be constructed in conjunction with the Trans-Texas Project; also under study by the TWDB. Some sponsors have already been identified for the Trans-Texas Project. However, there will certainly be room for future participants.

8.12 Supplemental Recharge Augmentation (SRA)

SRA is not presently a viable option in the Edwards Aquifer due to legal limitations set forth in Texas Water Code Section 11.023. However, SB 1477, if implemented, provides in Section 1.44 that a governmental entity may artificially recharge an aquifer such as the Edwards. A contract could be negotiated between the EAA and BMWD for this recharge option. This would entitle BMWD to withdraw, during any twelve month period, the amount of water actually injected into the Edwards Aquifer less any amount determined by the EAA to be attributable to discharges through springs and to compensate the authority in lieu of users fees. Subject to those two limitations, however, the amount of water that the BMWD could withdraw from the aquifer are not subject to the overall maximum total permitted withdrawals. In other words, if BMWD injects 1,000 gallons into the aquifer, they're entitled, during the next twelve month period, to take approximately 1,000 gallons out of the aquifer over and above their permitted limits. This option, as well as all others related to the Edwards Aquifer, requires a pumping permit from the EAA. Because of technological difficulties, the private bond market may view this as a particularly risky project resulting in higher interest rates. Funding is more likely from the TWDB. The TWDB has funded injection well recharge projects in the past to demonstrate that this technology is a viable option.

8.13 Inner-Aquifer Transfer

The institutional considerations for this option are extremely difficult to assess because of the great amount of regulatory uncertainty with this option. One must anticipate regulatory concern and stringent regulations by the TNRCC designed to protect the public interest. At a minimum, it should be anticipated that the TNRCC will want to protect interests similar to those expressed in inter-basin transfers of surface water. They will want to see that the applicant is avoiding wasting water and will implement water conservation. The TNRCC will want to see that this is the most feasible option for providing new water sources. They will be concerned about environmental, social and economic impacts. In addition, since this option would move water into the Edwards Aquifer, it would be subject to regulation by the EAA. The EAA might view this as artificial recharge and reduce the amount of water that can be withdrawn from the aquifer by a portion that the authority feels attributable to natural discharge, through the San Marcos and Comal Springs. We can expect major environmental concerns and permits for this option, including Parks and Wildlife and Fish and Wildlife permits. Because of these environmental concerns, it would be extremely difficult to attain federal funding for this project. Similarly, because of environmental concerns and the technological difficulties involved in the project, TWDB funding should not be relied upon. For similar reasons, the private bond market would likely assess this as a higher than average risk project and would offer higher interest rates as a consequence.

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

9.1.1 Future BMWD Water Demands

A conservative planning approach was used to predict the future populations and water demands for the BMWD, other water supply entities within the planning area, and the five military installations in the San Antonio area currently relying on the Edwards Aquifer as a principal source of supply. The Texas Water Development Board High Population/High Water Demand/With Conservation series data were used to estimate water demands through the year 2040. Those estimates assume a maximum regional population growth rate, drought condition water use rates, and implementation of strict conservation measures. Thus, those estimates represent probable maximum values.

Future water demand estimates for the planning area are shown in Figure 9-1. The year 2040 probable maximum water demand for the designated planning area is estimated at 155,000 ac-ft/yr (138 MGD). This is more than three times the current use of approximately 48,000 ac-ft/yr (43 MGD), and should be viewed as a conservative estimate.

9.1.2 Future BMWD Water Supplies

9.1.2.1 Sources and Quantities

Examination of each of the numerous alternatives, identified through the matrix analysis as significant potential future sources of water for the BMWD planning area, revealed that no single source will be sufficient to satisfy projected future demands (Figure 9-2). Phased implementation of all identified significant potential source alternatives will be necessary to satisfy the projected water demands through year 2040. If the direct use of effluent from the Living Waters Catfish Farm (LWCF) is eliminated from consideration, then another source, such as the proposed Lindenau or Goliad Reservoirs will be required. However, if the LWCF effluent is pumped back to Lake Medina, then Lindenau, Goliad or Trans-Texas Project participation would be unnecessary.

It is certain that satisfaction of future projected demands will require, at a least, some combination of (1) existing and new groundwater sources, (2) full development and use of the Lake Medina/Diversion (LM/DR) Reservoir System, (3) recovery of Edwards Aquifer recharge from the LM/DR System, (4) development of wells into the Carrizo Sands or Carrizo-Wilcox Formation and (5) either use of effluent from the LWCF or participation in the proposed Lindenau or Goliad Reservoir Projects or the Trans-Texas Pipeline.

9.1.2.2 Estimated Costs

Seven phased future development options (three of which considered direct use of the LWCF effluent as a possible source and three which did not, plus one option which considered pump-back of LWCF effluent to Lake Medina) were subjected to a rigorous cost analysis (Table 9-1). Comparison of the estimated phased development costs revealed that there were two options which compared favorably under a present worth cost analysis; one option which considered LWCF effluent (Option 5), and one which did not (Option 1) (Table 9-2). Comparison of unit production costs ($/1,000 gal) of those two options revealed that, while Option 5 has the highest estimated first year rate ($2.35/1,000 gal versus $2.04/1,000 gal), Option 5 has the lowest average rate ($1.33/1,000 gal) of any of the phased development options considered.

9.2 Recommendations

Based on the results of the matrix and cost analyses, the two recommended phased implementation options are offered for the development of future water supplies for users within the South Bexar County Region Water Supply Study Area. In addition, there is a recommendation for future research which will prove invaluable to the overall management of the Edwards Aquifer and absolutely necessary to the management of the LM/DR System if the provisions SB 1477 are implemented in any form.

9.2.1 Recommended Development Options

Option 1 which does not include use of Living Waters Catfish Farm Effluent:

- The BMWD should continue to utilize existing wells to the maximum extent practicable to satisfy existing water demands. Under 1993 Texas Senate Bill 1477, if implemented, the BMWD and other water purveyors within the study area will be required to obtain permits from the newly formed Edwards Aquifer Authority (EAA). Those permits will be issued for the highest use year of the purveyor. However, they can and will be reduced to achieve the legislatively mandated reduction from the current maximum aquifer use of 540,000 ac-ft/yr to 450,000 ac-ft/yr for the period beginning September 1, 1993 and ending December 31, 2007, and to 400,000 ac-ft/yr thereafter.

- The BMWD should immediately apply to the EAA for a permit to recover losses from the Lake Medina/Diversion Reservoir System which recharge the Edwards Aquifer. Under Senate Bill (SB) 1477, the maximum amount that can be recovered is limited to the actual amount recharged, and must be recovered within the next immediate 12 month period. The BMWD has sufficient existing well capacity to recover a significant portion of the Edwards Aquifer recharge from the LM/DR System.

- By 2000, the BMWD should begin construction of a 60 in pipeline between a diversion point on Lake Medina to the BMWD service area. Supplies pumped through the pipeline would initially consist of excess LM/DR System yield (above the 35,000 ac-ft/yr used annually by the BMA).

- Shortly after year 2000, the BMWD should pursue one of two options to procure use of the BMA irrigation water:

  - BMWD could purchase or lease the irrigation rights of BMA users, and convert those rights for municipal use. Permanent conversion of irrigation rights (TNRCC Use Priority #3) to municipal rights (TNRCC Use Priority #1) would require a TNRCC permit amendment.

  - BMWD could lease excess storage in Lake Medina for accumulation and diversion of unused irrigation rights. Again, diversion and use of Lake Medina water by the BMWD will require a TNRCC permit amendment.

  Both options will require construction of a 50 MGD surface water treatment plant and blending facilities to combine surface and groundwater prior to distribution.

- Shortly after year 2000, the BMWD should begin development of well fields in northern Atascosa County, or other suitable location, into the Carrizo Sands, or other suitable formation(s). Potential water quality problems encountered with Carrizo Formation water (hydrogen sulfide, iron, and manganese) could be easily treated in the surface water treatment process. High salinities could be controlled through selective blending of Edwards Aquifer and surface water. A pipeline of approximately 100,000 ft between the well fields and the treatment facilities will also be required.

- In approximately 2010, the surface water treatment plant should be expanded to 100 MGD to accommodate higher study area demands.

- In approximately 2030, the BMWD should begin procurement of additional surface water supplies from the proposed Lindenau or Goliad Reservoir Projects or the Trans-Texas Pipeline. At the same time the surfacewater treatment plant should be expanded to its ultimate capacity of 150 MGD.

Option 5 which does include use of Living Waters Catfish Farm Effluent:

- The BMWD should continue to utilize existing wells to the maximum extent practicable to satisfy existing water demands. Under 1993 Texas Senate Bill 1477, the BMWD and other water purveyors within the study area will be required to obtain permits from the newly formed Edwards Aquifer Authority (EAA). Those permits will be issued for the highest use year of the purveyor.

However, they can and will be reduced to achieve the mandated reduction from the current maximum aquifer use of 540,000 ac-ft/yr to 450,000 ac-ft/yr for the period beginning September 1, 1993 and ending December 31, 2007, and to 400,000 ac-ft/yr thereafter.

- The BMWD should immediately apply to the EAA for a permit to recover losses from the Lake Medina/Diversion Reservoir System which recharges the Edwards Aquifer. Under SB 1477, the maximum amount that can be recovered is limited to the actual amount recharged, and must be recovered within the next immediate 12 month period. The BMWD has sufficient existing well capacity to recover a significant portion of the Edwards Aquifer recharge from the LM/DR System.

- By 2000, the BMWD should exercise one of two options with respect to the Living Waters Catfish Farm:

  - The BMWD should purchase the Living Waters Catfish Farm from the current owner and either operate the catfish merriculture operation or lease operation of the catfish farm operation to an independent contractor.

  - The BMWD should execute a long-term contract with the Living Water Catfish Farm to purchase or lease the right to its effluent.

  Implementation of either option will require construction of an approximate 32,000 ft pipeline from the catfish farm to the BMWD treatment and distribution facilities.

- By 2000, the BMWD should begin construction of a 100 MGD wastewater/water treatment facility capable of blending treated effluent from the Living Waters Catfish Farm with groundwater from the Edwards Aquifer. The treatment plant should be base-loaded with the catfish farm water and peaked from groundwater.

- Shortly after year 2000, the BMWD should begin development of well fields in northern Atascosa County, or other suitable location, into the Carrizo Sands, or other suitable formation(s). Potential water quality problems encountered with Carrizo Formation water (hydrogen sulfide, iron, and manganese) could be easily treated in the surface water treatment process. High salinities could be controlled through selective blending of Edwards Aquifer and surface water. A pipeline of approximately 100,000 ft between the well fields and the treatment facilities will also be required.

- By 2025 the BMWD should begin construction of a 60 in pipeline between a diversion point on Lake Medina to the BMWD service area. Supplies pumped through the pipeline would initially consist of excess LM/DR System yield (above the 35,000 ac-ft/yr) used annually by the BMWD.

- Between 2025 and 2030, the BMWD should expand its LWCF/Carrizo Well/Surface Water treatment facility to its ultimate capacity of 150 MGD.

- In about 2035, the BMWD should pursue one of two options to procure use of the BMA irrigation water:

  - BMWD could purchase the irrigation rights BMA users, and convert those rights for municipal use. Permanent conversion of irrigation rights (TNRCC Use Priority #3) to municipal rights (TNRCC Use Priority #1) would require a TNRCC permit amendment.

  - BMWD could lease excess storage in Lake Medina for diversion of unused irrigation rights. Again, diversion and use of Lake Medina water by the BMWD will require a TNRCC permit amendment.

Either of the above phased development options will assure adequate supplies of water for the BMWD, other water users in the Planning Area and the military bases in the San Antonio Area. Selection of one option over the other will be a function of local preference. Both options require the development of several sources and the procurement of permits and the execution of contracts or agreements. The BMWD should commit to a course of action soon, and a critical path developed to assure the availability of additional supplies and treatment and distribution capacities as the future demand increases.

9.2.2 Recommended Future Research Options

In the event that SB 1477, or similar legislation, is enacted, there are two questions that need to be answered in order to effectively manage the Lake Medina/Diversion Reservoir System in conjunction with the Edwards Aquifer:

(1) How much water is permanently lost from the Lake Medina and the Diversion Reservoir system to the underlying formations?

(2) Are losses from the LM/DR System directly to the Edwards Aquifer or are other formations involved which either permanently or temporarily store water from either Lake Medina or the Diversion Reservoir?

A three phase study would be necessary to successfully answer the above questions. Table 9-3 is a suggested outline for the implementation of this study.

Table2-3
Recognized TWC Water Rights in the Medina River Basin, as of June 18, 1992

Ownership	Total Annual Diversion (ac-ft)	Maximum Diversion Rate (cfs)	Total Impoundment Allowed (ac-ft)	Authorized Use
J. Held	19.00	1.00		Irrigation
B. H. Gaskin	44.00	1.30		Irrigation
N. Marr	2.00	0.60		Irrigation
D. F. Mead	21.00	1.00		Irrigation
Texas Petroleum Co.	4.00	0.30		Irrigation
M. Winkenhower	27.00	0.20		Irrigation
S. C. Tracy	35.00	0.40		Irrigation
P. A. Grothues	16.00	2.20		Irrigation
M. E. Johnson	7.00	0.10		Irrigation
R. Hicks	3.00	0.22		Irrigation
Bandera Electric Coop.	2.00	0.22		Irrigation
D. F. Tobin	152.00	1.90		Irrigation
W. S. Thompson	47.50	0.56		Irrigation
J. B. Parker	16.00	0.50		Irrigation
BMA (CF No. 18)	66,750.00			Irrigation
BMA (CF No. 18)			4,500.00	Medina Div. Reservoir
BMA WID No. 1			237,874.00	Medina Lake
Total above Medina Lake	67,145.50		242,374.00	
BMA (CF No. 19)	2,000.00	22.20	730.00	Chacon Reservoir
Medina Ranch, Inc.			4,500.00	Recreation
H Tschirhart	18.00	0.10		Irrigation
M. I. Haby	50.00	3.30		Irrigation
A. C. Santleben	156.00	3.30		Irrigation
Meropolitan Resources inc.	963.00	2.20		Irrigation
Straus Medina Ranch	308.00	4.70		Irrigation
J. Spears	32.00	0.70		Irrigation
A. T. Walsh	200.00	8.00		Irrigation
C. L. Pattillo	240.00	5.00		Irrigation
City of San Antonio	294.00	7.80		Irrigation
Total Below Medina Lake	4,261.00		5,230.00	
Total River Basin	71,406.50		252,834.00	

Source: Final Determination of Claims of Water Rights in The Medina River Watershed of the San Antonio River Basin, May 23, 1978 and Texas Water Commission Report on Water Rights as of June 18, 1992

Table 2-4
San Antonio River and Tributary USGS Flow Gauging Stations

Station Name	USGS Station Number	Drainage Area (sq mi)	Period of Record
Olmos Creek at Dresden Dr	8177700	21.2	June 1968 - Sept. 1981 Oct. 1982 - Present
San Antonio River at Hildebrand Ave	8177820	34.8	Feb. 1980 - Present
San Antonio River at Loop 410	8178565	125	Oct. 1986 - Present
San Antonio River at San Antonio	8178000	41.8	Dec. 1895 - June 1906 a/ Jan. 1915 - Nov. 1929 Feb. 1939 - Present
Salado Ck. (Upper Sta.) at S.A	8178700	137	Sept. 1960 - Present
Salado Ck. (Lowerr Sta.) at S.A	8178800	189	Sept. 1960 - Present
San Antonio River Near Elmendorf	8181800	1,743	Sept. 1962 - Present
San Antonio River Near Falls City	8183500	2,113	April 1925 - Present
Cibolo Creek Near Boerne	8183900	68.4	March 1962 - Present
Cibolo Creek Near Selma	818500	271	March 1946 - Present
Cibolo Creek Near Falls City	8186000	827	Oct. 1930 - Present
San Antonio River at Goliad	8188500	3,921	June 1924 - March 1929 Feb. 1939 - Present

a/ Periodic discharge measurements

Table 2-5
Estimated Annual Recharge/Discharge to the Edwards Aquifer

Year	Total Annual Recharge (1000 AF)	Medina Lake Recharge (1000 AF)	Total Well Discharge (1000 AF)	Total Spring Discharge (1000 AF)	Medina County Discharge (1000 AF)	Bexar County Discharge (1000 AF)
1934	179.60	46.50	101.90	336.00	1.30	109.30
1935	1,258.20	71.10	103.70	415.90	1.50	171.80
1936	909.60	91.60	112.70	485.50	1.50	215.20
1937	400.70	80.50	120.20	451.00	1.50	201.80
1938	432.70	65.50	120.10	437.70	1.60	187.60
1939	399.00	42.40	118.90	313.90	1.60	122.50
1940	308.80	38.80	120.10	296.50	1.60	116.70
1941	850.70	54.10	136.80	464.40	1.60	197.40
1942	557.80	51.70	144.60	450.10	1.70	203.20
1943	273.10	41.50	149.10	390.20	1.70	172.00
1944	560.90	50.50	147.30	420.10	1.70	166.30
1945	527.80	54.80	153.30	461.50	1.70	199.80
1946	556.10	51.40	155.00	428.90	1.70	180.10
1947	422.60	44.00	167.00	426.50	2.00	193.30
1948	178.30	14.80	168.70	281.90	1.90	159.20
1949	508.10	33.00	179.40	300.40	2.00	165.30
1950	200.20	23.60	193.80	272.90	2.20	177.30
1951	139.90	21.10	209.70	215.90	2.20	186.90
1952	275.50	25.40	215.40	209.50	3.10	187.10
1953	167.60	36.20	229.80	238.50	4.00	193.70
1954	162.10	25.30	246.20	178.10	6.30	208.90
1955	192.00	16.50	261.00	127.80	11.10	215.20
1956	43.70	6.30	321.10	69.80	17.70	229.60
1957	1,142.60	55.60	237.30	219.20	11.90	189.40
1958	1,711.20	95.50	219.30	398.20	6.60	199.50
1959	690.40	94.70	234.50	384.50	8.30	217.50
1960	824.80	104.00	227.10	428.30	7.60	215.40
1961	717.10	88.30	228.20	455.30	6.40	230.30
1962	239.40	57.30	267.90	321.10	8.10	220.00
1963	170.70	41.90	276.40	239.60	9.70	217.30
1964	413.20	43.30	260.20	213.80	8.60	201.00
1965	623.50	54.60	256.10	322.80	10.00	201.10
1966	615.20	50.50	255.90	315.30	10.40	198.00
1967	466.50	44.70	341.30	216.10	15.20	239.70
1968	884.70	59.90	251.70	408.30	9.90	207.10
1969	610.50	55.40	307.50	351.20	13.60	216.30
1970	661.60	68.00	329.40	397.70	16.50	230.60
1971	925.30	68.70	406.80	272.70	32.40	262.80
1972	756.40	87.90	371.30	375.80	28.80	247.70
1973	1,486.50	97.60	310.40	527.60	14.90	273.00
1974	658.50	96.20	377.40	483.80	28.60	272.10
1975	973.00	93.40	327.80	540.40	22.60	259.00
1976	894.10	94.50	349.50	503.90	19.40	253.20
1977	952.00	77.70	380.60	580.30	19.90	317.50
1978	502.50	76.70	431.80	375.50	38.70	266.50
1979	1,117.80	89.40	391.50	523.00	32.90	294.50
1980	406.40	88.30	491.10	328.30	39.90	300.30
1981	1,448.40	91.30	387.10	407.30	26.10	280.70
1982	422.40	76.80	453.10	333.30	33.40	305.10
1983	420.10	74.40	418.50	301.60	29.70	271.60
1984	197.90	43.90	529.80	172.50	46.90	309.70
1985	1,003.30	64.70	522.50	334.00	59.20	295.50
1986	1,153.70	74.70	429.30	405.30	41.90	294.00
1987	2,003.60	90.40	364.10	576.30	15.90	326.60
1988	355.50	69.90	539.90	386.30	82.20	317.40
AVG	635.52	61.03	273.66	359.50	15.08	223.47
MAX	2,003.60	104.00	539.90	580.30	82.20	326.60
MIN	43.70	6.30	101.90	69.80	1.30	109.30

Source: Bulletin 48 - Edwards Underground Water District - San Antonio, Texas

Table 2-6
Species of Special Concern Found Within the Study Area

Eo#	USGS Quadrangle	County	Global Rank	State Rank	Fed. Status	State Status
Golden-cheeked Warbler: *Dendroica chrysoparia*						
010	Van Raub	N.W. Bexar	G2	S2	LE	E
Texas Salamander: *Eurycea neotenes*						
019	Bulverde	N. Bexar	G3	S3	C2	
020	Bulverde	N. Bexar	G3	S3	C2	
021	Bulverde	N. Bexar	G3	S3	C2	
022	Van Raub	N.W. Bexar	G3	S3	C2	
023	Van Raub	N.W. Bexar	G3	S3	C2	
024	San Geronimo	N.W. Bexar	G3	S3	C2	
106	Van Raub	N.W. Bexar	G3	S3	C2	
108	Van Raub	N.W. Bexar	G3	S3	C2	
Comal Blind Salamander: *Eurycea tridentifera*						
005	Castle Hills	Cent. Bexar	G1	S1	C2	T
008	Castle Hills	Cent. Bexar	G1	S1	C2	T
Sandhill Woolywhite: *Hymenopappus carrizoanus*						
003	Bigfoot	N. Atascosa	G2	S2		
008	Thelma/Poteet	N. Atascosa	G2	S2		
Parks' Jointweed: *Polygonella parksii*						
003	Thelma	N. Atascosa	G2	S2	3C	
004	Thelma	S. Bexar	G2	S2	3C	
Bracted Twistflower: *Streptanthus bracteatus*						
008	Medina Lake	N.E. Medina	G2	S2	C2	
Buckley Tridens: *Tridens buckleyanus*						
011	Medina Lake	N.E. Medina	G2	S2		
008	Medina Lake	N.E. Medina	G2	S2		

Key: Federal Status

- LE: Listed endangered
- LT: Listed threatened
- C1: USFW has substantial information on biological vulnerability; data being gathered on habitat needs and/or critical habitat designation
- C2: Further biological research necessary to ascertain the status and/or taxonomic validity
- 3C: Former candidate, rejected because more common, widespread or adequately protected

State Status

- E: Listed as endangered in the State of Texas
- T: Listed as threatened in the State of Texas

Table 2-7
Rare Vertebrates Found in Atascosa, Bexar, Bandera and Medina Counties

Common Name	Scientific Name	Global Rank	State Rank	Fed. Status	State Status
Amphibians					
Texas Salamander	*Eurycea neotenes*	G3	S3	C2	
Comal Blind Salamander	*E. tridentifera*	G1	S1	C2	T
Black-spotted Newt	*Notophthalmus meridionalis*	G1	S1	C2	E
Mexican Treefrog	*Smilisca baudinii*	G5	S3		T
Birds					
White-tailed Hawk	*Buteo albicaudatus*	G5	S2		T
Zone-tailed Hawk	*B. albonotatus*	G5	S3		T
Fulvous Whistling-duck	*Dendrocygna bicolor*	G5	S4	C2	
Golden-cheeked Warbler	*Dendroica chrysoparia*	G2	S2	LE	E
Reddish Egret	*Egretta rufescens*	G4	S2	C2	T
American Peregrine Falcon	*Falco peregrinus anatum*	G3T2	S1	LE	E
Arctic Peregrine Falcon	*F. peregrinus tundrius*	G3T1	S1	LT	T
Whooping Crane	*Grus americana*	G1	S1	LE	E
Wood Stork	*Mycteria americana*	G5	SH		T
Brown Pelican	*Pelecanus occidentalis*	G5	S1	LE	E
White-face Ibis	*Plegadis chihi*	G5	S2	C2	T
Interior Least Tern	*Sterna antillarum athalassos*	G4T2	S1	LE	E
Fishes					
Widemouth Blindcat	*Satan eurystomus*	G1	S1	C2	T
Toothless Blindcat	*Trogloglanis pattersoni*	G1	S1	C2	T
Reptiles					
Timber Rattlesnake	*Crotalus horridus*	G5	S5		T
Indigo Snake	*Drymarchon corais*	G5	S3		T
Texas Tortoise	*Gopherus berlandieri*	G4	S3		T
Cagle's Map Turtles	*Graptemys caglei*	G3	S3	C2	
Spot-tailed Earless Lizard	*Holbrookia lacerata*	G3?	S3?		
Keeled Earless Lizard	*H. propinqua*	G3?	S3?		
Texas Horned Lizard	*Phrynosoma cornutum*	G5	S4	C2	T
Texas Garter Snake	*Thamnophis sirtalis annectens*	G5T3	S3	C2	

Key: see Table 2-6.

Table 3-1

Water Supply System Populations and Water Uses for Study Area and Air Force Bases Located Within Bexar County

Water Supply System	CCN No.	Population Served	Number of Connections	Persons Per Connection	Average Daily Use (mgd)
Atascosa Rural Water Supply Corp.	11366	4,824	1,608	3.00	0.539
Bexar County WCID 16	11292	3,450	1,150	3.00	0.502
Bexar Metropolitan Water District-Castle Hills	10675	4,198	2,728	1.54	1.805
Bexar Metropolitan Water District-South San Antonio	10675	82,257	27,419	3.00	11.47
Brooks Air force Base	AFB	3,200	320	10.00	0.542
Coolcrest Water System	11106	693	231	3.00	0.071
Elmendorf, City of	10684	1,158	386	3.00	N/A
Ft. Sam Houston Army Base	AB	18,261	1,826	10.00	3.803
Kelly Air force Base	AFB	2,150	2,150	1.00	3.221
Kings Point Water System	10683	543	181	3.00	0.049
Lackland Air force Base	AFB	16,476	3,000	5.49	2.932
Lackland Air force Base - Annex	AFB	3,200	320	10.00	0.382
Lackland City Water Company - Columbia	10734	20,898	6,966	3.00	2.71
Lackland City Water Company - Park Village	10734	24,255	8,085	3.00	2.82
Lytle, City of	11007	2,751	917	3.00	0.454
Meadowood Acres Water Corp.	10657	540	180	3.00	N/A
Oakland Utility Company	11668	N/A	N/A	N/A	N/A
Randolph Air force Base	AFB	11,091	1,109	10.00	1.134
Rio Medina Water Corp	11671	192	64	3.00	0.022
San Antonio City Water Board	10640	7,708	2,023	3.81	N/A
Silver Mountain Water Co., Inc.	12321	72	24	3.00	N/A
Twin Valley Water System	10682	408	136	3.00	0.041
Vos Water Company	11987	306	102	3.00	0.031
Waterwood Utilities, Inc.	12082	357	119	3.00	0.031
Windy's Water Works, Inc.	10641	1,770	677	2.61	0.231
Source: Texas Department of Health Sanitary Surveys	**Total**	210,758	61,721	4	2

Table 3-2
Census Tracts Located Within the Primary Planning Area

Census Tract No.	Total Area w/i Census (sq miles)	Total Population w/i Census Tract (# of Persons)	Total Area w/i Planning Area (sq miles)	Total Population w/i Planning Area (# of Persons)
1201.85	5.18	8,245	5.18	8,245
1317.00	3.96	4,040	3.96	4,040
1415.00	2.13	830	2.13	830
* 1418.00	28.15	2,847	14.39	1,456
1505.00	1.03	8,814	1.03	8,814
1506.00	0.73	4,607	0.73	4,607
1509.00	1.06	5,853	1.06	5,853
1510.00	0.61	3,499	0.61	3,499
1511.00	1.35	7,605	1.35	7,605
1512.00	2.79	8,641	2.79	8,641
1513.00	2.64	8,544	2.64	8,544
1514.00	0.72	4,446	0.72	4,446
1515.00	0.74	2,451	0.74	2,451
1516.00	1.19	7,000	1.19	7,000
1517.00	2.46	6,782	2.46	6,782
* 1519.00	13.86	2,845	6.69	1,372
1520.00	17.75	637	17.75	637
1521.00	43.20	3,504	43.20	3,504
* 1522.00	61.09	4,584	47.07	3,532
* 1604.00	1.08	5,348	0.39	1,912
* 1605.00	1.28	8,745	0.33	2,284
* 1606.00	0.85	5,757	0.51	3,432
* 1607.85	2.13	9,162	1.20	5,158
1608.00	0.61	19	0.61	19
1609.00	1.94	8,036	1.94	8,036
1610.85	2.91	2,670	2.91	2,670
1611.00	4.03	7,846	4.03	7,846
1612.00	17.78	1,557	17.78	1,557
1613.00	4.31	11,454	4.31	11,454
1614.01	4.36	8,707	4.36	8,707
1614.85	5.57	1,765	5.57	1,765
1615.01	1.57	6,369	1.57	6,369
1615.02	1.74	6,520	1.74	6,520
1616.00	2.41	3,851	2.41	3,851
1617.00	6.06	647	6.06	647
1618.00	9.56	4,477	9.56	4,477
1619.00	55.99	4,436	55.99	4,436
1620.00	56.80	7,406	56.80	7,406
1719.03	1.22	5,894	1.22	5,894
* 1719.01	7.62	7,783	1.32	1,348
* 1719.02	2.75	2,054	1.32	987
1719.04	5.22	8,418	5.22	8,418
1719.05	3.93	11,914	3.93	11,914
* 1719.06	4.84	1,388	1.98	569
* 1720.00	54.69	5,436	21.26	2,113
1911.01	1.56	1,716	1.56	1,716
* 1911.02	0.92	2,482	0.92	2,482
Total	454.38	247,631	372.49	215,845

Note: Asterics Represent Those Census Tracts Which Fall Partially Within the Planning Area
Source: U.S. Census Bureau

Table 3-3

General Description of the Water Supply Systems within the Study Area

Water Supply System	CCN No.	Total Number of Wells	Total Well/Raw Water Pump Capacity b/ (gpm)	Total High Pressure Pump Capacity b/ (gpm)	Total Storage Capacity c/ (gal)	Total Number of Connections Served	Pressure Range (psi)	Date of Most Recent Sanitary Survey
Atascosa Rural Water Supply Corp	11366	2	2,000	4,970	479,700	1,608	45-65	1/14/91
Bexar Coounty WCID 16	11292	2	2,400	NA	223,000	1,150	42-48	11/18/91
Bexar Metropolitan Water District-Castle Hills	10675	5	9,600	6,200	3,250,000	2,728	55-100	4/17/91
Bexar Metropolitan Water District-South San Antonio	10675	18	42,000	32,100	12,400,000	27,419	55-82	4/30/92
Brooks Airforce Base	AFB	NA	NA	NA	NA	320	58-75	10/1/91
Coolcrest Wate System	11106	2	340	400	40,400	231	40-55	2/6/91
Elmendorf, City of	10684	3	600	1,850	164,500	386	42-62	12/16/91
Ft. Sam Houston Army Base	AB	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Kelly Airforce Base	AFB	8	5,750	NA	2,639,000	2,150	45-72	9/19/91
Kings Point Water System	10683	3	210	540	35,600	181	40-55	3/26/91
Lackland Airforce Base	AFB	5	6,905	800	1,500,000	3,000	30-75	10/1/91
Lackland Airforce Base - Annex	AFB	2	1,750	NA	375,000	320	35-50	10/1/91
Lackland City Water Company - Columbia	10734	5	8,920	7,600	2,260,000	6,966	50-75	4/30/92
Lackland City Water Company - Park Village	10734	5	11,150	1,500	2,000,000	8,085	45-82	4/30/92
Lytle, City of	11007	2	1,100	2,500	875,000	917	40-72	10/1/91
Meadowood Acres Water Corp.	10657	2	1,500	1,060	4,200	180	30-60	6/25/91
Oakland Utility Company	11668	NA	NA	NA	NA	NA	NA	NA
Randolph Airforce Base	AFB	5	5,250	NA	1,000,000	1,109	47-65	6/3/92
Rio Medina Water Corp	11671	1	200	200	15,700	64	35-50	1/27/92
San Antonio City Water Board	10640	NA	NA	NA	NA	2,023	48-72	1/31/92
Silver Mountain Water Co., Inc.	12321	2	500	190	75,215	24	40-60	4/26/91
Twin Valley Water System	10682	2	160	830	25,600	136	40-55	9/26/91
Vos Water Company	11987	2	300	600	50,700	102	40-55	2/6/91
Waterwood Utilities, Inc.	12082	1	150	400	72,500	119	45-72	5/9/91
Windy's Water Works, Inc.	10641	7	695	1,040	575,650	677	19-100	10/30/91
	Total	84	101,480	62,780	28,061,765	59,895		

a/ Source: Texas Department of Health Sanitary Surveys
b/ Rated Capacity of Wells
c/ Includes Elevated, Ground, Pressure Tank and Standpipe Storage

Table 3-4

Aggregate Historical Water Use for Bexar Metropolitan Water District
(Millions of Gallons)

Year	Number of Connections	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Annual Total
1980	27,353	330.23	323.27	394.78	427.59	406.19	615.97	750.61	544.93	434.83	398.80	357.53	333.03	5,317.74
1981	27,526	341.06	314.55	381.07	407.52	430.22	367.99	520.17	590.01	459.49	393.33	374.67	376.25	4,956.32
1982	27,759	399.83	341.10	395.07	413.84	396.76	529.14	698.98	660.91	549.11	426.44	360.82	353.35	5,525.35
1983	27,787	351.92	313.88	367.90	466.84	464.20	478.78	567.38	621.82	493.50	396.95	366.58	383.53	5,273.29
1984	27,965	367.89	354.96	447.64	589.35	556.06	532.67	579.54	541.86	443.79	355.82	333.04	333.25	5,435.88
1985	28,048	336.29	307.14	341.77	353.43	429.41	437.42	516.35	653.48	450.00	368.20	339.29	359.64	4,892.41
1986	28,156	368.77	326.41	410.48	438.07	393.48	374.96	580.94	579.54	408.79	374.32	337.74	331.27	4,924.77
1987	30,547	347.44	306.38	345.86	398.52	362.25	381.70	487.23	579.77	414.06	407.92	337.15	337.48	4,705.76
1988	29,716	330.16	316.83	373.58	406.93	480.37	525.89	495.16	537.24	457.23	461.28	399.11	368.67	5,152.44
1989	32,129	358.11	328.49	420.88	422.90	514.28	495.35	627.44	665.58	561.68	496.46	367.90	409.69	5,668.75
1990	30,927	383.64	329.97	377.24	384.50	463.52	574.99	499.16	516.34	450.63	422.33	380.05	371.80	5,154.16
Average	28,901	355.94	323.91	386.93	428.14	445.16	483.17	574.81	590.13	465.74	409.26	359.44	359.81	5,182.44

Source: Texas Water Development Board

Table 3-5
Bexar Metropolitan Water District Historical Water Use
(Millions of Gallons)

Castle Hills

Year	Number of Connections	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Annual Total
1980	2,489	39.22	39.15	57.03	69.08	49.69	119.46	143.87	88.29	60.48	60.03	51.58	45.75	823.61
1981	2,487	44.20	40.62	52.44	60.22	55.63	45.56	83.72	97.37	63.47	50.42	44.10	43.77	681.53
1982	2,494	44.18	41.79	55.11	64.36	48.83	82.32	122.42	134.94	92.70	60.45	47.69	41.49	836.27
1983	2,502	41.75	39.60	51.00	78.39	67.04	78.96	93.00	107.48	77.11	59.86	48.94	49.45	792.58
1984	2,507	49.88	50.31	73.73	119.84	100.54	84.93	104.59	94.20	85.15	46.36	45.61	41.48	896.61
1985	2,516	44.30	39.18	47.56	54.62	61.66	59.63	79.45	113.89	64.76	47.59	39.78	42.46	694.89
1986	2,527	41.88	42.40	70.34	70.09	50.54	49.21	121.40	116.47	61.91	51.01	44.39	42.89	762.53
1987	1,778	42.10	36.93	42.87	56.73	44.71	44.47	83.26	117.34	63.46	60.58	45.45	44.41	682.29
1988	1,780	42.38	40.50	56.74	73.11	87.14	86.12	73.08	90.39	82.42	72.52	58.98	49.92	813.29
1989	2,557	43.74	37.75	57.77	60.29	76.41	78.07	105.54	109.58	83.07	65.26	40.99	46.29	804.75
1990	2,727	41.92	35.57	40.27	46.81	43.42	58.06	97.11	62.58	84.30	51.99	55.02	39.96	657.02
Average	2,397	43.23	40.34	54.99	68.50	62.33	71.53	100.68	102.96	74.44	56.91	47.50	44.35	767.76

South Side

Year	Number of Connections	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Annual Total
1980	24,864	291.01	284.13	337.75	358.51	356.50	496.51	606.74	456.63	374.35	338.77	305.94	287.28	4,494.13
1981	25,039	296.85	273.93	328.63	347.30	374.59	322.44	436.45	492.64	396.02	342.91	330.57	332.47	4,274.79
1982	25,265	355.66	299.32	339.95	349.48	347.93	446.83	576.56	525.97	456.41	365.99	313.13	311.85	4,689.08
1983	25,285	310.17	274.28	316.90	388.45	397.16	399.82	474.38	514.34	416.40	337.09	317.64	334.08	4,480.71
1984	25,458	318.01	304.65	373.92	469.51	455.52	447.74	474.96	447.66	358.64	309.46	287.44	291.77	4,539.28
1985	25,532	291.99	267.95	294.21	298.81	367.75	377.79	436.91	539.58	385.24	320.61	299.51	317.18	4,197.52
1986	25,629	326.89	284.01	340.14	367.98	342.94	325.75	459.54	463.07	346.88	323.31	293.36	288.39	4,162.24
1987	28,769	305.35	269.46	302.99	341.79	317.54	337.23	403.96	462.44	350.59	347.34	291.70	293.08	4,023.47
1988	27,936	287.78	276.33	316.84	333.83	393.23	439.77	422.08	446.85	374.80	368.76	340.14	318.76	4,339.15
1989	29,572	314.37	290.75	363.11	362.61	437.87	417.28	521.90	556.00	478.61	431.20	326.92	363.40	4,864.01
1990	28,200	341.72	294.40	336.97	337.69	420.09	516.94	402.05	453.76	366.33	370.34	325.03	331.83	4,497.15
Average	26,504	312.71	283.56	331.95	359.63	382.83	411.64	474.14	487.18	391.30	352.34	311.94	315.46	4,414.68

Source: Texas Water Development Board

Table 3-6
Aggregate Historical Water Use Data for Military Bases within Bexar County
(Millions of Gallons)

Year	Number of Connections	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Annual Total
1980	N/A	329.40	329.40	391.29	1,458.44	387.01	551.05	693.61	558.09	455.28	416.83	345.86	331.51	6,246.76
1981	N/A	336.74	305.37	335.60	380.98	363.82	391.69	431.09	505.62	409.19	378.55	328.93	313.40	4,480.98
1982	N/A	336.52	313.51	245.88	321.40	364.27	450.24	563.88	614.63	593.37	410.72	380.76	312.14	4,907.33
1983	23,000	310.31	280.65	328.70	386.54	429.31	320.16	470.81	523.76	452.75	373.17	326.89	337.42	4,540.46
1984	23,791	350.05	304.86	387.50	467.12	516.45	541.39	600.49	610.95	535.25	387.66	338.90	317.74	5,358.35
1985	10,101	348.44	322.40	348.52	357.40	442.79	462.98	531.61	716.38	465.51	388.28	314.94	304.28	5,003.53
1986	10,101	310.28	304.43	390.28	446.84	411.29	381.52	655.66	669.99	432.17	348.40	300.64	296.62	4,948.12
1987	6,030	305.87	1,098.02	317.42	401.94	350.49	371.35	486.42	648.61	468.52	435.71	325.03	295.10	5,504.46
1988	10,627	311.53	302.95	365.03	394.09	523.84	540.78	495.82	511.58	454.17	433.91	375.92	312.52	5,022.14
1989	9,555	320.94	302.06	388.48	1,265.75	480.12	445.42	518.00	567.60	498.34	437.39	312.02	323.99	5,860.12
1990	10,602	319.26	304.04	318.84	324.10	358.91	539.05	432.04	469.74	381.85	332.47	220.66	299.91	4,300.85
1991	7,796	288.62	260.73	317.74	315.42	350.04	394.67	397.34	452.70	331.81	364.98	285.05	267.36	4,026.46
Average	9,300	321.69	372.64	340.36	460.14	417.39	439.93	507.56	571.96	456.63	390.11	319.07	307.32	4,904.80

Source: Texas Water Development Board

Table 3-7a
Historical Water Use for Military Bases Within Bexar County
(Millions of Gallons)

Brooks AFB

Year	Number of Connections	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Annual Total
1980	N/A	21.33	20.17	26.01	26.32	26.18	37.96	46.13	37.93	27.60	24.66	17.25	15.15	326.68
1981	N/A	14.35	14.73	17.97	20.85	22.19	23.75	28.98	28.29	26.72	22.37	21.01	20.36	261.29
1982	N/A	20.36	18.43	15.26	19.47	22.19	20.40	31.02	37.31	42.13	46.11	24.94	22.45	320.06
1983	N/A	14.93	12.56	15.19	20.36	25.56	21.76	26.43	33.76	30.94	15.99	19.16	14.70	251.36
1984	791	18.00	12.01	18.05	29.18	33.43	28.14	30.41	30.89	27.25	14.73	14.56	11.62	268.27
1985	N/A	15.30	16.07	11.71	13.27	17.38	15.26	23.63	37.97	33.07	12.85	11.81	12.29	220.61
1986	N/A	12.13	12.30	19.25	22.06	15.25	15.23	41.66	43.51	18.95	14.74	11.50	10.40	236.98
1987	N/A	13.64	12.61	14.15	20.15	15.54	16.06	30.06	43.87	20.20	18.63	14.37	10.95	230.24
1988	N/A	11.50	13.23	17.44	19.76	28.26	29.52	24.17	25.85	22.56	18.75	18.26	12.61	250.22
1989	N/A	12.08	11.37	18.56	19.30	25.90	19.26	27.45	38.74	30.68	21.38	12.97	12.53	250.22
1990	N/A	10.91	10.51	11.71	14.36	19.99	29.60	21.90	23.83	17.44	17.47	12.69	12.73	203.14
1991	N/A	12.10	10.52	15.21	15.58	17.77	23.63	25.16	29.35	21.42	22.24	14.41	11.95	219.34
Average	791	14.72	13.71	16.71	20.05	22.47	23.38	29.75	34.28	26.58	20.83	16.08	13.98	253.20

Fort Sam Houston

Year	Number of Connections	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Annual Total
1980	N/A	83.35	91.91	111.56	116.53	108.21	177.76	223.54	173.87	139.97	126.44	100.69	89.40	1,543.24
1981	N/A	92.77	77.07	84.52	101.05	101.05	115.50	106.36	143.25	105.39	92.17	80.44	73.10	1,172.65
1982	N/A	82.25	78.31	87.84	96.27	96.25	131.87	171.81	186.84	214.27	102.84	128.60	79.64	1,456.77
1983	6,000	74.76	70.22	84.77	109.56	117.47	125.60	132.88	141.27	113.04	95.53	78.48	89.03	1,232.59
1984	6,000	95.43	81.36	107.34	129.24	135.42	159.45	173.92	171.90	149.75	99.74	91.98	80.91	1,476.41
1985	N/A	92.12	87.62	98.87	103.11	132.25	123.21	143.90	183.41	112.02	92.58	74.99	65.91	1,309.97
1986	N/A	72.62	71.63	97.58	117.52	105.23	96.15	183.62	173.70	110.86	86.55	71.46	62.70	1,249.59
1987	N/A	68.12	68.81	71.40	113.68	86.94	93.81	122.25	167.93	123.00	109.92	84.24	72.39	1,182.48
1988	N/A	73.05	82.04	101.64	112.58	145.40	143.39	131.81	142.62	131.73	125.36	107.78	88.21	1,385.58
1989	N/A	91.16	86.34	113.82	116.94	139.27	119.03	148.30	156.60	133.93	123.31	90.96	97.30	1,416.94
1990	N/A	106.55	100.67	104.50	106.89	137.30	162.03	139.04	153.30	127.74	102.45	84.05	89.72	1,414.23
1991	1,729	89.15	89.01	112.00	100.31	113.03	112.68	112.64	146.54	103.50	114.03	95.40	97.14	1,285.30
Average	4,576	85.11	82.08	97.99	63.37	118.15	130.04	149.16	161.77	130.43	105.91	90.75	82.12	1,343.81

Source: Texas Water Development Board

Table 3-7b
Historical Water Use for Military Bases Within Bexar County
(Millions of Gallons)

Kelly AFB

Year	Number of Connections	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Annual Total
1980	N/A	103.49	92.30	101.73	118.18	110.35	146.94	179.01	151.47	130.85	123.00	103.72	103.09	1,464.12
1981	N/A	105.06	93.36	105.14	110.95	113.44	107.37	122.62	138.57	111.54	103.15	90.74	94.54	1,296.47
1982	N/A	105.96	97.47	100.29	99.46	98.77	121.82	142.61	154.96	133.87	112.67	103.96	98.42	1,370.26
1983	N/A	98.82	89.35	104.83	115.01	122.18	126.52	133.10	145.93	132.91	123.46	107.14	103.92	1,403.15
1984	N/A	102.02	89.49	112.21	127.36	147.63	156.13	169.30	166.09	138.33	116.00	106.11	108.95	1,539.63
1985	N/A	109.00	95.00	87.00	99.00	116.00	125.00	129.00	157.00	123.00	116.00	96.00	112.00	1,364.00
1986	N/A	104.28	103.57	114.73	123.37	115.66	108.00	139.43	149.30	116.34	102.64	91.58	102.85	1,371.74
1987	500	93.69	90.02	95.51	101.58	100.98	104.07	117.54	132.96	105.68	107.93	85.86	90.97	1,226.78
1988	525	101.58	90.70	103.46	100.91	123.05	130.23	126.01	126.67	110.94	105.48	96.05	87.52	1,302.59
1989	500	88.06	82.58	104.97	98.81	118.53	118.17	121.43	132.72	122.03	110.75	89.93	91.52	1,279.47
1990	500	88.79	80.25	88.45	91.03	103.20	122.90	103.79	119.41	102.45	89.71	81.42	90.51	1,161.91
1991	500	92.18	75.76	85.49	92.01	103.42	110.59	113.77	111.49	90.68	96.81	76.11	69.93	1,118.23
Average	505	99.41	89.99	100.32	106.47	114.43	123.14	133.13	140.55	120.72	108.97	94.05	96.18	1,324.86

Lackland Air Force Base

Year	Number of Connections	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Annual Total
1980	N/A	83.80	96.12	117.33	112.53	102.07	132.64	163.12	136.92	114.52	105.67	94.27	95.18	1,354.17
1981	N/A	94.07	93.43	98.83	113.91	123.46	109.93	128.88	146.42	129.05	128.41	106.87	97.18	1,370.43
1982	N/A	97.73	90.85	10.69	102.89	113.25	127.78	145.07	152.12	129.13	104.30	89.97	82.51	1,246.27
1983	10,000	87.34	81.72	92.14	103.66	118.60	118.90	133.11	137.56	123.16	100.11	86.54	96.62	1,279.43
1984	10,000	103.78	91.94	113.03	120.91	135.82	142.19	157.41	159.18	154.17	120.61	101.19	93.11	1,493.34
1985	8,175	108.97	102.61	127.09	116.79	144.23	162.05	194.68	265.98	164.54	141.13	112.50	95.29	1,735.87
1986	8,175	99.00	95.40	126.05	147.95	142.51	132.92	220.80	228.15	136.49	110.82	98.02	97.96	1,636.07
1987	3,604	101.52	899.77	101.01	118.20	114.20	120.63	160.69	218.60	158.92	138.04	105.31	93.80	2,330.70
1988	8,175	95.40	87.42	98.98	105.48	148.30	166.10	158.03	151.42	131.66	131.68	114.04	93.51	1,482.04
1989	8,175	99.45	93.65	108.03	98.49	128.09	123.53	140.45	145.74	128.07	122.49	88.23	93.62	1,369.83
1990	8,175	86.62	87.78	86.69	81.36	93.29	136.77	112.36	114.75	96.45	88.07	14.00	77.01	1,075.14
1991	3,640	74.66	62.62	76.24	79.00	80.66	95.69	98.84	102.65	81.30	83.14	68.90	65.41	969.12
Average	7,569	94.36	156.94	96.34	108.43	120.37	130.76	151.12	163.29	128.95	114.54	89.99	90.10	1,445.20

Source: Texas Water Development Board

Table 3-7c
Historical Water Use for Military Bases Within Bexar County
(Millions of Gallons)

Randolph AFB-Aquifer

Year	Number of Connections	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Annual Total
1980	N/A	30.78	28.89	34.67	35.99	40.19	55.75	81.81	57.90	42.35	37.06	29.93	28.68	503.99
1981	N/A	30.49	26.78	29.14	34.23	36.82	35.15	44.26	49.08	36.48	32.45	29.87	28.23	412.98
1982	N/A	29.97	28.44	31.80	33.32	33.82	48.38	73.38	83.40	73.97	44.81	33.31	29.14	543.74
1983	3,500	27.34	26.79	31.77	37.96	45.51	40.43	45.30	65.24	52.70	38.08	35.58	33.15	479.85
1984	3,500	30.58	30.06	36.86	60.42	64.15	55.48	69.46	82.90	65.76	36.58	25.06	23.16	580.46
1985	1,926	23.06	21.10	23.85	25.23	32.93	37.46	40.40	72.02	32.88	25.73	19.64	18.79	373.08
1986	1,926	22.25	21.53	32.66	35.95	32.64	29.23	70.16	75.32	42.34	33.65	28.08	22.72	446.54
1987	1,926	28.90	26.81	35.36	48.32	32.83	36.77	55.89	85.24	60.72	61.19	35.24	26.99	534.27
1988	1,927	30.00	29.57	43.52	55.36	78.84	71.53	55.80	65.02	57.28	52.65	39.79	30.68	610.02
1989	880	30.20	28.13	43.11	45.79	68.33	65.44	80.37	93.80	83.63	59.47	29.93	29.03	657.23
1990	1,927	26.39	24.81	27.50	30.47	45.58	87.76	54.95	58.45	37.78	34.77	28.50	29.94	486.89
1991	1,927	20.54	22.81	28.79	28.53	35.17	52.08	47.03	62.68	34.91	48.76	30.23	22.93	434.48
Average	2,160	27.54	26.31	33.25	39.30	45.57	51.29	59.90	70.92	51.73	42.10	30.43	26.95	505.29

Randolph AFB-Purchased

Year	Number of Connections	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Annual Total
1980	N/A	5.67	5.67	5.67	5.67	11.33	11.33	11.33	11.33	5.67	5.67	5.67	5.67	90.65
1981	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1982	N/A	0.24	0.24	0.33	0.49	0.57	0.65	0.81	0.81	0.81	0.81	0.57	0.24	6.60
1983	3,500	7.13	7.13	9.16	12.63	12.63	12.63	12.63	12.63	12.63	12.63	9.16	7.13	128.09
1984	3,500	0.24	0.35	0.50	1.50	3.00	4.70	6.00	6.00	4.50	3.00	1.50	0.35	31.64
1985	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1986	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1987	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1989	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1990	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1991	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Average	3;500	3.32	3.35	3.91	5.07	6.88	7.33	7.69	7.69	5.90	5.53	4.22	3.35	64.24

Source: Texas Water Development Board

Table 3-8

Aggregate Historical Water use for Non-Military Water Supply Systems Located Within the Primary Planning Area (Millions of Gallons)

Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	202,464	3,556	3,488	4,169	4,540	3,950	6,350	8,117	6,188	4,785	4,433	3,895	3,718	57,212
1981	209,987	3,707	3,315	4,015	4,144	4,347	4,182	5,418	6,138	4,739	4,487	3,437	3,838	51,766
1982	223,797	4,013	3,676	4,242	4,605	4,395	5,948	7,860	7,820	6,057	4,831	4,184	4,070	61,723
1983	231,856	3,956	3,654	4,204	5,043	4,959	5,144	5,644	6,190	5,456	4,807	4,184	4,483	57,729
1984	213,406	4,376	3,897	4,812	5,849	5,981	6,034	7,315	7,095	6,228	4,637	4,284	4,171	64,737
1985	210,650	4,606	4,053	4,389	4,676	5,173	5,110	5,863	7,438	5,452	4,728	4,179	4,095	59,818
1986	246,722	3,874	3,723	5,018	5,247	4,980	4,841	7,773	7,843	5,212	4,638	4,033	4,043	61,273
1987	265,223	4,105	3,661	4,298	4,611	4,589	4,601	6,008	7,596	5,246	5,331	4,306	3,999	58,414
1988	250,128	4,514	4,265	4,865	5,348	6,180	6,175	5,988	6,760	5,986	5,660	4,947	4,676	65,414
1989	257,641	3,974	3,541	4,536	5,173	6,194	5,905	7,173	7,354	6,298	5,653	4,378	4,748	64,960
1990	261,190	4,206	3,863	3,922	3,977	5,219	7,486	5,406	6,141	4,856	4,818	4,161	4,394	58,480
Average	236,473	4,080.64	3,739.72	4,406.34	4,837.56	5,087.95	5,616.06	6,596.75	6,960.31	5,483.12	4,911.09	4,180.67	4,203.28	60,138.75

Source: Texas Water Development Board

Table 3-9a
Historical Water Use for Non-Military Water Supply Systems Located Within the Primary Planning Area
(Millions of Gallons)

Atascosa Rural Water System

Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	1,127	6.57	5.99	8.38	9.03	10.70	12.78	19.38	13.54	10.74	9.67	9.08	6.70	122.55
1981	1,170	8.07	8.46	9.59	10.94	12.56	9.96	14.93	15.57	11.97	11.95	9.68	9.81	133.47
1982	1,184	10.83	8.63	11.08	12.71	11.40	16.84	21.38	21.17	17.08	12.78	10.45	9.83	164.16
1983	1,189	9.25	8.61	10.77	14.33	14.49	15.72	18.15	18.65	16.59	14.10	12.09	15.06	167.80
1984	1,194	53.84	11.16	15.85	19.45	21.11	20.15	23.48	21.44	9.51	7.09	6.41	5.25	214.74
1985	1,368	12.88	10.94	12.84	12.14	16.04	17.64	24.74	24.97	19.54	17.63	10.33	10.60	190.28
1986	1,432	19.58	17.62	20.72	23.74	18.98	18.04	29.85	30.00	18.74	18.05	14.43	16.04	245.79
1987	1,469	16.13	15.15	18.03	8.17	19.64	20.79	27.27	33.89	23.55	23.60	19.60	18.83	244.66
1988	1,510	19.41	17.88	22.10	24.57	27.65	28.77	28.40	31.69	26.56	26.88	22.63	17.97	294.51
1989	1,542	17.05	16.98	16.19	18.22	25.67	19.20	28.92	27.82	22.82	21.82	14.54	18.54	247.76
1990	1,608	13.08	13.57	14.16	13.60	20.49	21.89	18.07	23.20	14.29	15.22	14.11	14.39	196.07
Average	1,345	16.97	12.27	14.52	15.17	18.06	18.34	23.14	23.81	17.40	16.25	13.03	13.00	201.98

Bexar County WCID 16

Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	1,200	15.35	14.71	17.13	20.87	16.16	22.13	24.06	22.88	14.64	17.27	16.06	15.37	216.63
1981	1,225	17.77	17.68	18.72	12.20	12.49	11.65	19.95	22.30	28.83	16.61	16.03	15.45	209.68
1982	1,356	15.43	14.30	16.47	17.57	16.98	20.69	34.57	27.51	24.68	18.59	17.39	17.06	241.25
1983	1,250	17.78	15.96	10.03	13.85	13.59	12.47	14.54	16.35	16.44	11.30	10.55	13.79	166.65
1984	1,200	1.24	1.26	1.26	1.61	1.52	1.70	2.18	1.87	1.72	0.75	1.04	1.03	17.18
1985	1,200	15.72	12.56	12.59	16.14	20.02	20.74	24.44	30.28	23.02	18.71	16.08	16.82	227.12
1986	1,150	32.16	28.91	18.89	19.86	10.91	19.32	18.40	17.59	9.85	9.95	8.96	8.25	203.06
1987	1,150	16.73	15.09	17.70	17.87	13.30	18.08	21.21	29.41	19.39	22.20	17.63	17.70	226.31
1988	1,150	17.06	15.92	12.63	15.85	25.10	22.03	28.06	24.04	16.32	17.17	15.52	15.06	224.76
1989	1,160	13.91	13.26	15.37	15.14	18.28	17.07	23.61	26.28	18.11	17.12	12.69	14.23	205.08
1990	1,155	12.30	11.45	12.80	13.14	17.42	23.50	15.73	18.11	16.22	15.55	12.94	13.02	182.18
Average	1,200	15.95	14.65	13.96	14.92	15.07	17.22	20.61	21.51	17.20	15.02	13.17	13.44	192.72

Source: Texas Water Development Board

Table 3-9b
Historical Water Use for Non-Military Water Supply Systems Located Within the Primary Planning Area
(Millions of Gallons)

Coolcrest Water System														
Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	203	1.20	1.31	1.11	1.60	2.33	1.71	4.28	3.68	3.37	1.34	1.44	1.22	24.57
1981	197	1.17	1.73	1.55	1.14	2.31	2.22	1.32	2.46	3.31	1.84	2.22	1.49	22.75
1982	220	1.46	1.45	1.39	1.68	2.00	1.84	2.18	4.93	2.65	4.07	1.81	1.55	27.01
1983	223	1.62	2.01	1.38	1.64	3.89	1.53	3.35	2.57	4.17	2.49	1.64	1.50	27.77
1984	240	1.75	1.56	1.62	1.92	3.28	3.22	2.09	3.47	4.97	3.20	1.38	1.30	29.76
1985	242	1.62	1.71	1.51	1.30	1.93	2.29	1.59	3.06	4.00	3.16	1.87	1.50	25.54
1986	290	1.58	1.45	1.63	2.00	3.26	1.92	2.15	3.68	3.71	2.12	1.94	1.51	26.95
1987	240	1.53	1.65	1.81	1.51	2.53	2.15	1.82	2.80	3.20	2.39	1.67	1.56	24.62
1988	235	1.66	1.44	1.73	1.75	2.33	2.93	3.63	3.18	4.18	2.97	2.33	2.09	30.21
1989	231	1.95	2.06	1.62	1.90	2.20	3.50	2.81	3.91	4.16	3.04	2.61	1.61	31.35
1990	228	1.71	1.45	1.35	1.61	2.46	3.79	2.16	3.40	2.23	2.31	1.68	1.77	25.92
Average	232	1.57	1.62	1.52	1.64	2.59	2.46	2.49	3.38	3.63	2.63	1.87	1.55	26.95

City of Elmendorf a/														
Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	226	1.23	1.17	1.78	2.16	1.79	3.20	4.06	2.25	2.07	2.03	1.75	1.67	25.16
1981	237	2.07	1.93	1.09	1.78	1.93	1.62	2.08	2.99	1.78	1.71	2.07	1.98	23.03
1982	247	1.86	1.70	1.65	2.23	2.04	3.05	4.67	3.08	3.07	2.62	1.63	1.80	29.39
1983	249	2.41	1.69	1.77	2.48	2.53	2.69	3.58	3.54	2.65	2.16	2.40	2.19	30.09
1984	280	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	52.83
1985	285	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	51.08
1986	285	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	43.42
1987	319	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	48.60
1988	305	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	21.07
1989	291	3.22	1.77	2.72	2.32	2.51	4.06	4.83	3.91	5.47	1.91	1.92	1.96	36.59
1990	350	1.96	1.92	0.59	5.47	3.91	4.83	4.06	2.51	2.32	2.72	1.77	3.22	35.27
Average	279	2.12	1.70	1.60	2.74	2.45	3.24	3.88	3.05	2.89	2.19	1.92	2.14	36.05

a/ TWDB lists an annual total but does not give monthly totals for the years 1984 through 1988.
Source: Texas Water Development Board

Table 3-9c
Historical Water Use for Non-Military Water Supply Systems Located Within the Primary Planning Area
(Millions of Gallons)

Kings Point Water Co.

Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	166	0.66	0.85	0.98	1.04	1.34	1.33	2.47	1.66	0.12	0.88	1.05	0.91	13.28
1981	171	0.67	0.72	0.80	0.78	1.19	0.98	1.53	1.62	1.61	1.08	1.16	0.62	12.77
1982	167	0.59	1.00	0.84	1.03	1.10	1.02	1.89	1.86	1.98	1.44	1.34	1.14	15.22
1983	184	0.88	0.98	0.96	1.16	1.57	1.69	1.77	1.56	0.23	1.89	1.14	1.25	15.07
1984	189	1.99	0.76	1.21	1.40	1.92	2.11	2.11	2.48	1.99	1.55	1.13	1.11	19.76
1985	194	1.04	1.15	1.18	1.16	1.68	1.75	1.84	2.31	2.74	2.17	1.73	1.31	20.06
1986	210	1.30	1.33	1.49	1.59	2.26	1.59	1.84	3.02	2.46	2.14	1.33	1.26	21.60
1987	200	1.47	1.33	1.29	1.45	1.85	1.76	1.57	2.27	2.55	1.65	1.56	1.27	20.00
1988	200	1.33	1.16	1.39	1.57	1.70	1.97	2.45	1.70	2.73	2.03	1.90	1.79	21.72
1989	200	1.14	1.19	1.28	1.41	1.58	2.22	2.10	2.64	2.73	2.26	1.69	1.27	21.49
1990	182	1.27	1.17	1.16	1.21	1.25	1.98	1.93	1.96	1.28	1.55	1.06	1.25	17.07
Average	188	1.12	1.06	1.14	1.26	1.58	1.67	1.95	2.10	1.85	1.69	1.37	1.20	18.00

City of Lytle

Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	710	6.65	7.75	11.44	13.94	10.14	19.08	13.76	14.16	14.63	12.25	8.65	8.90	141.34
1981	732	8.01	7.20	9.30	11.33	12.74	10.84	19.37	20.37	13.52	10.45	9.18	8.51	140.81
1982	753	8.68	9.63	10.58	12.30	7.22	16.94	11.44	16.65	13.32	9.99	7.97	8.11	132.82
1983	788	8.25	7.32	8.92	13.47	13.13	13.04	14.73	14.63	12.16	9.42	8.90	10.10	134.06
1984	830	8.91	8.52	13.40	14.99	15.24	15.67	23.16	23.34	16.77	10.07	9.59	9.14	168.78
1985	843	9.72	9.16	10.39	11.63	13.10	14.28	20.08	26.40	18.19	13.13	9.96	10.22	166.25
1986	866	9.82	9.79	14.18	17.02	12.33	11.09	22.85	22.15	13.43	10.96	8.90	8.83	161.35
1987	884	8.75	7.75	9.51	13.60	11.21	10.53	17.67	24.56	13.67	15.55	10.65	10.04	153.48
1988	900	12.41	10.96	14.38	15.47	17.60	14.93	15.21	27.02	19.51	18.96	12.74	10.51	189.69
1989	917	9.78	8.99	14.15	15.86	22.65	19.98	25.33	27.06	24.38	21.02	14.01	15.16	218.37
1990	932	13.93	10.57	10.10	10.08	16.10	26.61	16.85	21.20	15.80	14.70	11.13	12.74	179.82
Average	832	9.54	8.88	11.49	13.61	13.77	15.72	18.22	21.59	15.94	13.32	10.15	10.20	162.43

Source: Texas Water Development Board

Table 3-9d
Historical Water Use for Non-Military Water Supply Systems Located Within the Primary Planning Area
(Millions of Gallons)

Lackland City Water Co. (Park Village Water Co. & Columbia)-Aquifer														
Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	7,681	76.62	74.77	93.71	112.07	93.37	158.44	204.70	150.54	123.64	100.22	90.10	82.78	1,360.96
1981	8,433	87.15	74.49	94.35	101.92	107.98	94.64	131.88	154.91	114.71	106.03	96.32	93.60	1,257.98
1982	8,867	102.95	95.37	109.27	120.34	119.85	163.51	235.38	204.18	165.02	141.25	111.27	109.96	1,678.35
1983	9,612	104.25	85.42	116.11	147.58	144.03	148.50	152.45	157.92	141.49	124.54	108.90	113.19	1,544.39
1984	9,514	128.02	93.79	123.46	165.44	164.32	160.04	200.37	208.94	170.31	118.87	114.66	115.69	1,763.90
1985	10,859	127.33	107.10	128.57	138.08	152.24	151.60	171.87	255.47	186.19	165.42	160.50	162.90	1,907.25
1986	13,790	134.02	128.32	179.66	112.15	165.74	160.97	279.36	265.95	168.73	153.10	140.85	138.10	2,026.92
1987	31,918	137.45	122.18	147.80	191.49	158.45	161.35	212.16	303.58	202.85	200.82	154.01	146.89	2,139.01
1988	14,893	146.15	139.42	174.30	197.75	234.72	235.78	227.44	256.36	210.62	199.48	166.98	158.05	2,347.04
1989	15,294	149.52	139.34	179.51	185.23	221.64	206.49	268.76	280.28	231.18	216.68	159.66	170.95	2,409.24
1990	15,532	149.00	138.08	151.51	159.52	195.53	258.67	200.88	224.06	185.17	173.83	151.67	163.02	2,150.92
Average	13,513	126.58	112.35	140.45	151.95	166.45	174.15	208.05	231.17	177.62	160.00	136.48	137.24	1,922.50

Lackland City Water Co. (Park Village Water Co & Columbia)-Purchased Water														
Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	7,681	0.01	N/A	N/A	N/A	0.00	0.03	0.01	0.00	0.00	0.00	0.00	N/A	0.05
1981	8,433	0.00	0.63	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.63
1982	8,867	0.00	N/A	N/A	N/A	N/A	N/A	0.08	0.13	N/A	0.25	2.67	N/A	3.13
1983	9,612	0.01	0.01	0.02	0.08	0.03	0.19	0.00	7.15	2.17	0.29	0.11	0.08	10.13
1984	9,514	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1985	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1986	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1987	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1989	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1990	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Average	9106.50	N/A	N/A	N/A	N/A	0.03	0.19	0.04	3.64	2.17	0.27	1.39	0.08	4.63

Source: Texas Water Development Board

Table 3-9e
Historical Water Use for Non-Military Water Supply Systems Located Within the Primary Planning Area
(Millions of Gallons)

Meadowood Acres a/

Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1981	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1982	135	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	18.25
1983	141	0.89	0.68	0.70	1.01	1.23	1.41	1.67	1.70	1.58	0.99	1.19	0.78	13.84
1984	154	1.30	1.19	1.18	1.50	2.08	2.11	2.29	2.47	2.04	2.25	1.17	1.20	20.79
1985	165	1.85	1.43	1.17	1.53	1.36	1.52	1.45	2.54	2.16	1.53	1.08	1.12	18.74
1986	158	1.24	1.00	1.15	1.42	1.45	1.30	1.69	2.65	1.46	1.32	0.93	0.89	16.49
1987	165	1.03	0.86	0.93	1.19	1.26	1.07	1.77	2.26	1.31	1.48	1.14	1.12	15.42
1988	154	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	15.83
1989	180	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	18.50
1990	180	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	18.87
Average	159	1.26	1.03	1.03	1.33	1.48	1.48	1.77	2.32	1.71	1.52	1.10	1.02	17.41

a/ TWDB lists an annual total but does not give monthly totals for the years 1982, 1988, 1989, and 1990.

Rio Medina Water Corp.

Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1981	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1982	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1983	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1984	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1985	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1986	127	0.52	0.56	0.70	1.03	1.45	0.89	1.89	1.82	1.69	0.85	0.60	0.56	12.55
1987	119	0.55	0.57	0.49	0.74	1.02	0.75	0.88	1.29	1.50	0.96	0.90	0.71	10.36
1988	116	0.62	0.67	0.63	0.90	1.31	1.36	1.78	1.30	1.96	1.25	1.12	0.83	13.73
1989	119	0.69	0.78	0.70	1.09	1.13	1.65	1.37	2.11	1.87	1.37	1.01	0.60	14.37
1990	119	0.86	0.60	0.59	0.73	0.81	1.40	1.55	0.79	1.19	0.82	0.74	0.64	10.72
Average	120	0.65	0.64	0.62	0.90	1.14	1.21	1.49	1.46	1.64	1.05	0.87	0.67	12.34

Source: Texas Water Development Board

Table 3-9f

Historical Water Use for Non-Military Water Supply Systems Located Within the Primary Planning Area

(Millions of Gallons)

San Antonio City Water Board

Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	183,084	3,447.31	3,380.96	4,033.12	4,378.85	3,813.42	6,130.08	7,842.48	5,977.64	4,614.19	4,288.54	3,765.86	3,599.76	55,272.21
1981	188,969	3,580.45	3,200.99	3,878.09	4,001.85	4,193.19	4,048.57	5,224.62	5,915.59	4,560.40	4,335.38	3,297.79	3,704.54	49,941.46
1982	201,370	3,868.28	3,540.51	4,087.94	4,434.37	4,230.67	5,719.53	7,544.19	7,536.37	5,824.06	4,635.67	4,025.98	3,916.79	59,364.36
1983	207,908	3,807.34	3,528.90	4,049.86	4,843.23	4,759.41	4,940.14	5,427.62	5,959.70	5,252.76	4,635.08	4,032.55	4,320.21	55,556.80
1984	189,570	4,174.63	3,774.93	4,649.09	5,637.09	5,764.44	5,822.61	7,051.41	6,823.53	6,014.81	4,488.72	4,144.55	4,031.78	62,377.59
1985	194,695	4,430.77	3,903.77	4,215.24	4,487.93	4,959.93	4,892.89	5,608.20	7,082.14	5,188.67	4,499.87	3,971.93	3,884.73	57,126.07
1986	227,598	3,667.38	3,528.51	4,771.33	5,060.07	4,756.26	4,619.52	7,404.95	7,487.02	4,983.84	4,431.89	3,849.07	3,862.70	58,422.54
1987	227,946	3,916.54	3,490.90	4,093.48	4,368.10	4,372.94	4,377.95	5,714.71	7,185.84	4,969.83	5,054.75	4,091.40	3,795.76	55,432.20
1988	229,835	4,309.40	4,070.34	4,629.52	5,082.50	5,862.80	5,857.77	5,671.80	6,404.17	5,696.73	5,383.64	4,719.20	4,464.16	62,152.06
1989	236,709	3,771.36	3,351.31	4,297.32	4,924.25	5,889.82	5,620.16	6,803.02	6,967.79	5,975.65	5,359.55	4,162.46	4,515.16	61,637.85
1990	239,891	4,004.57	3,677.73	3,723.96	3,762.04	4,947.29	7,128.05	5,134.70	5,833.34	4,606.71	4,579.55	3,957.86	4,175.53	55,531.33
Average	211,598	3,907.09	3,586.26	4,220.81	4,634.57	4,868.20	5,377.93	6,311.61	6,652.10	5,244.33	4,699.33	4,001.70	4,024.65	57,528.59

Silver Mountain Water Co.

Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1981	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1982	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1983	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1984	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1985	26	0.22	0.21	0.24	0.32	0.44	0.40	0.64	0.73	0.40	0.23	0.14	0.19	4.14
1986	28	0.15	0.24	0.38	0.54	0.26	0.31	0.44	0.44	0.23	0.33	0.20	0.24	3.77
1987	25	0.26	0.19	0.25	0.45	0.28	0.25	0.44	0.43	0.32	0.31	0.21	0.26	3.66
1988	23	0.27	0.21	0.47	0.41	0.42	0.45	0.36	0.48	0.43	0.45	0.26	0.29	4.50
1989	24	0.18	0.17	0.37	0.30	0.61	0.54	0.63	0.46	0.50	0.30	0.19	0.27	4.54
1990	24	0.28	0.26	0.27	0.28	0.44	0.94	0.42	0.53	0.30	0.27	0.26	0.39	4.63
Average	25	0.22	0.21	0.33	0.38	0.41	0.48	0.49	0.51	0.36	0.32	0.21	0.27	4.21

Source: Texas Water Development Board

Table 3-9g
Historical Water Use for Non-Military Water Supply Systems Located Within the Primary Planning Area
(Millions of Gallons)

Twin Valley Water Corp.

Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	123	0.48	0.57	0.66	0.70	0.82	1.07	1.30	1.83	0.99	0.68	0.81	0.66	10.57
1981	124	0.56	0.45	0.69	0.53	1.02	1.04	1.10	0.93	1.15	0.69	1.00	0.58	9.74
1982	136	0.62	1.16	0.77	0.81	1.24	0.81	0.15	0.17	1.75	1.32	1.03	0.86	10.69
1983	141	0.70	0.79	0.63	0.88	1.01	1.34	1.51	1.53	1.62	1.35	0.87	1.04	13.25
1984	143	1.32	0.65	0.94	1.06	1.46	1.40	1.43	1.86	1.65	0.94	0.78	0.78	14.26
1985	149	0.83	0.96	0.84	0.88	1.12	1.05	1.19	1.81	1.74	1.43	1.11	1.06	14.01
1986	144	0.72	0.87	1.64	1.00	1.53	0.98	1.21	1.97	1.90	1.33	0.89	0.90	14.94
1987	137	0.85	0.78	0.85	0.89	1.29	1.07	1.08	1.61	1.81	1.08	1.09	0.84	13.22
1988	139	0.81	0.74	0.95	1.13	1.12	1.39	1.77	1.12	1.75	1.29	1.09	1.24	14.37
1989	140	0.75	0.90	1.00	1.00	1.18	1.74	1.71	1.84	1.87	1.55	1.20	0.91	15.66
1990	138	0.97	0.87	0.94	0.96	1.48	1.97	0.19	1.48	1.09	1.32	0.94	0.98	13.18
Average	138	0.78	0.79	0.90	0.89	1.20	1.26	1.15	1.47	1.57	1.18	0.98	0.89	13.08

Vos Water Company a/

Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1981	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1982	90	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.59
1983	113	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5.47
1984	113	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6.29
1985	113	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5.66
1986	113	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5.10
1987	113	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	13.40
1988	94	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	11.15
1989	103	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	12.83
1990	102	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	12.95
Average	106	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.60

Source: Texas Water Development Board

Table 3-9h
Historical Water Use for Non-Military Water Supply Systems Located Within the Primary Planning Area
(Millions of Gallons)

Waterwood Utilities, Inc.

Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1981	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1982	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1983	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1984	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1985	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1986	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1987	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1989	114	0.44	0.47	0.48	0.75	0.74	1.26	1.11	1.36	1.47	1.14	1.01	0.61	10.82
1990	113	0.54	0.53	0.82	0.90	1.13	1.76	0.87	1.32	0.86	1.09	0.65	0.71	11.19
Average	114	0.49	0.50	0.65	0.83	0.93	1.51	0.99	1.34	1.16	1.11	0.83	0.66	11.00

Windys Water Works, Inc., (Whispering Winds-Crestwood Acres & Palo Alto Park) a/

Year	Number of Connections	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1980	263	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.25	0.25	0.24	0.24	0.24	24.68
1981	296	0.58	1.07	0.90	1.10	1.27	0.86	1.54	1.68	1.26	1.15	1.34	1.03	13.78
1982	405	2.64	2.21	2.13	2.37	2.32	3.36	3.89	3.83	3.16	3.02	2.55	2.77	34.23
1983	446	2.53	2.09	3.04	3.51	3.72	4.84	4.68	4.23	3.87	3.87	3.75	3.60	43.72
1984	465	2.65	2.79	3.80	4.24	5.37	5.40	6.09	5.85	4.62	3.19	3.15	3.50	50.64
1985	511	4.28	3.93	4.48	4.60	5.29	5.83	6.72	8.11	5.64	4.32	3.83	4.84	61.85
1986	531	5.11	4.22	6.15	6.16	5.35	5.06	8.29	6.85	6.11	5.68	5.08	4.03	68.09
1987	538	4.13	4.52	6.27	5.48	5.34	5.35	6.98	7.90	5.85	5.98	6.55	4.50	68.83
1988	574	5.04	6.74	6.49	5.88	5.72	8.03	7.46	9.24	5.46	6.27	3.34	3.96	73.63
1989	617	4.26	3.64	5.12	5.96	6.46	7.43	9.10	8.81	8.00	5.14	4.67	7.19	75.77
1990	636	5.34	5.01	3.98	7.78	11.02	10.51	8.47	8.71	8.20	8.59	5.84	6.71	90.17
Average	500	3.35	3.31	3.87	4.30	4.74	5.17	5.77	5.95	4.76	4.31	3.67	3.85	55.03

a/ TWDB lists an annual total but does not give monthly totals for the year 1980 for Whispering Winds-Crestwood Acres.

Source: Texas Water Development Board

Table 3-10
Bexar-Medina-Atascosa Counties Water Control and Improvement District No. 1
Canal System Inventory

Name	Canal Length (ft)	Canal Length (mi)	Lateral Length (ft)	Lateral Length (mi)	Service Source	Canal Type (1-6)	Right-of-Way Width (ft)	Normal Design Storage Capacity (ac-ft)	Maximum Design Capacity (ac-ft)	Normal Water Surf. Elevation (ft MSL)	Maximum Water Surf. Elevation (ft MSL)
MAIN CANAL	117,200	22.20		0.00	MAIN CANAL	6	215.24	72.64	181.61	48.43	64.57
A-1 CANAL SYSTEM AND SUBORDINATE LATERALS											
A-5	7,200	1.36	5,800	1.10	WEST/A-1	5	18.55	3.77	6.80	2.98	3.84
A-1 CANAL	30,400	5.76	0	0.00		6	55.83	18.84	47.11	12.56	16.75
NO NAME	23,000	4.36	22,800	4.32	A-1	5	63.18	12.39	22.36	10.01	12.91
SER.LAT 1	5,200	0.98	9,000	1.70	A-1	5	17.81	3.11	5.62	2.70	3.49
SER.LAT 2	13,000	2.46	38,000	7.20	A-1	5	58.77	9.02	16.33	8.54	11.04
DEVINE S.	46,800	8.86	0	0.00	A-1	3	85.95	17.19	32.23	12.89	17.19
A-3	23,000	4.36	48,000	9.09	A-1	6	42.24	14.26	35.64	15.01	19.83
CANAL 9	7,800	1.48	6,000	1.14	A-3	4	19.83	3.71	6.79	3.02	3.94
A-4	18,400	3.48	40,600	7.69	A-3	5	71.07	11.71	21.17	10.57	13.66
NATALIA	20,000	3.79	33,400	6.33	A-3	5	67.40	11.87	21.44	10.26	13.25
FORT EWELL	11,000	2.08	7,800	1.48	NATALIA	4	27.36	5.17	9.48	4.18	5.46
B CANAL	2,800	0.53	0	0.00	S CANAL	5	5.14	1.29	2.31	0.90	1.16
B-1	12,000	2.27	0	0.00	S CANAL	3	19.28	4.41	8.26	3.31	4.41
B1-F	4,400	0.83	0	0.00	B1	2	5.05	0.62	1.21	0.68	0.91
B1-K	6,800	1.29	800	0.15	B1	2	8.54	1.01	1.99	1.15	1.52
B1-K-3	6,000	1.14	1,000	0.19	B1-K	1	6.43	0.56	1.03	0.80	1.04
B1-H	6,800	1.29	4,800	0.91	B1	2	12.21	1.34	2.58	1.60	2.12
B1-H-5	6,600	1.25	3,200	0.61	B1-H	1	9.00	0.79	1.44	1.12	1.46
B1-H-3	2,000	0.38	0	0.00	B1-H	1	1.84	0.16	0.29	0.23	0.30
B-19	7,800	1.48	1,000	0.19	B CANAL	3	13.45	2.95	5.52	2.26	3.01
BILLOLIVER	1,600	0.30	0	0.00	B-19	2	1.84	0.22	0.44	0.25	0.33
B-20	2,400	0.45	0	0.00	B CANAL	2	2.75	0.34	0.66	0.37	0.50
B-14	2,400	0.45	0	0.00	B CANAL	2	2.75	0.34	0.66	0.37	0.50
B-12	19,000	3.60	0	0.00	B CANAL	2	21.81	2.66	5.23	2.94	3.93
B-12-A	4,000	0.76	0	0.00	B-12	1	3.67	0.32	0.59	0.46	0.60
B-12-E	2,600	0.49	800	0.15	B-12	1	3.12	0.27	0.50	0.39	0.51
B-12-P	5,800	1.10	0	0.00	B-12	1	5.33	0.47	0.85	0.67	0.87
B-12-B	7,600	1.44	1,000	0.19	B-12	1	7.90	0.69	1.26	0.99	1.28
B-22	2,200	0.42	0	0.00	B CANAL	2	2.53	0.31	0.61	0.34	0.45
B-24	6,000	1.14	1,200	0.23	B CANAL	2	7.99	0.94	1.83	1.07	1.42
B-24-A	2,200	0.42	2,400	0.45	B-24	1	4.22	0.37	0.68	0.53	0.69
B-35	10,000	1.89	4,200	0.80	B CANAL	3	19.93	4.01	7.50	3.24	4.30
B-35-E	2,400	0.45	0	0.00	B-35	2	2.75	0.34	0.66	0.37	0.50
B-35-A	5,200	0.98	0	0.00	B-35	2	5.97	0.73	1.43	0.81	1.07
B-42	9,200	1.74	2,200	0.42	B CANAL	3	16.80	3.56	6.66	2.79	3.71
B-42-D	2,000	0.38	0	0.00	B-42	2	2.30	0.28	0.55	0.31	0.41
B-42-F	11,800	2.23	8,400	1.59	B-42	2	21.26	2.32	4.48	2.79	3.69
B-45	3,200	0.61	0	0.00	B CANAL	2	3.67	0.45	0.88	0.50	0.66
B-51	3,200	0.61	600	0.11	B CANAL	2	4.22	0.50	0.97	0.56	0.75
B-69	12,200	2.31	0	0.00	B CANAL	2	14.00	1.71	3.36	1.89	2.52
B-69-B	1,600	0.30	0	0.00	B-69	1	1.47	0.13	0.24	0.18	0.24
B-62	10,200	1.93	5,000	0.95	B CANAL	2	16.30	1.83	3.54	2.15	2.85
B-66	3,800	0.72	4,000	0.76	B CANAL	2	8.03	0.85	1.63	1.05	1.38
B-72	4,000	0.76	0	0.00	B CANAL	2	4.59	0.56	1.10	0.62	0.83
B-73	7,800	1.48	800	0.15	B CANAL	2	9.69	1.15	2.27	1.30	1.73
B-81	2,800	0.53	0	0.00	B CANAL	2	3.21	0.39	0.77	0.43	0.58
B-77	4,800	0.91	0	0.00	B CANAL	3	7.71	1.76	3.31	1.32	1.76
B-77-D	1,200	0.23	0	0.00	B CANAL	2	1.38	0.17	0.33	0.19	0.25
B-4	7,200	1.36	0	0.00	B CANAL	3	11.57	2.64	4.96	1.98	2.64
MACDONA	14,400	2.73	2,000	0.38	B CANAL	4	28.28	6.11	11.20	4.53	5.92
M-24	10,000	1.89	0	0.00	MACDONA	3	16.07	3.67	6.89	2.75	3.67
M-6	2,800	0.53	0	0.00	MACDONA	3	4.50	1.03	1.93	0.77	1.03
M-15	4,000	0.76	0	0.00	MACDONA	3	6.43	1.47	2.75	1.10	1.47
M-15-A	2,800	0.53	0	0.00	M-15	2	3.21	0.39	0.77	0.43	0.58
M-11	5,200	0.98	0	0.00	MACDONA	3	8.36	1.91	3.58	1.43	1.91
M-11-C	4,000	0.76	0	0.00	M-11	2	4.59	0.56	1.10	0.62	0.83
S CANAL	25,000	4.73	5,800	1.10	A-1 CANAL	4	51.24	10.80	19.79	8.13	10.62
S-4	4,800	0.91	0	0.00	S CANAL	2	5.51	0.67	1.32	0.74	0.99
S-4-D	2,000	0.38	0	0.00	S-4	1	1.84	0.16	0.29	0.23	0.30
S-8	3,000	0.57	0	0.00	S CANAL	2	3.44	0.42	0.83	0.46	0.62
S-19	2,000	0.38	0	0.00	S CANAL	2	2.30	0.28	0.55	0.31	0.41
S-35	2,800	0.53	0	0.00	S CANAL	2	3.21	0.39	0.77	0.43	0.58
S-35-1	3,800	0.72	0	0.00	S-35	1	3.49	0.31	0.56	0.44	0.57
S-28	4,000	0.76	0	0.00	S CANAL	2	4.59	0.56	1.10	0.62	0.83
S-29	1,200	0.23	0	0.00	S CANAL	2	1.38	0.17	0.33	0.19	0.25
JARRATT	3,200	0.61	2,000	0.38	S CANAL	3	6.98	1.34	2.50	1.11	1.47
J-1	2,000	0.38	0	0.00	JARRATT	2	2.30	0.28	0.55	0.31	0.41
RANDLE	17,000	3.22	4,400	0.83	S CANAL	3	31.36	6.60	12.35	5.19	6.90
R-8	2,000	0.38	0	0.00	RANDLE	2	2.30	0.28	0.55	0.31	0.41
R-8-F	1,200	0.23	0	0.00	R-8	1	1.10	0.10	0.18	0.14	0.18
R-12	4,000	0.76	3,000	0.57	RANDLE	2	7.35	0.80	1.54	0.96	1.27
R-4	2,200	0.42	0	0.00	RANDLE	2	2.53	0.31	0.61	0.34	0.45
WHEELER	2,800	0.53	0	0.00	RANDLE	2	3.21	0.39	0.77	0.43	0.58

Table 3-10 (Continued)
Bexar-Medina-Atascosa Counties Water Control and Improvement District No. 1
Canal System Inventory

Name	Canal Length (ft)	Canal Length (mi)	Lateral Length (ft)	Lateral Length (mi)	Service Source	Canal Type (1-6)	Right-of-Way Width (ft)	Normal Design Storage Capacity (ac-ft)	Maximum Design Capacity (ac-ft)	Normal Water Surf. Elevation (ft MSL)	Maximum Water Surf. Elevation (ft MSL)
LUCKEY	3,800	0.72	0	0.00	RANDLE	2	4.36	0.53	1.05	0.59	0.79
WISDOM L.	6,200	1.17	0	0.00	S CANAL	3	9.96	2.28	4.27	1.71	2.28
W-6	3,600	0.68	0	0.00	WISDOM L.	2	4.13	0.50	0.99	0.56	0.74
W-15	1,800	0.34	0	0.00	WISDOM L.	2	2.07	0.25	0.50	0.28	0.37
W-16	4,000	0.76	0	0.00	WISDOM L.	2	4.59	0.56	1.10	0.62	0.83
W-1	1,600	0.30	0	0.00	WISDOM L.	2	1.84	0.22	0.44	0.25	0.33
SUBTOTAL	566,600	107.31	270,000	51.14			1,060.24	197.77	388.74	171.64	225.83
D-1 CANAL AND SUBORDINATE LATERALS											
D-1 CANAL	60,000	11.36	0	0.00		6	110.19	37.19	92.98	24.79	33.06
A-6	9,000	1.70	10,800	2.05	D-1	5	26.45	5.00	9.02	4.13	5.33
1-F	8,000	1.52	0	0.00	D-1	3	12.86	2.94	5.51	2.20	2.94
1-K	5,000	0.95	0	0.00	D-1	3	8.03	1.84	3.44	1.38	1.84
2-W	2,600	0.49	0	0.00	D-1	2	2.98	0.36	0.72	0.40	0.54
2-X	8,800	1.67	1,200	0.23	D-1	2	11.20	1.33	2.60	1.50	2.00
2-A	12,000	2.27	12,000	2.27	D-1	2	24.79	2.64	5.07	3.24	4.27
33-B	13,800	2.61	31,200	5.91	D-1	4	53.99	8.21	15.04	7.70	10.04
33-Y	17,000	3.22	0	0.00	D-1	2	19.51	2.38	4.68	2.63	3.51
33-BB	4,400	0.83	0	0.00	D-1	2	5.05	0.62	1.21	0.68	0.91
33-A-A	5,000	0.95	2,400	0.45	D-1	3	10.24	2.03	3.80	1.65	2.19
33-K	19,800	3.75	14,000	2.65	D-1	3	44.67	8.40	15.69	7.06	9.36
34-A	11,600	2.20	0	0.00	33-K	2	13.31	1.62	3.20	1.80	2.40
D-2	90,000	17.05	0	0.00	D-1	6	165.29	55.79	139.46	37.19	49.59
33-FF	3,600	0.68	0	0.00	D-1	3	5.79	1.32	2.48	0.99	1.32
2-N	5,600	1.06	0	0.00	D-1	2	6.43	0.78	1.54	0.87	1.16
33-HH	4,400	0.83	0	0.00	D-1	2	5.05	0.62	1.21	0.68	0.91
33-II	15,000	2.84	0	0.00	D-1	2	17.22	2.10	4.13	2.32	3.10
SEC 32	44,000	8.33	0	0.00	D-2	3	70.71	16.16	30.30	12.12	16.16
SEC 35	25,000	4.73	0	0.00	D-2	2	28.70	3.50	6.89	3.87	5.17
2-V	15,000	2.84	0	0.00	D-2	2	17.22	2.10	4.13	2.32	3.10
SUBTOTAL	379,600	71.89	71,600	13.56			659.69	156.90	353.11	119.55	158.88
TOTAL	1,063,400	201.40	341,600	64.70			1,935.17	427.32	923.46	339.62	449.29

Table 3-11
List of Major Land Owners with Irrigation
from the BMA canal System, As of May, 1992

	Name	Acreage
1	Martina Milward	865.35
2	Henry Lee Keller	614.55
3	H. Kyle Seale	321.25
4	Alta Vista Farms	293.78
5	Manhattan Farms	269.40
6	Rex Mayhew	267.23
7	Clines Haby Estate	250.00
8	Hymann Farms	219.00
9	Kohlleppel Brothers	217.22
10	E. E. Liebe	206.14
11	Aldredge Nursery	206.12
12	W. H. Lampkin	200.00
13	Albert Grothues	199.21
14	William Centilli	157.87
15	Steve Bourquin	150.46
16	Tony Constanzo	148.43
17	Alamo Stud Farm	132.00
18	Silver Lake Farms	128.60
19	Mark Lamon	120.65
20	Ronert Brady	117.47
21	W. A. Peauy	111.81
22	Carl Hurber	109.64
23	W. E. Russell	107.80
24	Cole Brothers (L. R. Cole)	106.64
25	J. W. Ward III	104.18
26	A. V. Thurman	103.00
27	Carles. Holtzhauser	101.00
28	James U. Haby	100.03
29	Constanzo Brothers	94.76
30	V. Hansmann Kinsley	94.00
31	Forrest Rotramel	87.22
32	Thomas Key	85.11
33	Al Mansur	84.00
34	Harry Bohl	82.00
35	Carlos Barrera	80.34
36	Carl Lucker	80.00
37	Alfonso Villarreal	80.00
38	James McGrath	75.00
39	Glenn Haass	74.00
	Total Acreage	6845.26

Owners of Irrigation Tracts Greater than 50 Acres in size
Source: Bexar-Medina Atascosa WCID No. 1

Table 3-12
Tabulation of Annual Fixed Assessments and Water Sales to BMA Irrigators for the Period 1980 - 1990

Year	Fixed Water Assessments ($)	Flat Tax ($/ac.)	Total Acreage (ac.)	Irrigation Water Sales ($)	Water Charges ($/ac.)	Total Water Sold (ac.)
1980	204250.00	6.00	34041.67	141485.00	4.00	35371.25
1981	205821.00	6.00	34303.50	64498.00	4.00	16124.50
1982	205973.00	6.00	34328.83	147637.00	6.00	24606.17
1983	205671.00	6.00	34278.50	124557.00	6.00	20759.50
1984	205925.00	6.00	34320.83	261273.00	6.00	43545.50
1985	275752.00	8.00	34469.00	95160.00	6.00	15860.00
1986	206925.00	6.00	34487.50	118856.00	6.00	19809.33
1987	275642.00	8.00	34455.25	73727.00	6.00	12287.83
1988	275009.00	8.00	34376.13	205101.00	6.00	34183.50
1989	308943.00	9.00	34327.00	258169.00	6.00	43028.17
1990	308815.00	9.00	34312.78	180796.00	7.00	25828.00
Average	243520.55	7.09	34336.45	151932.64	5.73	26491.25

Source: Bexar-Medina-Atascosa Counties Water Control and Improvement District No. 1 - Audited Financial Statements 1980 - 1990

Table 3-13
Mathematical Relationship between Total Acres Receiving Water and Total Water Diverted

Year	Total Water Sold (ac)	Total Water Diverted (ac-ft)
1980	35,371.25	46,246.23
1981	16,124.50	30,194.78
1982	24,606.17	46,401.90
1983	20,759.50	37,655.89
1984	43,545.50	53,134.45
1985	15,860.00	23,216.39
1986	19,809.33	34,323.88
1987	12,287.83	30,274.28
1988	34,183.50	39,728.98
1989	43,028.17	62,332.22
1990	25,828.00	36,308.29
AVG	26,491.25	39,983.39
Regression Output		
Constant		-8210.63
Std Err of Y Est		5223.87
R-Squared		0.80
No. of Observations		11
Degrees of Freedom		9
X Coefficient(s)		0.87
Std. Err. of Est.		0.15

TARW = 0.97*TWD - 8,210.63

Where:
TARW = Total Acres Receiving Water
TWD = Total Water Diverted as measure at the USGS gage in the main Canal

Table 3-14
Irrigation Summary for Medina and Bexar Counties
1958, 1964, and 1974: Surface Water Irrigation Only

	Medina County			Bexar County		
Year	Acres	Acre-Feet	Acre-Feet Application Rate (ac-ft/ac)	Acres	Acre-Feet	Acre-Feet Application Rate (ac-ft/ac)
1958	5,400	10,661	1.97	10,500	14,845	1.41
1964	10,500	23,708	2.26	14,700	29,371	2.00
1969	13,100	29,967	2.29	6,573	7,053	1.07
1974	13,250	28,634	2.16	14,128	13,953	0.99
		Average Per County	2.17			1.37
		Average for Both Counties	1.77			

Table 3-15
Projection of BMA Irrigation Lands and Water Requirements

Year	Actual Acres Irrigated High Case (ac)	Actual Acres Irrigated Low Case (ac)	Total Acres Receiving Water One or more Times High (ac)	Total Acres Receiving Water One or more Times Low (ac)	High Projected Without Conservation (ac-ft)	Low Projected Without Conservation (ac-ft)	High Projected With Conservation (ac-ft)	Low Projected With Conservation (ac-ft)
1990	11836	11836	22762	22762	35687	35687	35687	35687
1995	11688	11514	22478	22143	35359	34974	33591	33225
2000	11542	11201	22197	21542	35036	34281	31532	30852
2005	11398	10897	21920	20956	34717	33606	29509	28565
2010	11256	10601	21647	20387	34401	32950	27521	26360
2015	11116	10313	21376	19833	34090	32312	27272	25849
2020	10977	10033	21110	19294	33783	31691	27026	25352

Table 3-16
Bexar-Medina-Atascosa Counties W.C.I.D. No. 1
Historical Irrigation by Crop Category

Year 1980

Month	Corn (ac.)	Grain (ac.)	Grass (ac.)	Vegetables (ac.)	Other (ac.)	Total (ac.)	Tank (ac-ft)
Jan			45.0	57.0	436.0	538.0	92.0
Feb	147.0		224.0	160.8	529.0	1060.8	104.0
Mar	227.0	50.0	312.0	100.0	366.0	1055.0	72.0
Apr	1824.1	261.0	1826.0	539.5	1081.3	5531.9	200.0
May	557.0	44.0	320.0	152.0	214.8	1287.8	21.0
Jun	4749.6	2963.5	1870.7	637.0	924.7	11145.4	259.0
Jul	1336.6	91.0	2753.5	547.0	1010.5	5738.6	293.0
Aug		4.0	500.7	346.5	452.4	1303.6	116.0
Sep		4.0	469.0	329.0	173.0	975.0	88.0
Oct			873.0	366.0	181.9	1420.9	144.0
Nov			339.5	160.0	116.0	615.5	111.0
Dec			31.0	6.0	16.0	53.0	68.0
Total	8841.3	3417.5	9564.3	3400.8	5501.6	30725.4	1568.0

Year 1981

Month	Corn (ac.)	Grain (ac.)	Grass (ac.)	Vegetables (ac.)	Other (ac.)	Total (ac.)	Tank (ac-ft)
Jan		9.0	41.0	105.0	55.0	210.0	94.0
Feb	37.0		42.0	114.0	39.0	232.0	97.0
Mar	14.0	54.0	159.0	180.0	181.5	588.5	144.0
Apr	28.5	47.0	699.5	304.5	380.0	1459.5	147.0
May	3744.5	243.0	496.5	364.0	751.5	5599.5	187.5
Jun	389.0		66.0	25.0	28.0	508.0	70.0
Jul	488.0	4.0	522.0	289.0	382.0	1685.0	146.0
Aug	24.0	17.0	646.0	453.0	500.5	1640.5	272.5
Sep			296.5	386.0	238.0	920.5	122.0
Oct			180.0	156.0	102.0	438.0	70.0
Nov			176.5	220.0	93.0	489.5	62.5
Dec			259.5	263.0	276.5	799.0	83.0
Total	4725.0	374.0	3584.5	2859.5	3027.0	14570.0	1495.5

Year 1982

Month	Corn (ac.)	Grain (ac.)	Grass (ac.)	Vegetables (ac.)	Other (ac.)	Total (ac.)	Tank (ac-ft)
Jan	163.0	5.0	52.0	97.0	242.5	559.5	92.0
Feb	1070.0	11.0	81.0	192.0	321.0	1675.0	70.0
Mar	28.0		370.7	246.0	235.0	879.7	117.0
Apr	666.0	133.0	979.5	522.7	551.1	2852.2	162.0
May	19.0		12.0	44.0	12.0	87.0	36.0
Jun	6017.0	128.0	729.0	644.0	374.3	7892.3	186.0
Jul	794.0	36.0	1708.0	498.5	597.2	3633.7	241.0
Aug	13.5	26.0	1408.6	530.0	703.5	2681.6	144.0
Sep		4.0	1243.0	496.5	377.5	2121.0	145.0
Oct		6.0	430.0	165.0	230.0	831.0	95.0
Nov			96.0	122.0	97.0	315.0	125.0
Dec			5.0	8.0	32.3	45.3	36.0
Total	8770.5	349.0	7114.7	3565.7	3773.4	23573.3	1449.0

Table 3-16 (Cont.)
Bexar-Medina-Atascosa Counties WCID No. 1
Historical Irrigation by Crop Category

Year 1983

Month	Corn (ac.)	Grain (ac.)	Grass (ac.)	Vegetables (ac.)	Other (ac.)	Total (ac.)	Tank (ac-ft)
Jan			5.0	24.0	44.0	73.0	75.0
Feb			4.0	46.0	75.0	125.0	69.0
Mar			89.0	131.0	132.0	352.0	78.0
Apr	476.0	96.0	1039.0	489.5	568.0	2668.5	147.0
May	2837.8	223.0	1133.0	354.0	281.0	4828.8	142.0
Jun	2512.0	31.0	295.0	213.0	203.5	3254.5	121.0
Jul	1431.0	4.0	678.3	237.0	457.9	2808.2	123.0
Aug	16.0	4.0	835.5	448.5	566.5	1870.5	188.0
Sep		85.0	530.0	317.5	535.0	1467.5	110.0
Oct		202.0	271.0	364.0	248.8	1085.8	105.0
Nov	5.0	257.0	101.0	211.0	254.0	828.0	131.0
Dec		141.0	32.0	91.0	135.0	399.0	79.0
Total	7277.8	1043.0	5012.9	2926.5	3500.6	19760.8	1368.0

Year 1984

Month	Corn (ac.)	Grain (ac.)	Grass (ac.)	Vegetables (ac.)	Other (ac.)	Total (ac.)	Tank (ac-ft)
Jan		36.0	24.0	54.0	89.0	203.0	80.0
Feb	13.0	64.0	193.0	153.0	253.0	676.0	97.0
Mar	1466.0	307.0	1284.0	432.0	2303.0	5792.0	183.0
Apr	2179.0	311.0	2071.0	495.5	1186.0	6242.5	167.0
May	5158.0	297.0	2454.0	1786.0	1502.0	11197.0	206.0
Jun	4998.0	50.0	1528.0	346.0	2493.0	9415.0	126.0
Jul	718.6	50.0	3406.0	552.0	3625.7	8352.2	262.0
Aug	3.0	62.0	3233.0	500.0	1044.6	4842.6	267.0
Sep		7.0	1440.0	400.5	313.0	2160.5	194.0
Oct			286.0	28.0	106.0	420.0	54.0
Nov			12.0	28.0	29.0	69.0	28.0
Dec				7.0	8.3	15.3	
Total	14535.6	1184.0	15931.0	4782.0	12952.5	49385.1	1664.0

Year 1985

Month	Corn (ac.)	Grain (ac.)	Grass (ac.)	Vegetables (ac.)	Other (ac.)	Total (ac.)	Tank (ac-ft)
Total	5558.0	3050.0	1250.0	980.0	754.0	11592.0	1124.0

Table 3-16 (Cont.)
Bexar-Medina-Atascosa Counties WCID No. 1
Historical Irrigation by Crop Category

Year 1986

Month	Corn (ac.)	Grain (ac.)	Grass (ac.)	Vegetables (ac.)	Other (ac.)	Total (ac.)	Tank (ac-ft)
Jan		8.0	50.0	98.0	17.0	173.0	85.0
Feb	60.0		364.0	161.0	145.0	730.0	144.0
Mar	395.7	65.0	892.0	387.7	700.8	2441.2	218.0
Apr	2654.0	434.0	1428.0	480.5	555.5	5552.0	186.0
May	2421.0	27.0	567.5	115.5	111.8	3242.8	88.0
Jun	501.0		12.0	18.0	25.9	556.9	16.0
Jul	78.0	8.0	1325.0	502.0	538.3	2451.3	209.0
Aug		17.0	1407.0	447.0	689.6	2560.6	223.0
Sep		64.0	169.0	363.0	88.0	684.0	180.0
Oct		8.0	82.0	63.0	37.2	190.2	24.0
Nov		4.0		5.0	15.9	24.9	46.0
Dec				12.0		12.0	29.0
Total	6109.7	635.0	6296.5	2652.7	2925.0	18618.9	1448.0

Historical Irrigation by Crop Category (Summary)

Year	Corn (ac.)	Grain (ac.)	Grass (ac.)	Vegetables (ac.)	Other (ac.)	Total (ac.)	Tabk (ac-ft)
1980	8841.29	3417.5	9564.28	3400.81	5501.56	30725.44	1568
1981	4725	374	3584.5	2859.5	3027	14570	1495.5
1982	8770.48	349	7114.73	3565.66	3773.41	23573.28	1449
1983	7277.8	1043	5012.85	2926.5	3500.63	19760.78	1368
1984	14535.59	1184	15931	4782	12952.51	49385.1	1664
1985	5558	3050	1250	980	754	11592	1124
1986	6109.66	635	6296.5	2652.74	2925.01	18618.91	1448
AVG	7973.97	1436.07	6964.84	3023.89	4633.45	24032.22	1445.21

Source: BMA Records and TWC Report of Surface Water Used

1985 monthly data was not available from BMA. Annual data for 1985 was obtained from the TWC's Annual Report of Surface Water Used

Table 3-17
Monthly Diversions (ac-ft) To BMA Main Canal

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1958	75.01	250.03	696.07	2,570.27	2,170.23	5,140.54	3,500.37	6,040.64	1,040.11	463.05	740.08	2,800.30	25,486.70
1959	2,230.24	315.03	2,490.26	2,570.27	2,360.25	5,240.55	4,940.52	4,870.52	3,610.38	2,640.28	2,230.24	1,360.14	34,858.69
1960	1,540.16	1,110.12	2,050.22	2,810.30	5,030.53	6,950.74	2,330.25	3,860.41	4,540.48	3,610.38	1,060.11	510.05	35,403.74
1961	853.09	660.07	4,500.48	6,020.64	8,410.89	4,590.49	2,820.30	3,250.34	4,800.51	3,490.37	953.10	1,430.15	41,780.42
1962	3,320.35	2,450.26	4,600.49	2,430.26	5,690.60	5,550.59	7,710.82	7,880.83	4,280.45	5,560.59	3,490.37	3,030.32	55,995.92
1963	114.01	2,850.30	3,250.34	3,610.38	3,860.41	7,080.75	6,410.68	8,820.93	4,460.47	4,160.44	1,870.20	414.04	46,902.96
1964	1,660.18	473.05	1,540.16	1,980.21	4,890.52	3,290.35	8,590.91	5,740.61	2,830.30	2,240.24	253.03	757.08	34,246.62
1965	1,590.17	201.02	569.06	636.07	536.06	3,250.34	6,900.73	4,980.53	4,490.47	611.06	1,280.14	171.02	25,216.67
1966	388.04	401.04	1,530.16	2,470.26	680.07	5,940.63	5,800.61	2,890.31	1,310.14	2,650.28	3,210.34	2,760.29	30,032.18
1967	2,280.24	2,660.28	5,610.59	2,010.21	7,750.82	9,020.95	6,160.65	6,340.67	616.07	1,170.12	400.04	365.04	44,385.69
1968	1.10	117.01	587.06	931.10	980.10	3,820.40	4,030.43	6,680.71	657.07	2,510.27	2,030.21	612.06	22,957.53
1969	994.11	735.08	1,040.11	1,820.19	1,010.11	4,810.51	6,030.64	5,250.56	2,190.23	1,180.12	843.09	550.06	26,454.80
1970	716.08	583.06	337.04	2,150.23	2,290.24	3,610.38	4,290.45	4,350.46	2,980.32	1,730.18	3,680.39	2,910.31	29,629.13
1971	440.05	4,610.49	5,860.62	7,390.78	9,661.02	7,990.85	5,400.57	1,030.11	1,040.11	182.02	806.09	250.03	44,662.72
1972	1,132.77	921.64	4,848.63	7,821.26	1,329.30	3,024.39	5,290.85	2,285.38	3,399.97	2,821.94	664.91	894.73	34,435.75
1973	370.30	521.27	954.91	292.11	4,141.06	3,199.02	1,203.35	2,300.67	878.19	109.05	722.97	1,949.37	16,642.27
1974	1,657.85	2,518.51	4,440.11	6,617.53	2,049.63	6,353.78	8,049.31	2,800.84	306.07	1,473.01	281.34	789.25	37,337.23
1975	747.22	609.42	3,238.37	2,157.47	204.81	1,985.06	3,010.35	4,697.91	2,225.01	3,563.71	2,225.01	2,312.29	26,976.64
1976	1,622.95	4,461.92	2,801.71	392.97	219.98	5,225.97	1,513.21	4,144.63	3,058.78	167.39	110.30	2.72	23,722.53
1977	5.02	387.61	2,405.47	1,067.73	1,010.38	5,429.27	4,755.42	6,926.89	2,201.83	2,381.82	1,459.55	2,082.23	30,113.21
1978	1,877.97	1,260.09	4,104.97	3,124.12	4,271.55	7,404.61	10,992.20	3,353.78	385.23	2,728.71	600.99	837.47	40,941.71
1979	137.07	144.05	805.19	757.99	4,652.10	4,197.30	4,019.94	3,153.09	3,387.67	4,757.40	2,728.71	927.49	29,668.01
1980	1,435.15	1,901.77	5,364.23	5,627.97	1,946.85	9,405.74	9,264.94	3,471.38	2,245.84	3,535.83	1,669.75	376.78	46,246.23
1981	878.31	937.60	1,108.56	2,321.59	5,314.65	1,035.78	4,580.91	4,993.39	2,744.58	1,698.51	2,298.39	2,282.52	30,194.78
1982	2,076.28	2,413.43	2,447.12	4,323.11	2,203.56	8,408.25	7,626.92	6,000.79	5,635.91	2,732.28	1,745.27	788.99	46,401.90
1983	716.09	1,156.13	1,080.84	3,694.47	5,512.56	4,300.07	5,069.14	3,802.75	4,301.30	2,840.56	2,954.79	2,227.19	37,655.89
1984	53.54	1,753.04	5,199.63	7,137.10	7,920.41	7,121.23	9,623.88	7,212.45	5,645.82	1,141.86	325.48	0.00	53,134.45
1985	0.00	711.92	1,155.34	1,269.17	3,147.14	4,477.79	5,326.55	2,256.74	1,549.38	1,270.06	904.48	1,147.81	23,216.39
1986	1,245.97	1,290.19	4,170.41	6,292.31	3,520.08	842.21	5,606.16	6,746.43	2,564.12	700.26	826.15	519.59	34,323.88
1987	710.74	559.05	819.21	2,970.65	1,293.56	1,452.60	5,572.45	5,844.13	2,833.82	4,465.89	2,108.01	1,644.17	30,274.28
1988	5,074.70	3,426.76	2,956.77	2,679.14	2,585.93	2,617.66	2,340.03	2,187.33	1,879.96	6,312.14	3,884.85	3,783.71	39,728.98
1989	2,699.48	1,070.92	2,839.77	3,825.36	8,658.12	9,036.89	9,794.42	9,161.82	7,843.07	6,464.89	0.00	937.48	62,332.22
1990	3,874.93	2,338.17	598.89	961.79	3,809.49	9,673.45	5,294.82	5,588.31	4,168.43	0.00	0.00	0.00	36,308.29
Avg	1,288.46	1,387.89	2,606.14	3,113.18	3,609.49	5,196.34	5,571.30	4,815.65	2,912.18	2,465.60	1,465.40	1,255.29	35,686.92
Max	5,074.70	4,610.49	5,860.62	7,821.26	9,661.02	9,673.45	10,992.20	9,161.82	7,843.07	6,464.89	3,884.85	3,783.71	62,332.22
Min	0.00	117.01	337.04	292.11	204.81	842.21	1,203.35	1,030.11	306.07	0.00	0.00	0.00	16,642.27

Source: USGS Water Resources Data, Texas, Volume 3 Gage No. 08180000 - Medina Canal near Rio Medina

Table 3-18
Recognized TWC Water Rights in the Medina River Basin, as of June 18, 1992

Ownership	Total Annual Diversion (ac-ft)	Maximum Diversion Rate (cfs)	Total Impoundment Allowed (ac-ft)	Authorized Use
J. Held	19	1.00		Irrigation
B. H. Gaskin	44	1.30		Irrigation
N. Marr	2	0.60		Irrigation
D. F. Mead	21	1.00		Irrigation
Texas Petroleum Co.	4	0.30		Irrigation
M. Winkenhower	27	0.20		Irrigation
S. C. Tracy	35	0.40		Irrigation
P. A. Grothues	16	2.20		Irrigation
M. E. Johnson	7	0.10		Irrigation
R. Hicks	3	0.22		Irrigation
Bandera Electric Coop.	2	0.22		Irrigation
D. F. Tobin	152	1.90		Irrigation
W. S. Thompson	48	0.56		Irrigation
J. B. Parker	16	0.50		Irrigation
BMA (CF No. 18)	66750			Irrigation
BMA (CF No. 18)			4500	Medina Div. Reservoir
BMA WID No. 1			237874	Medina Lake
Total above Medina Lake	67146		242374	
BMA (CF No. 19)	2000	22.20	730	Chacon Reservoir
Medina Ranch, Inc.			4500	Recreation
H Tschirhart	18	0.10		Irrigation
M. I. Haby	50	3.30		Irrigation
A. C. Santleben	156	3.30		Irrigation
Meropolitan Resources inc.	963	2.20		Irrigation
Straus Medina Ranch	308	4.70		Irrigation
J. Spears	32	0.70		Irrigation
A. T. Walsh	200	8.00		Irrigation
C. L. Pattillo	240	5.00		Irrigation
City of San Antonio	294	7.80		Irrigation
Total Below Medina Lake	4261		5230	
Total River Basin	71407		252834	

Source: Final Determination of Claims of Water Rights in The Medina River Watershed of the San Antonio River Basin, May 23, 1978 and Texas Water Commission Report on Water Rights as of June 18, 1992

Table 3-19
Discharge Measurements, Medina Canal Performed by the USGS 1969

Site No.	Date 1969	Stream	Location	Canal miles from head	Water Temp. (F)	Water Temp. (C)	Discharge (cfs)	Remarks
1	Aug. 15	Medina Canal	At stream gaging station Medina Canal near Riomedina	0.4	68	20.5	106	Canal is concrete-lined, trapezoidal shape, and with a slight algae growth.
2	Aug. 15	Medina Canal	At Medina Dam Road 1.6 miles northwest of Riomedina	4.8	69	21	106	Canal bed is firm clay and gravel. Heavy growth of grass and some brush on banks.
3	Aug. 15	Medina Canal	On Quihi Road, 2.4 miles west of Riomedina	6.3	73	23	103	Canal bed is firm clay and gravel. Heavy growth of grass and weeds with a heavy growth of brush on right bank.
4	Aug. 15	Medina Canal	On U.S. Highway 90, 0.2 mile west of Castroville	16.3	78	26	104	Canal bed is firm clay. Heavy growth of grass and some brush on banks.
5	Aug. 15	Medina Canal	On private road, 1.1 miles northwest of Pearson	24	82	28	102	Canal bed is firm clay. Heavy growth of grass and weeds with on banks.

Source: USGS , August 1969

Table 3-20
Bexar-Medina-Atascosa Irrigation District Canal Study by TWDB
October 1-4, 1991

Location	Date	Sta. No.	Mile	Flow (cfs)	Total Flow (cfs)	Gain/ Loss (cfs)
Medina River Below Dam	10/1/91	1	-	76.13	76.13	-
Release Through Diversion Dam	10/1/91	2	-	3.70	-	-
Diversion Into Canal	10/1/91	2	-	36.03	-	-
Flow At Diversion Dam	10/1/91	2	-	-	39.73	-36.40
Diversion Into Canal	10/1/91	2	-	36.03	-	-
Below Siphon #2	10/1/91	3	2	34.32	34.32	-1.71
100' Below Siphon #2	10/1/91	4	2	34.12	34.12	-0.20
Diversion Into Canal	10/2/91	2	-	36.55	36.55	-
Irrigation Canal	10/2/91	5	2.8	30.02	30.02	-6.53
Irrigation Canal	10/2/91	6	4.8	28.42	28.42	-1.60
Irrigation Canal	10/2/91	7	6.4	27.07	27.07	-1.35
Irrigation Canal	10/2/91	8	10.5	25.93	25.93	-1.14
Irrigation Canal	10/3/91	9	13.8	24.63	24.63	-1.30
Irrigation Canal	10/3/91	10	15.1	26.63	26.63	2.00
Irrigation Canal	10/3/91	11	16.1	26.63	26.23	-0.40
Irrigation Canal	10/4/91	11	16.1	29.92	29.92	-
Irrigation Canal	10/4/91	12	18.1	34.73	34.73	4.81
Irrigation Canal	10/4/91	13	19.5	30.88	30.88	-3.85
Irrigation Canal	10/4/91	14	21.4	31.10	31.10	0.22
Irrigation Canal	10/4/91	15	22.3	30.49	30.49	-0.61
Irrigation Canal	10/4/91	16	24.3	28.63	28.63	-1.86

Source: Texas Water Development Board, October 1991

Table 3-20 (Continued)
Bexar-Medina-Atascosa Irrigation District Canal Flow Study
October 15-17, 1991

Location	Date	Sta. No.	Mile	Flow (cfs)	Total Flow (cfs)	Gain/ Loss (cfs)
Main Below D1	10/15/91	1	25.8	-	36.37	-
Lateral	10/15/91	2	27.6	6.77	29.60	-
Lateral	10/15/91	3	30.7	0.78	29.52	-
Lateral Leak	10/15/91	4	31.5	3.65	26.97	-
Lateral	10/15/91	4	31.5	0.03	26.94	-
Lateral	10/15/91	6	32.4	3.67	23.27	-
Main	10/15/91	7	32.9	-	26.30	3.83
Main	10/16/91	7	32.9	-	21.39	-
Lateral	10/16/91	8	33.2	6.77	14.62	-
Lateral	10/16/91	9	34.1	2.34	12.28	-
Lateral	10/16/91	11	33.4	0.49	11.79	-
Main	10/16/91	10	34.2	-	8.08	-3.71
Lateral	10/16/91	12	36.4	1.91	6.17	-
Main	10/16/91	13	37.8	-	5.96	-0.21
Lateral	10/16/91	14	-	1.20	4.76	-
Lateral	10/16/91	15	38.2	0.56	4.20	-
Lateral	10/16/91	16	39.9	0.46	3.74	-
Lateral	10/16/91	18	41.1	2.48	1.26	-
Main	10/16/91	19	42.6	-	2.93	1.67

Source: Texas Water Development Board, October 1991

Table 4-1
Projected Population for Bexar County
From Texas Water Development Board Draft 1992 Report
(1990-2040)

	Castle Hills				Fort Sam Houston				Lackland AFB			
	Low Series		High Series		Low Series		High Series		Low Series		High Series	
Year	Population (# People)	Projected % Change	Population (# People)	Projected % Change	Population (# People)	Projected % Change	Population (# People)	Projected % Change	Population (# People)	Projected % Change	Population (# People)	Projected % Change
1990	4,198		4,198		12,000		12,000		9,352		9,352	
2000	4,791	14.13%	4,792	14.15%	11,998	-0.02%	12,000	0.00%	9,735	4.10%	9,736	4.11%
2010	5,081	6.05%	5,112	6.68%	11,928	-0.58%	12,000	0.00%	9,678	-0.59%	9,736	0.00%
2020	5,360	5.49%	5,410	5.83%	11,890	-0.32%	12,000	0.00%	9,647	-0.32%	9,736	0.00%
2030	5,527	3.12%	5,681	5.01%	11,674	-1.82%	12,000	0.00%	9,471	-1.82%	9,736	0.00%
2040	5,529	0.04%	5,830	2.62%	11,380	-2.52%	12,000	0.00%	9,233	-2.51%	9,736	0.00%

	Randolph AFB				City of San Antonio				Other Rural			
	Low Series		High Series		Low Series		High Series		Low Series		High Series	
Year	Population (# People)	Projected % Change	Population (# People)	Projected % Change	Population (# People)	Projected % Change	Population (# People)	Projected % Change	Population (# People)	Projected % Change	Population (# People)	Projected % Change
1990	4,000		4,000		935,933		935,933		136,662		136,662	
2000	3,999	-0.03%	4,000	0.00%	1,097,204	17.23%	1,097,349	17.25%	195,504	43.06%	195,531	43.08%
2010	3,976	-0.58%	4,000	0.00%	1,297,777	18.28%	1,305,620	18.98%	249,186	27.46%	250,692	28.21%
2020	3,963	-0.33%	4,000	0.00%	1,534,018	18.20%	1,548,224	18.58%	312,501	25.41%	315,393	25.81%
2030	3,891	-1.82%	4,000	0.00%	1,804,095	17.61%	1,854,525	19.78%	387,060	23.86%	397,881	26.15%
2040	3,793	-2.52%	4,000	0.00%	2,046,303	13.43%	2,157,699	16.35%	454,856	17.52%	479,616	20.54%

	Other Metropolitan a/				County Total			
	Low Series		High Series		Low Series		High Series	
Year	Population (# People)	Projected % Change	Population (# People)	Projected % Change	Population (# People)	Projected % Change	Population (# People)	Projected % Change
1990	83,249		83,249		1,185,394		1,185,394	
2000	99,210	19.17%	99,221	19.19%	1,422,441	20.00%	1,422,629	20.01%
2010	117,205	18.14%	117,914	18.84%	1,694,831	19.15%	1,705,074	19.85%
2020	138,037	17.77%	139,317	18.15%	2,015,416	18.92%	2,034,080	19.30%
2030	161,142	16.74%	165,645	18.90%	2,382,860	18.23%	2,449,468	20.42%
2040	181,835	12.84%	191,734	15.75%	2,712,929	13.85%	2,860,615	16.79%

a/ Other Metropolitan includes the following: Alamo Heights, Balcones Heights, Converse, Fairoaks Ranch Helotes, Hill Country Village, Hollywood Park, Kirby, Leon Valley, Live Oak, Lytle, Olmos Park, Schertz, Shavano Park, Somerset, St. Hedwig, Terrell Hills, Universal City, and Windcrest.

Table 4-2
Projected Growth Rates for Primary Planning Area

	Low Population Series			
Year	BMWD - Castlehills	BMWD - South Side	Military Bases	Other Water Purveyors
1990	4,198	82,257	54,378	69,925
2000	4,791	117,674	56,605	100,032
2010	5,081	149,985	56,274	127,499
2020	5,360	188,095	56,093	159,895
2030	5,527	232,972	55,070	198,045
2040	5,529	273,778	53,686	232,733

	High Population Series			
Year	BMWD - Castlehills	BMWD - South Side	Military Bases	Other Water Purveyors
1990	4,198	82,257	54,378	69,925
2000	4,792	117,690	56,611	100,046
2010	5,112	150,892	56,611	128,270
2020	5,410	189,835	56,611	161,375
2030	5,681	239,485	56,611	203,581
2040	5,830	288,681	56,611	245,402

Table 4-3
Projected Water Use for the Primary Planning Area
(Acre-Feet/Year)

Year	Demand (AF)										
	BMWD-South Side & Castle Hills Projected Demand (Based on Other Rural & Castle Hills Growth Rates)										
	Low Population Series						High Population Series				
	Projected Population	Avg. Demand Without Conservation	Avg. Demand With Conservation	High Demand Without Conservation	High Demand With Conservation		Projected Population	Avg. Demand Without Conservation	Avg. Demand With Conservation	High Demand Without Conservation	High Demand With Conservation
2000	122,466	26,939	25,709	33,962	32,463		122,482	26,946	25,716	33,971	32,472
2010	155,066	33,863	30,754	42,751	39,120		156,004	34,263	31,116	43,254	39,581
2020	193,455	42,014	36,620	53,095	46,518		195,245	42,775	37,278	54,058	47,462
2030	238,499	51,563	44,368	65,220	56,688		245,166	54,422	46,824	68,842	59,833
2040	279,307	60,203	51,448	76,189	65,671		294,511	66,804	57,083	84,562	72,766

Year	Demand (AF)										
	Projected Future Demands for Other Non-Military Water Purveyors (Based on Other Rural Growth Rate)										
	Low Population Series						High Population Series				
	Projected Population	Avg. Demand Without Conservation	Avg. Demand With Conservation	High Demand Without Conservation	High Demand With Conservation		Projected Population	Avg. Demand Without Conservation	Avg. Demand With Conservation	High Demand Without Conservation	High Demand With Conservation
2000	100,032	21,709	20,700	27,424	26,191		100,046	21,715	20,706	27,432	26,198
2010	127,499	27,524	24,953	34,808	31,809		128,270	27,855	25,253	35,227	32,191
2020	158,895	34,363	29,906	43,516	38,144		161,375	35,017	30,456	44,321	38,848
2030	198,045	42,459	36,469	53,773	46,674		203,581	44,851	38,522	56,806	49,305
2040	232,733	49,803	42,603	63,098	54,235		245,402	55,342	47,227	70,126	60,269

Year	Demand (AF)										
	Projected Future Demands for Airforce Bases Within Bexar County a/										
	Low Population Series						High Population Series				
	Projected Population	Avg. Demand Without Conservation	Avg. Demand With Conservation	High Demand Without Conservation	High Demand With Conservation		Projected Population	Avg. Demand Without Conservation	Avg. Demand With Conservation	High Demand Without Conservation	High Demand With Conservation
2000	56,605	18,131	17,566	23,014	22,258		56,611	18,138	17,566	23,022	22,261
2010	56,274	18,025	16,828	22,881	21,369		56,611	18,244	17,034	23,158	21,625
2020	56,093	17,973	16,211	22,810	20,549		56,611	18,303	16,513	23,232	20,926
2030	55,070	17,641	15,728	22,392	19,985		56,611	18,643	16,623	23,664	21,118
2040	53,696	17,200	15,153	21,828	19,304		56,611	19,124	16,849	24,274	21,466

Source: Texas Water Development Board
a/ Water Demand for Military Bases Based on Lackland AFB Water Use.

Table 5-1
BMWD Future Development Options

1. Limited/No Action Alternative
    - Continued Use of Existing Canal Maintenance Program
    - Limited Upgrade of Canal Maintenance Program
2. BMA Canal System Improvements
    - Main Canal System
        - Line Main Canal
        - Improve Maintenance of Main Canal
        - Flow Metering at All Main Canal Diversions
        - Implement Enforced Conservation Measures
    - Lateral Canal System
        - Line Lateral Canals
        - Improved Maintenance of Lateral Canals
        - Flow Metering at All Lateral Canal Turnouts
3. BMA Diversion Point Relocation
    - Medina Lake
    - Medina River Downstream of Diversion Lake
    - Edwards Aquifer Wells
4. Use of Living Waters Catfish Farm Effluent

Table 5-2
IDENTIFICATION OF FUTURE DEVELOPMENT OPTIONS

1. Limited/No Action Alternative
   - Continue on Existing Wells
   - Drill New Wells to Carrizo Sands
   - Drill New Wells to Other Formations
2. Develop Lake Medina/Diversion Reservoir Sources
   - Medina Lake Diversion
     - Without Pump-back of Living Water Catfish Farm Effluent
     - With Pump-back of Living Water Catfish Farm Effluent
   - Diversion Reservoir Diversion
     - Without Pump-back of Living Water Catfish Farm Effluent
     - With Pump-back of Living Water Catfish Farm Effluent
3. Diversion of Lake Medina Releases Below Diversion Reservoir
4. Medina/Applewhite Reservoir Combination
5. Medina/Cibolo Reservoir Combination
6. Edwards Aquifer (Application for New Permits)
7. Direct BMWD Use of Living Waters Catfish Farm Effluent
   - Without Off-channel Storage
   - With Off-channel Storage
8. Purchase and Conversion of BMA Irrigation Rights
9. Develop Cibolo Reservoir as a Stand-alone Project
10. Wastewater Reuse
    - BMWD Service Area Wastewater
    - Regional Wastewater
11. Purchase New Supplies From Other Entities
    - San Antonio Water System (SAWS)
    - Canyon Regional Water Authority (CRWA)
    - Other Regional Purveyors
12. Supplementary Recharge Augmentation (SRA)
    - Austin Chalk Recharge
    - Glenn Rose Aquifer
13. Inter-Aquifer Transfer

Table 6-1
Example of BMA Water Supply Options Evaluation Matrix
(Part 1)

Source Option	Engineering a/									
	Engineering Feasibility		Firm Supply		Flexibility		Environmental		Total Engineering	
	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
1. Limited/No Action Alternative										
a. Continue Existing Maint. Prog.										
b. Limited Upgraded Maint. Prog.										
2. Canal System Improvements										
a. Main Canal System										
(1) Line Canal										
(2) Improved Maintenance										
(3) Flow Metering										
(4) Conservation Measures										
d. Lateral Canal system										
(1) Line Canals										
(2) Improved Maintenance										
(3) Turn-out Metering										
3. Diversion Point Relocation										
a. Medina Lake										
b. Medina River Below Diversion Lake										
c. Edwards Underground River										
d. Living Water Catfish Farm Effluent										
(1) Without Off-channel Storage										
(2) With Off-channel Storage										

a/

Supply Evaluation Weighting	Issues	Range	
Engineering Feasibility	Are there significant engineering challanges to this option?	-10	10
Firm Supply	Will this option carry BMWD and BMA through drought conditions? With/without augmentation?	-10	10
Flexibility	How well does this option fit in with implementation of other options?	-8	8
Environmental	Habitat Preservation/Creation and other possible environmental impacts.	-8	8

Table 6-1
Example of BMA Water Supply Options Evaluation Matrix
(Part 2)

	Institutional/Legal b/									
	Legal Considerations		Institutional Consid.		Public Acceptance		Total Intitutional		TOTAL	
Source Option	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
1. Limited/No Action Alternative										
a. Continue Existing Maint. Prog.										
b. Limited Upgraded Maint. Prog.										
2. Canal System Improvements										
a. Main Canal System										
(1) Line Canal										
(2) Improved Maintenance										
(3) Flow Metering										
(4) Conservation Measure										
d. Lateral Canal system										
(1) Line Canals										
(2) Improved Maintenance										
(3) Turn-out Metering										
3. Diversion Point Relocation										
a. Medina Lake										
b. Medina River Below Diversion Lake										
c. Edwards Underground River										
d. Living Water Catfish Farm Effluent										
(1) Without Off-channel Storage										
(2) With Off-channel Storage										

b/

Supply Evaluation Weighting	Issues	Range	
Legal Restrictions	Are there any legal obsticals, impepements or restrictions to implementation of this option?	-10	0
Institutional Considerations	What institutional arrangements can/must be made to facilitate/allow development of this option?	-8	8
Public Acceptance	Will the BMWD, BMA and CRWA accept this option? Will other regional and state entities accept th	-8	8

Table 6-2
BMWD Water Supply Options Evaluation Matrix - Example
(Part 1)

	Engineering a/									
	Engineering Feasibility		Firm Supply		Flexibility		Environmental		Total Engineering	
Source Option	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
1. Limited/No Action Alternative										
a. Continue on Existing Wells										
b. New Wells to Carrizo Sands										
c. New Wells to Other Formations										
2. Medina River Surface Water Source										
a. Medina Lake										
(1) Without Living Waters Catfish										
(2) With Living Waters Catfish										
b. Diversion Reservoir										
(1) Without Living Waters Catfish										
(2) With Living Waters Catfish										
3. Medina River Below Diversion Lake										
4. Medina/Applewhite Reservoir Combination										
5. Medina/Cibolo Reservoir Combination										
6. Edwards Underground Aquifer (New Permits for Recharge Recovery)										
7. Living Waters Catfish Farm Effluent										
a. Without Off-channel Storage										
b. With Off-channel Storage										
8. Purchase and Convert BMA Irrig. Rights										
9. Develop Cibolo Reservoir										
a. Without Living Waters Catfish										
b. With Living Waters Catfish										
10. Wastewater Reuse										
a. BMWD Service Area Wastewater										
b. Regional Wastewater										
11. Purchase Supplies from Other Entities										
a. San Antonio Water Board										
b. Canyon Regional Water Authority										
c. Other (Lindenau, Goliad or Trans-Texas)										
12. Recharge Enhancement										
13. Interaquifer Transfer										

a/

Supply Evaluation Weighting	Issues	Range	
Engineering Feasibility	Are there significant engineering challanges to this option?	-10	10
Firm Supply	Will this option carry BMWD and BMA through drought conditions? With/without augmentation?	-10	10
Flexibility	How well does this option fit in with implementation of other options?	-8	8
Environmental	Habitat Preservation/Creation and other possible environmental impacts.	-8	8

Table 6-2 (Continued)
BMWD Water Supply Options Evaluation Matrix - Example
(Part 2)

	Institutional/Legal b/									
	Legal Considerations		Institutional Consid.		Public Acceptance		Total Intitutional		TOTAL	
Source Option	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
1. Limited/No Action Alternative										
a. Continue on Existing Wells										
b. New Wells to Carrizo Sands										
c. New Wells to Other Formations										
2. Medina River Surface Water Source										
a. Medina Lake Diversion										
(1) Without Living Waters Catfish										
(2) With Living Waters Catfish										
b. Diversion										
(1) Without Living Waters Catfish										
(2) With Living Waters Catfish										
3. Medina River Below Diversion Lake										
4. Medina/Applewhite Reservoir Combination										
5. Medina/Cibolo Reservoir Combination										
6. Edwards Underground Aquifer (New Permits)										
7. Living Waters Catfish Farm Effluent										
a. Without Off-channel Storage										
b. With Off-channel Storage										
8. Purchase and Convert BMA Irrig. Rights										
9. Develop Cibolo Reservoir										
a. Without Living Waters Catfish										
b. With Living Waters Catfish										
10. Wastewater Reuse										
a. BMWD Service Area Wastewater										
b. Regional Wastewater										
11. Purchase Supplies from Other Entities										
a. San Antonio Water Board										
b. Canyon Regional Water Authority										
c. Other										
12. Recharge Enhancement										
13. Interaquifer Transfer										

b/

Supply Evaluation Weighting	Issues	Range	
Legal Restrictions	Are there any legal obsticals, impepements or restrictions to implementation of this option?	-10	0
Institutional Considerations	What institutional arrangements can/must be made to facilitate/allow development of this option?	-8	8
Public Acceptance	Will the BMWD, BMA and CRWA accept this option? Will other regional and state entities accept th	-8	8

Table 6-6
BMWD Water Supply Options Evaluation Matrix
(Part 1)

	Engineering a/									
	Engineering Feasibility		Firm Supply		Flexibility		Environmental		Total Engineering	
Source Option	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
1. Limited/No Action Alternative										
a. Continue on Existing Wells	10	10	8	6	8	8	6	6	32	30
b. New Wells to Carrizo Sands	5	5	6	4	8	8	6	6	25	23
c. New Wells to Other Formations	-5	-5	6	2	6	6	6	6	13	9
2. Medina River Surface Water Source										
a. Medina Lake										
(1) Without Living Waters Catfish	-5	-5	0	-5	-4	4	-4	4	-13	-2
(2) With Living Waters Catfish	-10	-10	10	10	4	6	-4	4	0	10
b. Diversion Reservoir										
(1) Without Living Waters Catfish	-10	-10	-5	-5	-4	4	-4	4	-23	-7
(2) With Living Waters Catfish	-10	-10	6	2	-4	4	-4	4	-12	0
3. Medina River Below Diversion Lake	5	5	-10	-10	8	8	2	2	5	5
4. Medina/Applewhite Reservoir Combination	-10	-10	0	10	5	5	-5	-5	-10	0
5. Medina/Cibolo Reservoir Combination	-10	-10	0	10	-8	-8	-5	-5	-23	-13
6. Edwards Underground Aquifer (New Permits for Recharge Recovery)	10	10	10	8	8	8	-4	-4	24	22
7. Living Waters Catfish Farm Effluent										
a. Without Off-channel Storage	5	5	10	8	8	8	-5	-5	18	16
b. With Off-channel Storage	-5	-5	10	10	8	8	-5	-5	8	8
8. Purchase and Convert BMA Irrig. Rights	0	0	5	5	8	8	-5	-5	8	8
9. Develop Cibolo Reservoir										
a. Without Living Waters Catfish	-5	-5	0	-5	8	8	-5	-5	-2	-7
b. With Living Waters Catfish	-10	-10	10	10	8	8	-5	-5	3	3
10. Wastewater Reuse										
a. BMWD Service Area Wastewater	-10	-2	0	-5	-8	-2	8	8	-10	-1
b. Regional Wastewater	-10	-2	8	0	-8	-2	8	8	-2	4
11. Purchase Supplies from Other Entities										
a. San Antonio Water Board	10	10	-8	-8	0	0	-5	-5	-3	-3
b. Canyon Regional Water Authority	-5	-5	-8	-8	-8	-8	8	8	-13	-13
c. Other (Lindenau, Goliad or Trans-Texas)	-10	5	-8	5	0	0	8	8	-10	18
12. Recharge Enhancement	-10	-10	-8	-8	0	0	8	8	-10	-10
13. Interaquifer Transfer	-10	-10	-10	-10	-10	-10	0	0	-30	-30

a/

Supply Evaluation Weighting	Issues	Range	
Engineering Feasibility	Are there significant engineering challanges to this option?	-10	10
Firm Supply	Will this option carry BMWD and BMA through drought conditions? With/without augmentation?	-10	10
Flexibility	How well does this option fit in with implementation of other options?	-8	8
Environmental	Habitat Preservation/Creation and other possible environmental impacts.	-8	8

Table 6-6 (Continued)
BMWD Water Supply Options Evaluation Matrix
(Part 2)

	Institutional/Legal b/									
	Legal Considerations		Institutional Consid.		Public Acceptance		Total Intitutional		TOTAL	
Source Option	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
1. Limited/No Action Alternative										
a. Continue on Existing Wells	0	0	0	0	8	8	8	8	40	38
b. New Wells to Carrizo Sands	0	0	0	0	-2	4	-2	4	23	27
c. New Wells to Other Formations	0	0	0	0	4	4	4	4	17	13
2. Medina River Surface Water Source										
a. Medina Lake Diversion										
(1) Without Living Waters Catfish	-5	0	0	0	0	-5	-5	-5	-18	-7
(2) With Living Waters Catfish	-5	0	-4	0	-8	-8	-17	-8	-17	2
b. Diversion										
(1) Without Living Waters Catfish	-5	0	-4	-4	-8	-8	-17	-12	-40	-19
(2) With Living Waters Catfish	-5	0	-4	-4	-8	-8	-17	-12	-29	-12
3. Medina River Below Diversion Lake	-5	-5	-5	-5	-2	-2	-12	-12	-7	-7
4. Medina/Applewhite Reservoir Combination	-5	-5	-5	-5	-8	-8	-18	-18	-28	-18
5. Medina/Cibolo Reservoir Combination										
6. Edwards Underground Aquifer (New Permits to Recover Recharge)	-2	-2	-2	-2	4	2	0	-2	24	20
7. Living Waters Catfish Farm Effluent										
a. Without Off-channel Storage	0	0	-4	-4	-8	-8	-12	-12	6	4
b. With Off-channel Storage	-5	-5	-4	-4	-8	-8	-17	-17	-9	-9
8. Purchase and Convert BMA Irrig. Rights	-5	-5	-5	-5	-5	-5	-15	-15	-7	-7
9. Develop Cibolo Reservoir										
a. Without Living Waters Catfish	-5	-5	-8	-5	-2	-2	-15	-12	-17	-19
b. With Living Waters Catfish	-5	-5	-8	-5	-2	-2	-15	-12	-12	-9
10. Wastewater Reuse										
a. BMWD Service Area Wastewater	-5	-5	-5	-5	-5	-5	-15	-15	-25	-16
b. Regional Wastewater	-5	-5	-5	-5	-5	-5	-15	-15	-17	-11
11. Purchase Supplies from Other Entities										
a. San Antonio Water Board	-3	-3	-3	-3	-5	-5	-11	-11	-14	-14
b. Canyon Regional Water Authority	-5	-5	0	0	-2	-2	-7	-7	-20	-20
c. Other (Lindenau, Goliad, Trans-Texas)	-5	-5	-5	-5	0	0	-10	-10	-20	8
12. Recharge Enhancement	-5	-5	-5	-5	-4	0	-14	-10	-24	-20
13. Interaquifer Transfer	-5	-5	-5	-5	0	0	-10	-10	-40	-40

b/

Supply Evaluation Weighting	Issues	Range	
Legal Restrictions	Are there any legal obsticals, impepements or restrictions to implementation of this option?	-10	0
Institutional Considerations	What institutional arrangements can/must be made to facilitate/allow development of this option?	-8	8
Public Acceptance	Will the BMWD, BMA and CRWA accept this option? Will other regional and state entities accept th	-8	8

Table 6-5 (Continued)
Bexar Metropolitan Water District
Future Water Supply Development Options
Advantages and Disadvantages

Development Option	Advantages	Disadvantages
10. ***Wastewater Reuse***		
a. BMWD Service Area Wastewater	• Reduced raw water demand from other sources • Relatively firm supply	• Must construct wastewater/water treatment facility(ies) • Supply limited to wastewater generated within BMWD service area • Must construct a "grey water" distribution system • Possible public opposition • Possible public health problems • Wastewater currently committed to City of San Antonio
b. Regional Wastewater	• Reduced raw water demand from other sources • Relatively firm supply	• Must construct a regional collection system • Must construct wastewater/water treatment facility(ies) • Supply limited to wastewater generated within BMWD service area • Must construct a "grey water" distribution system • Possible public opposition • Possible public health problems • Most regional wastewater currently committed to City of San Antonio
11. ***Purchase Supplies from Other Entities***		
a. San Antonio Water System (SAWS)	• Obviates supply development activities	• Continued reliance on Edwards Aquifer • Independent system management options hindered • Possible public opposition • Possible preclusion under pending Texas legislation
b. Canyon Regional Water Authority	• True regional development option	• Requires interbasin transfer approval from TWC • Relatively in-firm supply • Supplies purchased from GBRA • Extremely long pumping distances
c. Other		• Unavailable or in-firm supplies
12. Recharge Enhancement	• Water banking encouraged by TWC	• May not achieve total recovery of deposits • Requires tight formation • May be mined by other entities if total surface area not controlled
13. Inter-aquifer Transfer	• Relatively firm supplies	• Technologically not sound • Environmentally not sound

Table 6-5 (Continued)
Bexar Metropolitan Water District
Future Water Supply Development Options
Advantages and Disadvantages

Development Option	Advantages	Disadvantages
6. ***Edwards Underground Aquifer - New Wells***	• Relatively inexpensive option • Totally compatible with existing system • Does not require construction of a surface water treatment facility • SB 1477 allows for recovery of recharge surface water to Edwards Aquifer	• SB 1477 requires Edwards Aquifer Authority (EAA) permits for all new Edwards wells. From 9/1/93 to 12/31/2007, permitted withdrawls are limited to 450,000 ac-ft/yr (83% of current 540,000 ac-ft/yr). After 12/13/2007, permitted withdrawls are limited to 400,000 ac-ft/yr (74% of current withdrawls). • Recharge recovery must be only to the maximum amount recharged, and withdrawn with 12 months • Possible public opposition; does not comply with BMWD stated goal of partial or total conversion to surface
7. ***Living Waters Catfish Farm Effluent - Direct Use***		
a. Without Off-channel Storage	• Direct diversion and use obviates storage requirements. Water treatment facilities could be base loaded with LWCF water and peaked from Edwards wells. • Firm yield at 50-60 MGD • Short pumping distance ≤ 42,000 ft • Flexible source compatible with current distribution system	• Possible public opposition to use of what appears to be wastewater effluent • Must construct wastewater/water treatment facility capable of treating relatively high organic loads • May be subject to TWC permit amendment
b. With Off-channel Storage	• Storage would allow base loading of treatment plant with groundwater and peaking from storage facilities. • Firm yield at 50-60 MGD • Short pumping distance ≤ 42,000 ft • Flexible source compatible with current distribution system	• Possible public opposition to use of what appears to be wastewater effluent • Must construct wastewater/water treatment facility capable of treating relatively high organic loads • May be subject to TWC permit amendment to store effluent • Possible preclusion under pending Texas legislation • Subject to TWC permit issuance for construction of off-channel reservoir
8. ***Purchase and Convert BMA Irrigation Rights***	• Obviates BMA irrigation system improvements • Obviates need to move BMA diversion point to avoid 18,000 ac-ft/yr DR recharge loss • Allows BMWD relatively firm yield of 29,000 - 35,000 ac-ft/yr, if taken from Medina Lake • Eliminates BMA as a consumptive use • May require substitution of all or part of BMA's irrigation water obligation with other sources such as wastewater reuse • Purchase of resource could be on a one-time sum or per ac-ft	• Requires TWC approval for conversion of agricultural water right to municipal priority • Possible negative impact on wetland derived from canal leakage and irr-igation tailwaters: Mitigation plan required • Possible BMA member opposition • Relatively expensive – irrigation right purchase – mitigation
9. ***Develop Cibolo Reservoir***		
a. Without Living Waters Catfish	• Relatively high system yield with San Antonio River floods scalped to oversized Cibolo Reservoir • Flexible system operation • Supplies could serve both BMWD and CRWA service areas	• Must construct major reservoir which is subject to NEPA review • Possible public opposition • Possible TWDB opposition - Cibolo is not on TWDB list of preferable near-term projects • Only viable as a long-term option due to long development time of reservoir projects
b. With Living Waters Catfish	• Relatively high system yield with San Antonio River floods scalped to oversized Cibolo Reservoir along with Living Waters Catfish Farm effluent • Flexible system operation • Supplies could serve both BMWD and CRWA service areas • Public perception problems associated with direct use of Living Water Catfish Farm effluent ameliorated	• Must construct major reservoir which is subject to NEPA review • Possible public opposition • Possible TWDB opposition - Cibolo is not on TWDB list of preferable near-term projects • Must construct a major diversion facility and long pipelines

Table 6-5 (Continued)
Bexar Metropolitan Water District
Future Water Supply Development Options
Advantages and Disadvantages

Development Option	Advantages	Disadvantages
2. ***Medina River Surface Water Source***		
b. Diversion Reservoir (1) Without Living Waters Catfish	• Reduced dependence on Edwards Aquifer as sole supply • Increased total supply available to BMWD users - conditional water up to 65 MGD • Convenient for service area expansion to West of San Antonio and USAA	• Relatively in-firm supply; ≤ 11,000 ac-ft/yr (10 MGD) supply available, and only 25% of time • Existing well capacity must be maintained • Contracts dependent on LM diversions must be for interruptible supplies • Must construct approx. 27 mi 60 in pipeline from LM to BMWD • Must construct a surface water supply treatment facility • Major right-of-way acquisition program must be implemented • Evaporative and infiltration losses for all stored waters • Difficult construction of diversion point and pipeline
(2) With Living Waters Catfish (LWCF) Effluent	• Reduced dependence on Edwards Aquifer as sole supply • Could allow total conversion of existing demand from groundwater to surface water • Very firm supply with yields 68,000 - 120,000 ac-ft/yr (54 - 107 MGD). 95,000 ac-ft/yr available up to 90% of time. • Public perception problems associated with direct use of Living Water Catfish Farm effluent ameliorated	• Must construct approx. 27 mi, 54 in pipeline nearly from LWCF to LM plus 60 in pipeline from DR to BMWD • Must construct a surface water supply treatment facility • Increased evaporative and infiltration losses for all stored waters; however, ≥ 1:1 increase in yield for pumped waters because critical period eliminated • Major right-of-way acquisition program must be implemented
3. ***Medina River Below Diversion Lake***	• Requires shortest pumping distance from source to BMWD service area ≤ 5 mi • Does not require construction of major pipeline	• Excessive channel losses below Lake Medina limits available supply • Relatively infirm yield; Run-of-river diversions only, which are subalternate to all other downstream permit holders • Requires TWC water right permit • Must construct of a surface water treatment facility
4. ***Medina/Applewhite Reservoir Combination***	• Allows recapture of Medina Lake uncontrolled stormwater spills • Allows system operation of Lakes Medina and Applewhite, which maximizes system yield. System operation results in more than the sum of the individual project yields. • Requires short pumping distance to BMWD service area ≤ 5 mi	• Must purchase existing permit or lease storage from the City of San Antonio • Requires completion of the expensive Applewhite Reservoir which may be ultimately needed and constructed as terminal storage for Lindenau or Goliad Reservoirs • Possible significant public opposition - San Antonio voters already rejected project • Possible preclusion under pending Texas legislation which would reauthorize Applewhite as part of a TWDB Lindenau and/or Goliad Reservoir project • Must construct a surface water treatment facility
5. ***Lake Medina/Cibolo Reservoir Combination***	• Relatively high system yield with San Antonio River floods scalped to oversized Cibolo Reservoir • Flexible system operation • Supplies could serve both BMWD and CRWA service areas	• Possible TWDB opposition - Cibolo is an authorized federal project but is not on TWDB list of preferable near-term projects • Limited to long-term option. Must construct major reservoir - 15 to 20 yr development period. • Possible public opposition from environmental groups • Possible preclusion under pending Texas legislation or TWDB Tran-Texas pipeline plan

Table 6-5
Bexar Metropolitan Water District
Future Water Supply Development Options
Advantages and Disadvantages

Development Option	Advantages	Disadvantages
1. *Limited/No Action Alternative*		
a. Continue on Existing Wells	• Least cost option • No new construction required • No new permits or contracts required	• Possible future pumping limits on existing Edwards Aquifer wells under 1993 Texas Senate Bill (SB) 1477. From 9/1/93 to 12/31/2007, permitted withdrawls are limited to 450,000 ac-ft/yr (83% of current 540,000 ac-ft/yr). After 12/13/2007, permitted withdrawls are limited to 400,000 ac-ft/yr (74% of current withdrawls). • Limits BMWD service area and new customer expansion • Possible shortages during prolonged droughts
b. Limited Development of New Wells		
(1) Well to Edwards Aquifer	• Relatively inexpensive - BMWD currently has over 25,000 gpm of excess well capacity • Lake Medina and Diversion Reservoir (LM/DR) recharge on average over 60,000 ac-ft/yr directly to Edwards Aquifer. Texas SB 1477 allows for limited recharge recovery.	• SB 1477 requires Edwards Aquifer Authority (EAA) permits for all new Edwards wells • Recharge recovery must be only to the maximum amount recharged, and withdrawn with 12 months
(2) Wells to Carrizo Sands	• Relatively firm supplies - wells yielding approx. 600 gpm have been drilled in northwestern Atascosa County. Up to 10 MGD could be pulled from a 19 well field. • Water is relatively shallow - approx. 500 - 600 ft	• Possible water quality problems (H_2S, Fe and Mn), which will require special water treatment plant considerations • Potentially long pumping distances - approx. 18 - 20 mi
(3) Other Formations	• Relatively constant supplies - approx. 30 - 160 gpm wells are located in southern Bexar County • Relatively short pumping distances - ≤ 10 mi	• Shallow formation water is limited to local recharge and is quickly depleted during droughts • Possible water quality problems because of local pollution - may require special water treatment plant construction
2. *Medina River Surface Water Source*		
a. Medina Lake		
(1) Without Living Waters Catfish	• Reduced dependence on Edwards Aquifer as sole supply • Increased total supply available to BMWD users - conditional water up to 65 MGD • Convenient for service area expansion to West of San Antonio and USAA • Minimization of 18,000+ ac-ft/yr groundwater recharge (loss) from Diversion Reservoir	• Relatively in-firm supply - Assuming satisfaction of BMA irrigation diversions, BMWD yields range 0 - 21,000 ac-ft/yr (approx. 20 MGD). Median BMWD yield (10 MGD) available approx. 25% of time. Moving the BMA diversion point to LM increases BMWD yield to 0 - 62,000 ac-ft/yr (55 MGD). Median yield (22 MGD) availability increases to 53% of time. • Existing excess well capacity must be maintained or expanded to supply drought demands • Contracts dependent on Lake Medina diversions must be for interruptible supplies • Must construct approx. 27 mi, 60 in pipeline from LM to BMWD service area • TWC must approve conversion of irrigation rights to a higher municipal priority • Must construct a surface water supply treatment facility • Major right-of-way acquisition program must be implemented
(2) With Living Waters Catfish Farm (LWCF) Effluent	• Reduced dependence on Edwards Aquifer as sole supply • Could allow total conversion of existing demand from groundwater to surface water • Very firm supply with yields 68,000 - 120,000 ac-ft/yr (54 - 107 MGD). 95,000 ac-ft/yr available up to 90% of time. • Public perception problems associated with direct use of Living Water Catfish Farm effluent ameliorated	• Must construct approx. 27 mi, 54 in pipeline nearly from LWCF to LM plus 60 in pipeline from LM to BMWD • Must construct a surface water supply treatment facility • Increased evaporative and infiltration losses for all stored waters; however, ≥ 1:1 increase in yield for pumped waters because critical period eliminated • Major right-of-way acquisition program must be implemented

Table 6-4
BMA Water Supply Options Evaluation Matrix
(Part 1)

	Engineering a/									
	Engineering Feasibility		Firm Supply		Flexibility		Environmental		Total Engineering	
Source Option	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
1. Limited/No Action Alternative										
a. Continue Existing Maint. Prog.	5	-5	5	-5	5	-5	8	8	23	-7
b. Limited Upgraded Maint. Prog	5	-5	8	-3	5	-5	8	8	26	-5
2. Canal System Improvements										
a. Main Canal System										
(1) Line Canal	5	5	8	8	8	8	5	5	26	26
(2) Improved Maintenance	5	5	6	6	8	8	6	6	25	25
(3) Flow Metering	5	5	8	8	8	8	8	8	29	29
(4) Conservation Measures	10	10	8	8	8	8	8	8	34	34
d. Lateral Canal system										
(1) Line Canals	5	5	8	8	8	8	5	5	26	26
(2) Improved Maintenance	5	5	6	6	8	8	6	6	25	25
(3) Turn-out Metering	5	5	8	8	8	8	7	7	28	28
3. Diversion Point Relocation										
a. Medina Lake	-10	-10	10	10	8	8	8	8	16	16
b. Medina River Below Diversion Lake	5	5	-5	-5	8	8	8	8	16	16
c. Edwards Underground River	5	5	8	6	8	8	-8	-8	13	11
d. Living Water Catfish Farm Effluent										
(1) Without Off-channel Storage	5	5	10	10	8	8	-8	-8	15	15
(2) With Off-channel Storage	-10	-5	10	10	8	8	-5	-5	3	8

a/

Supply Evaluation Weighting	Issues	Range	
Engineering Feasibility	Are there significant engineering challanges to this option?	-10	10
Firm Supply	Will this option carry BMWD and BMA through drought conditions? With/without augmentation?	-10	10
Flexibility	How well does this option fit in with implementation of other options?	-8	8
Environmental	Habitat Preservation/Creation and other possible environmental impacts.	-8	8

Table 6-4
BMA Water Supply Options Evaluation Matrix
(Part 2)

	Institutional/Legal b/									
	Legal Considerations		Institutional Consid.		Public Acceptance		Total Intitutional		TOTAL	
Source Option	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
1. Limited/No Action Alternative										
a. Continue Existing Maint. Prog	0	0	8	8	7	7	15	15	38	8
b. Limited Upgraded Maint. Prog.	0	0	8	8	7	7	15	15	41	10
2. Canal System Improvements										
a. Main Canal System										
(1) Line Canal	0	0	0	0	7	7	7	7	33	33
(2) Improved Maintenance	0	0	0	0	7	7	7	7	32	32
(3) Flow Metering	0	0	0	0	7	7	7	7	36	36
(4) Conservation Measure	0	0	0	0	7	7	7	7	41	41
d. Lateral Canal system										
(1) Line Canals	0	0	0	0	7	7	7	7	33	33
(2) Improved Maintenance	0	0	0	0	7	7	7	7	32	32
(3) Turn-out Metering	0	0	0	0	7	7	7	7	35	35
3. Diversion Point Relocation										
a. Medina Lake	-5	0	-5	-5	-5	-5	-15	-10	1	6
b. Medina River Below Diversion Lake	-5	-5	-5	-5	0	0	-10	-10	6	6
c. Edwards Underground River	-10	-10	-8	-8	-8	-8	-26	-26	-13	-15
d. Living Water Catfish Farm Effluent							0	0	0	0
(1) Without Off-channel Storage	-3	-3	-2	-2	-8	-8	-13	-13	2	2
(2) With Off-channel Storage	-5	-5	-2	-2	-8	-8	-15	-15	-12	-7

b/

Supply Evaluation Weighting	Issues	Range	
Legal Restrictions	Are there any legal obsticals, impepements or restrictions to implementation of this option?	-10	0
Institutional Considerations	What institutional arrangements can/must be made to facilitate/allow development of this option?	-8	8
Public Acceptance	Will the BMWD, BMA and CRWA accept this option? Will other regional and state entities accept th	-8	8

Table 6-3
BMA Future Development Options
Advantages and Disadvantages

Development Option	Advantages	Disadvantages
1. Limited/No Action Alternative		
a. Continue Existing Maint. Prog.	• Least cost option • No institutional or legal ramifications • Ensures perpetual wetland maintenance	• Escalating future maintenance cost because of continued system deterioration • Relatively unreliable supply from the Lake Medina/Diversion Reservoir system
b. Limited Upgraded Maint. Prog.	• Minimal capital expenditures • No negative institutional or legal ramifications	• Escalating future maintenance cost because of continued system deterioration • Relatively unreliable supply from the Lake Medina/Diversion Reservoir system • Some loss of perpetual wetlands
2. Canal System Improvements		
a. Main Canal System		
(1) Line Canal	• Decrease channel losses • Decreased demand because of decreased channel losses • Decreased future maintenance costs	• Relatively expensive option • Some engineering difficulties
(2) Improved Maintenance	• Decrease channel losses • Decreased demand because of decreased channel losses • Decreased future maintenance costs	• Additional BMA staff required • Additional BMA equipment required
(3) Flow Metering	• Allows accurate usage records • Facilitates rate structure modification • Promotes conservation	• Additional BMA staff required • Additional BMA equipment required
(4) Conservation Measures	• Reduces consumption • Inexpensive to implement	• Generally a low level of voluntary compliance • Requires monitoring program • Additional BMA equipment required
d. Lateral Canal system		
(1) Line Canals	• Decrease channel losses • Decreased demand because of decreased channel losses • Decreased future maintenance costs	• Relatively expensive option • Some engineering difficulties
(2) Improved Maintenance	• Decrease channel losses • Decreased demand because of decreased channel losses • Decreased future maintenance costs	• Additional BMA staff required • Additional BMA equipment required
(3) Turn-out Metering	• Allows accurate usage records • Facilitates rate structure modification • Promotes conservation	• Additional BMA staff required • Additional BMA equipment required
3. Diversion Point Relocation		
a. Medina Lake	• Reduces or eliminated loss from Diversion Reservoir	• Requires pipeline construction between diversion point on Lake Medina to main canal • Requires right-of-way acquisition • Very expensive
b. Medina River Below Diversion Lake	• Low cost	• Does not eliminate losses from Diversion Reservoir unless a pipeline is constructed to bypass the Diversion Lake • Additional losses may occur below the lake • Requires pumping
c. Edwards Aquifer	• Totally eliminates main canal system losses • Increases Lake Medina yield for BMWD M&I diversions • Reduces canal system maintenance program and costs	• Negative impact to main canal and associated wetlands • Possible preclusion by pending or proposed legislation • Possible public opposition • Requires new well(s), pump station(s) and pipelines • Will require TWC approval and a permit from EAA
4. Living Waters Catfish Farm Effluent		
(1) Without Off-channel Storage	• Firm consistent supply • Eliminates main canal losses • Increases Lake Medina yield for BMWD M&I diversions • Reduces canal system maintenance program and costs • Relative inexpensive	• May requires supplemental supply(ies) during prolonged droughts • Requires right-of-way acquisition • Requires pumping • Some loss of wetlands associated with main canal • Possible water quality problems • Possible public opposition
(2) With Off-channel Storage	• Firm consistent supply • Eliminates main canal losses • Increases Lake Medina yield for BMWD • Reduces canal system maintenance program and costs • Relative inexpensive	• May requires supplemental supply(ies) during prolonged droughts • Requires right-of-way acquisition • Requires pumping • Some loss of wetlands associated with main canal • Possible water quality problems • Possible public opposition • Requires reservoir construction • Will require TWC and USCOE permits

Table 6-7
Future BMWD Water Supply Development Options and Phased Buildout With and Without Consideration of Living Waters Catfish Farm Effluent as a Potential Source a/

		Development Options Which Do Not Include Use of Living Waters Catfish Farm Effluent					
Year	Average Annual Demand (MGD)	Option 1 and Yield (MGD)		Option 2 and Yield (MGD)		Option 3 and Yield (MGD)	
1995	54	Continue to utilize existing wells at the reduced capacities specified in 1993 Edwards Aquifer legislation (30 MGD maximum pumpage for entire study area).	30	Continue to utilize existing wells at the reduced capacities specified in 1993 Edwards Aquifer legislation (30 MGD maximum pumpage for entire study area).	30	Continue to utilize existing wells at the reduced capacities specified in 1993 Edwards Aquifer legislation (30 MGD maximum pumpage for entire study area).	30
		Utilize existing excess well capacity of BMWD (37 MGD) and local Airforce Bases (30 MGD) to recover LM/DR losses to Edwards Aquifer up to a total of 27 MGD (59 MGD LM/DR permitted yield - 32 MGD BMA diversions).	22	Utilize existing excess well capacity of BMWD (37 MGD) and local Airforce Bases (30 MGD) to recover LM/DR losses to Edwards Aquifer up to a total of 27 MGD (59 MGD LM/DR permitted yield - 32 MGD BMA diversions).	22	Utilize existing excess well capacity of BMWD (37 MGD) and local Airforce Bases (30 MGD) to recover LM/DR losses to Edwards Aquifer up to a total of 27 MGD (59 MGD LM/DR permitted yield - 32 MGD BMA diversions).	22
2000	72	Build 60 MGD pipeline between Lake Medina and BMWD (maximum permitted LM/DR System diversions). Maximum diversion is 60 MGD - 30 MGD BMA diversion - LM/DR loss recovery pumping.	10	Build 60 MGD pipeline between Lake Medina and BMWD (maximum permitted LM/DR System diversions). Maximum diversion is 60 MGD - 30 MGD BMA diversion - LM/DR loss recovery pumping.	10	Build 60 MGD pipeline between Lake Medina and BMWD (maximum permitted LM/DR System diversions). Maximum diversion is 60 MGD - 30 MGD BMA diversion - LM/DR loss recovery pumping.	10
		Drill new 10 MGD well field into Carrizo Sands in northern Atascosa County.	10	Purchase remaining BMA Irrigation rights and eliminate diversions.	30	Drill new 10 MGD well field into Carrizo Sands in northern Atascosa County.	10
		Purchase remaining BMA Irrigation rights and eliminate diversions.	30	Build 75 MGD surface water treatment plant and groundwater blending capabilities.		Purchase remaining BMA Irrigation rights and eliminate diversions.	30
		Build 50 MGD surface water treatment plant and groundwater blending capabilities.				Build 100 MGD surface water treatment plant and groundwater blending capabilities.	
2005	78	Continue to utilize existing wells, but at the reduced capacities specified in 1993 Edwards Aquifer legislation (27 MGD maximum pumpage for entire study area).		Continue to utilize existing wells, but at the reduced capacities specified in 1993 Edwards Aquifer legislation (27 MGD maximum pumpage for entire study area).			
2010	83	Expand water treatment plant to 100 MGD.					
2015	90			Drill new well field into Carrizo Sands in northern Atascosa County	10		
				Expand water treatment plant to 100 MGD.			
2020	96						
2025	106			Purchase additional water supplies (30 MGD) from Lindenau or Goliad Reservoir Projects.	40	Purchase additional water supplies (30 MGD) from Lindenau or Goliad Reservoir Projects.	40
				Expand water treatment plant to 150 MGD.		Expand water treatment plant to 150 MGD.	
2030	116	Purchase additional water supplies (30 MGD) from Lindenau or Goliad Reservoir Projects.	40				
		Expand water treatment plant to 150 MGD.					
2035	127						
2040	138						

a/ All options assumed continued use of groundwater supplies, reduced to 83% of current pumpage rate by 2007 and 74% of current rate thereafter.

Table 6-8
Future BMWD Water Supply Development Options and Phased Buildout Without Consideration of Living Waters Catfish Farm Effluent as a Potential Source a/

Year	Average Annual Demand (MGD)	Development Options Which Do Not Include Use of Living Waters Catfish Farm Effluent					
		Option 4 and Yield (MGD)		Option 5 and Yield (MGD)		Option 6 and Yield (MGD)	
1995	54	Continue to utilize existing wells at the reduced capacities specified in 1993 Edwards Aquifer legislation (30 MGD maximum pumpage for entire study area).	30	Continue to utilize existing wells at the reduced capacities specified in 1993 Edwards Aquifer legislation (30 MGD maximum pumpage for entire study area).	30	Continue to utilize existing wells at the reduced capacities specified in 1993 Edwards Aquifer legislation (30 MGD maximum pumpage for entire study area).	30
		Utilize existing excess well capacity of BMWD (37 MGD) and local Airforce Bases (30 MGD) to recover LM/DR losses to Edwards Aquifer up to a total of 27 MGD (59 MGD LM/DR permitted yield - 32 MGD BMA diversions).	22	Utilize existing excess well capacity of BMWD (37 MGD) and local Airforce Bases (30 MGD) to recover LM/DR losses to Edwards Aquifer up to a total of 27 MGD (59 MGD LM/DR permitted yield - 32 MGD BMA diversions).	22	Utilize existing excess well capacity of BMWD (37 MGD) and local Airforce Bases (30 MGD) to recover LM/DR losses to Edwards Aquifer up to a total of 27 MGD (59 MGD LM/DR permitted yield - 32 MGD BMA diversions).	22
2000	72	Purchase Living Waters Catfish Farm Effluent.	50	Purchase Living Waters Catfish Farm Effluent.	50	Purchase Living Waters Catfish Farm Effluent.	50
		Construct an approximate 32,000 ft pipeline between LWCF and BMWD.		Construct an approximate 32,000 ft pipeline between LWCF and BMWD.		Construct an approximate 32,000 ft pipeline between LWCF and BMWD.	
		Build 100 MGD surface water treatment plant and groundwater blending capabilities.		Build 100 MGD surface water treatment plant and groundwater blending capabilities.		Build 100 MGD surface water treatment plant and groundwater blending capabilities.	
2005	78						
2010	83					Develop new wells to Carrizo Sands.	10
						Construct an approximate 100,000 ft pipeline between well fields and BMWD.	
2015	90						
2020	96	Build 60 MGD pipeline between Lake Medina and BMWD (maximum permitted LM/DR System diversions). Maximum diversion is 60 MGD - 30 MGD BMA diversion - LM/DR loss recovery pumping.	10	Build 60 MGD pipeline between Lake Medina and BMWD (maximum permitted LM/DR System diversions). Maximum diversion is 60 MGD - 30 MGD BMA diversion - LM/DR loss recovery pumping.	10		
		Expand surface water treatment plant to 150 MGD.		Purchase remaining BMA Irrigation rights and eliminate diversions.	30		
				Expand surface water treatment plant to 150 MGD.			
2025	106	Drill new 10 MGD well field into Carrizo Sands in northern Atascosa County.	10			Build 60 MGD pipeline between Lake Medina and BMWD (maximum permitted LM/DR System diversions). Maximum diversion is 60 MGD - 30 MGD BMA diversion - LM/DR loss recovery pumping.	10
2030	116					Expand surface water treatment plant to 150 MGD.	
2035	127	Purchase remaining BMA Irrigation rights and eliminate diversions.	30			Purchase remaining BMA Irrigation rights and eliminate diversions.	30
2040	138			Drill new 10 MGD well field into Carrizo Sands in northern Atascosa County.	10		

a/ All options assumed continued use of groundwater supplies, reduced to 83% of current pumpage rate by 2007 and 74% of current rate thereafter.

Table 6-9
Future BMWD Water Supply Development Options and Phased Buildout With Pump-back of Living Waters Catfish Farm Effluent to Lake Medina a/

Year	Average Annual Demand (MGD)	Development Options Which Include Use of Living Waters Catfish Farm Effluent	
		Option 4 and Yield (MGD)	
1995	54	Continue to utilize existing wells at the reduced capacities specified in 1993 Edwards Aquifer legislation (30 MGD maximum pumpage for entire study area).	30
		Utilize existing excess well capacity of BMWD (37 MGD) and local Airforce Bases (30 MGD) to recover LM/DR losses to Edwards Aquifer up to a total of 27 MGD (59 MGD LM/DR permitted yield - 32 MGD BMA diversions).	22
2000	72	Purchase or lease effluent from Living Waters Catfish Farm	40
		Construct an approximate 140,000 ft 52 in pipeline between LWCF and Lake Medina.	
		Construct an approximate 140,000 ft 60 in pipeline between Lake Medina and BMWD.	
		Build 100 MGD surface water treatment plant and groundwater blending capabilities.	
2005	78		
2010	83		
2015	90	Purchase, or lease, and convert remaining BMA irrigation rights, and eliminate diversion	50
		Expand surface water treatment plant to 150 MGD	
2020	96		
2025	106		
2030	116		
2035	127		
2040	138		

a/ All options assumed continued use of groundwater supplies, reduced to 83% of current pumpage rate by 2007 and 74% of current rate thereafter.

Table 7-1
Current Required and Provided Well Capacity Within the Study Area a/

Serving Entity	Well Capacity							
	Amount Required		Amount Provided		Excess		Deficit	
	gpm	MGD	gpm	MGD	gpm	MGD	gpm	MGD
Bexar Co. WCID#1	690	1	1,960	3	1,270	2	0	0
BMWD	16,451	24	42,000	60	25,549	37	0	0
Brooks AFB	N/A		N/A					
Coolcrest Water System	136	0	340	0	202	0	0	0
City of Elmondorf	232	0	672	1	440	1	0	0
Kelly AFB	1,290	2	6,800	10	5,510	8	0	0
King's Pt. Water System	109	0	210	0	101	0	0	0
Lackland AFB - Main	1,800	3	7,075	10	5,275	8	0	0
Lackland AFB - Main	192	0	1,750	3	1,558	2	0	0
Lackland City - Columbia	4,180	6	880	1	4,700	7	0	0
Lackland City - Columbia	N/A		N/A					
City of Lytle	550	1	1,100	2	550	1	0	0
Meadwood Acres	108	0	1,500	2	1,392	2	0	0
Randolf AFB	665	1	4,715	7	4,050	6	0	0
Rio Medina Estates	39	0	178	0	139	0	0	0
SAWS	N/A		N/A					
Silver Mt. Water Co.	14	0	500	1	486	1	0	0
Twin Valley Water System	81	0	175	0	94	0	0	0
Vos Water Co.	61	0	300	0	239	0	0	0
Waterwood Utilities	71	0	95	0	24	0	0	0
Windy's Water Works	406	1	427	1	21	0	0	0
Total b/	27,075	39	70,677	102	46,642	67	0	0

a/ Source: Texas Department of Health Sanitary Surveys.
b/ Includes only BMWD plus Kelly, Lacklland and Randolf AFBs.

Table 7-2
Bexar Metropolitan Water District Water Supply Study
Estimated Costs for Initial 50 MGD Surface Water Treatment Facility and 50 MGD Expansions
(Option 1)

Item	50 MGD Water Treatment Plant Estimated Cost		50 MGD Water Treatment Plant Expansion Estimated Cost	
RAW WATER METER VAULT				
A. Structure	$850,000		$722,500	
B. Equipment	$150,000		$127,500	
C. Piping	$10,000		$8,500	
D. Miscellaneous	$30,000		$25,500	
		$1,040,000		$884,000
RAPID MIX BASIN				
A. Structure	$440,000		$374,000	
B. Equipment	$125,000		$106,250	
C. Miscellaneous	$55,000		$46,750	
		$620,000		$527,000
FLOCCULATION BASINS				
A. Structure	$1,165,000		$990,250	
B. Equipment	$1,200,000		$1,020,000	
C. Miscellaneous	$23,000		$19,550	
		$2,388,000		$2,029,800
SEDIMENTATION BASINS				
A. Structure	$3,300,000		$2,805,000	
B. Equipment	$1,635,000		$1,389,750	
C. Miscellaneous	$500,000		$425,000	
		$5,435,000		$4,619,750
FILTERS				
A. Structure	$1,700,000		$1,445,000	
B. Equipment	$1,410,000		$1,198,500	
C. Media	$385,000		$327,250	
C. Miscellaneous	$360,000		$306,000	
		$3,855,000		$3,276,750
CHEMICAL FEED FACILITIES				
A. Structure	$3,500,000		$2,975,000	
B. Equipment	$2,040,000		$1,734,000	
C. Piping	$275,000		$233,750	
D. Miscellaneous	$550,000		$467,500	
		$6,365,000		$5,410,250
ADMINISTRATION/MAINTENANCE BUILDING				
A. Structure	$2,750,000		$2,337,500	
B. Equipment	$415,000		$352,750	
C. Miscellaneous	$330,000		$280,500	
		$3,495,000		$2,970,750
WASHWATER RECOVERY TANK				
A. Structure	$435,000		$369,750	
B. Equipment	$140,000		$119,000	
C. Miscellaneous	$55,000		$46,750	
		$630,000		$535,500
CLEARWELL	$1,750,000	$1,750,000	$1,487,500	$1,487,500
HIGH SERVICE PUMP STATION	$2,500,000	$2,500,000	$2,125,000	$2,125,000
YARD PIPING				
A. Piping	$1,650,000		$1,402,500	
B. Valves	$1,650,000		$1,402,500	
C. Miscellaneous	$330,000		$280,500	
		$3,630,000		$3,085,500
SITE WORK				
A. Grading	$330,000		$280,500	
B. Landscaping	$110,000		$93,500	
C. Paving	$440,000		$374,000	
D. Curb and Gutter	$165,000		$140,250	
E. Miscellaneous	$135,000		$114,750	
		$1,180,000		$1,003,000
SLUDGE HANDLING	$2,350,000	$2,350,000	$1,997,500	$1,997,500
ELECTRICAL				
A. General Electrical	$4,175,000		$3,548,750	
B. Instrumentation	$3,470,000		$2,949,500	
		$7,645,000		$6,498,250
MISCELLANEOUS	$6,350,000	$6,350,000	$5,397,500	$5,397,500
TOTAL		$49,233,000		$41,848,050

Table 7-3
Bexar Metropolitan Water District Water Supply Study
Estimated Costs for Initial 75 MGD Surface Water Treatment Facility and 50 and 25 MGD Expansions
(Option 2)

Item	75 MGD Water Treatment Plant Estimated Cost		50 MGD Water Treatment Plant Expansion Estimated Cost		25 MGD Water Treatment Plant Expansion Estimated Cost	
RAW WATER METER VAULT						
A. Structure	$1,275,000		$722,500		$361,250	
B. Equipment	$225,000		$127,500		$63,750	
C. Piping	$15,000		$8,500		$4,250	
D. Miscellaneous	$45,000		$25,500		$12,750	
		$1,560,000		$884,000		$442,000
RAPID MIX BASIN						
A. Structure	$660,000		$374,000		$187,000	
B. Equipment	$187,500		$106,250		$53,125	
C. Miscellaneous	$82,500		$46,750		$23,375	
		$930,000		$527,000		$263,500
FLOCCULATION BASINS						
A. Structure	$1,747,500		$990,250		$495,125	
B. Equipment	$1,800,000		$1,020,000		$510,000	
C. Miscellaneous	$34,500		$19,550		$9,775	
		$3,582,000		$2,029,800		$1,014,900
SEDIMENTATION BASINS						
A. Structure	$4,950,000		$2,805,000		$1,402,500	
B. Equipment	$2,452,500		$1,389,750		$694,875	
C. Miscellaneous	$750,000		$425,000		$212,500	
		$8,152,500		$4,619,750		$2,309,875
FILTERS						
A. Structure	$2,550,000		$1,445,000		$722,500	
B. Equipment	$2,115,000		$1,198,500		$599,250	
C. Media	$577,500		$327,250		$163,625	
C. Miscellaneous	$540,000		$306,000		$153,000	
		$5,782,500		$3,276,750		$1,638,375
CHEMICAL FEED FACILITIES						
A. Structure	$5,250,000		$2,975,000		$1,487,500	
B. Equipment	$3,060,000		$1,734,000		$867,000	
C. Piping	$412,500		$233,750		$116,875	
D. Miscellaneous	$825,000		$467,500		$233,750	
		$9,547,500		$5,410,250		$2,705,125
ADMINISTRATION/MAINTENANCE BUILDING						
A. Structure	$4,125,000		$2,337,500		$1,168,750	
B. Equipment	$622,500		$352,750		$176,375	
C. Miscellaneous	$495,000		$280,500		$140,250	
		$5,242,500		$2,970,750		$1,485,375
WASHWATER RECOVERY TANK						
A. Structure	$652,500		$369,750		$184,875	
B. Equipment	$210,000		$119,000		$59,500	
C. Miscellaneous	$82,500		$46,750		$23,375	
		$945,000		$535,500		$267,750
CLEARWELL	$2,625,000	$2,625,000	$1,487,500	$1,487,500	$743,750	$743,750
HIGH SERVICE PUMP STATION	$3,750,000	$3,750,000	$2,125,000	$2,125,000	$1,062,500	$1,062,500
YARD PIPING						
A. Piping	$2,475,000		$1,402,500		$701,250	
B. Valves	$2,475,000		$1,402,500		$701,250	
C. Miscellaneous	$495,000		$280,500		$140,250	
		$5,445,000		$3,085,500		$1,542,750
SITE WORK						
A. Grading	$495,000		$280,500		$140,250	
B. Landscaping	$165,000		$93,500		$46,750	
C. Paving	$660,000		$374,000		$187,000	
D. Curb and Gutter	$247,500		$140,250		$70,125	
E. Miscellaneous	$202,500		$114,750		$57,375	
		$1,770,000		$1,003,000		$501,500
SLUDGE HANDLING	$3,525,000	$3,525,000	$1,997,500	$1,997,500	$998,750	$998,750
ELECTRICAL						
A. General Electrical	$6,262,500		$3,548,750		$1,774,375	
B. Instrumentation	$5,205,000		$2,949,500		$1,474,750	
		$11,467,500		$6,498,250		$3,249,125
MISCELLANEOUS	$9,525,000	$9,525,000	$5,397,500	$5,397,500	$2,698,750	$2,698,750
TOTAL		$73,849,500		$41,848,050		$20,924,025

Table 7-4
Bexar Metropolitan Water District Water Supply Study
Estimated Costs for Initial 100 MGD Surface Water Treatment Facility and 50 MGD Expansions
(Option 3 - 6)

Item	100 MGD Water Treatment Plant Estimated Cost		50 MGD Water Treatment Plant Expansion Estimated Cost	
RAW WATER METER VAULT				
A. Structure	$1,700,000		$765,000	
B. Equipment	$300,000		$135,000	
C. Piping	$20,000		$9,000	
D. Miscellaneous	$60,000		$27,000	
		$2,080,000		$936,000
RAPID MIX BASIN				
A. Structure	$880,000		$396,000	
B. Equipment	$250,000		$112,500	
C. Miscellaneous	$110,000		$49,500	
		$1,240,000		$558,000
FLOCCULATION BASINS				
A. Structure	$2,330,000		$1,048,500	
B. Equipment	$2,400,000		$1,080,000	
C. Miscellaneous	$46,000		$20,700	
		$4,776,000		$2,149,200
SEDIMENTATION BASINS				
A. Structure	$6,600,000		$2,970,000	
B. Equipment	$3,270,000		$1,471,500	
C. Miscellaneous	$1,000,000		$450,000	
		$10,870,000		$4,891,500
FILTERS				
A. Structure	$3,400,000		$1,530,000	
B. Equipment	$2,820,000		$1,269,000	
C. Media	$770,000		$346,500	
C. Miscellaneous	$720,000		$324,000	
		$7,710,000		$3,469,500
CHEMICAL FEED FACILITIES				
A. Structure	$7,000,000		$3,150,000	
B. Equipment	$4,080,000		$1,836,000	
C. Piping	$550,000		$247,500	
D. Miscellaneous	$1,100,000		$495,000	
		$12,730,000		$5,728,500
ADMINISTRATION/MAINTENANCE BUILDING				
A. Structure	$5,500,000		$2,475,000	
B. Equipment	$830,000		$373,500	
C. Miscellaneous	$660,000		$297,000	
		$6,990,000		$3,145,500
WASHWATER RECOVERY TANK				
A. Structure	$870,000		$391,500	
B. Equipment	$280,000		$126,000	
C. Miscellaneous	$110,000		$49,500	
		$1,260,000		$567,000
CLEARWELL	$3,500,000	$3,500,000	$1,575,000	$1,575,000
HIGH SERVICE PUMP STATION	$5,000,000	$5,000,000	$2,250,000	$2,250,000
YARD PIPING				
A. Piping	$3,300,000		$1,485,000	
B. Valves	$3,300,000		$1,485,000	
C. Miscellaneous	$660,000		$297,000	
		$7,260,000		$3,267,000
SITE WORK				
A. Grading	$660,000		$297,000	
B. Landscaping	$220,000		$99,000	
C. Paving	$880,000		$396,000	
D. Curb and Gutter	$330,000		$148,500	
E. Miscellaneous	$270,000		$121,500	
		$2,360,000		$1,062,000
SLUDGE HANDLING	$4,700,000	$4,700,000	$2,115,000	$2,115,000
ELECTRICAL				
A. General Electrical	$8,350,000		$3,757,500	
B. Instrumentation	$6,940,000		$3,123,000	
		$15,290,000		$6,880,500
MISCELLANEOUS	$12,700,000	$12,700,000	$5,715,000	$5,715,000
TOTAL		$98,466,000		$44,309,700

Table 7-5
South Bexar County RegionaL Water Supply Study
Raw Water Intake, Pump Station and Water Transmission Line Costs
for Future Development Options

	Diameter (in)	Length (ft)	Unit Cost ($/ft)	Total Cost
BMWD Lake Medina Raw Water Intake and Pump Satation				$4,800,000
BMWD Lake Medina Raw Water Transmission Line a/ b/	60	142,000	250	$35,500,000
BMA Lake Medina Raw Water Intake and Pump Satation				$5,600,000
BMA Lake Medina Raw Water Transmission Line b/	60	40,000	250	$10,000,000
BMWD Living Waters Catfish Farm Pump Station				$1,600,000
BMWD Living Waters Catfish Farm Transmission Line	54	42,000	205	$8,610,000
BMWD Carrizo Sands Well Field Pump Station				$1,200,000
BMWD Carrizo Sands Well Field Transmission Line	36	100,000	115	$11,500,000
BMWD Wastewate Pump Station				$2,800,000
BMWD Wastewater Transmission Line to BMA	42	120,000	155	$18,600,000

a/ All transmission lines assumed Concrete Steel Cylindar (CSC) pipe.
b/ Assumes $25/ft additional cost for difficult terrain construction.
c/ Waste water pumped ftom BMWD service area to Pearson Junction.

Table 7-6
South Bexar County Regional Water Supply Study
Estimated Cost of Proposed Wells to Carrizo Sands
Wells Developed in 2000 (Options 1 and 3) a/

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040
Number of Connections	0	19,269	19,269	19,269	19,269	19,269	19,269	19,269	19,269	19,269	19,269
Average Annual Demand, ac-ft	0	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200
Average Day Demand, MGD	0.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Well Capacity Required, MGD	0.0	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
Number of Existing Wells	0	0	19	19	19	19	19	19	19	19	19
Number of Wells Required	0	19	19	19	19	19	19	19	19	19	19
Number of Wells to be Developed	0	0	19	0	0	0	0	0	0	0	0
Estimated Well Level	0	-500	-510	-520	-530	-540	-550	-560	-570	-580	-590
Pumping Head	100	600	610	620	630	640	650	660	670	680	690
Annual Electricity Consumption, kwh	0	0	8,757,579	8,901,146	9,044,713	9,188,280	9,331,847	9,475,414	9,618,981	9,762,548	9,906,114
Annual Electric Cost	$0	$0	$613,031	$623,080	$633,130	$643,180	$653,229	$663,279	$673,329	$683,378	$693,428
Annual ClO2 Consumption,	0	0	0	0	0	0	0	0	0	0	0
Annual ClO2 Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual PO4 Consumption	0	0	0	0	0	0	0	0	0	0	0
Annual PO4 Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual Cl Consumption	0	0	0	0	0	0	0	0	0	0	0
Annual Cl Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Capital Cost for New Wells Required	$0	$0	$12,350,000	$0	$0	$0	$0	$0	$0	$0	$0
Annual Cost for Wells Constructed in 1995		$0	$0	$0	$0						
Annual Cost for Wells Constructed in 2000			$1,165,717	$1,165,717	$1,165,717	$1,165,717					
Annual Cost for Wells Constructed in 2005				$0	$0	$0	$0				
Annual Cost for Wells Constructed in 2010					$0	$0	$0	$0			
Annual Cost for Wells Constructed in 2015						$0	$0	$0	$0		
Annual Cost for Wells Constructed in 2020							$0	$0	$0	$0	
Annual Cost for Wells Constructed in 2025								$0	$0	$0	$0
Annual Cost for Wells Constructed in 2030									$0	$0	$0
Annual Cost for Wells Constructed in 2035										$0	$0
Annual Cost for Wells Constructed in 2040											$0
Total Annual Operating and Capital Cost	$0	$0	$1,778,747	$1,788,797	$1,798,846	$1,808,896	$653,229	$663,279	$673,329	$683,378	$693,428
Water Production Cost, $/1,000 gall.	$0.00	$0.00	$0.49	$0.49	$0.49	$0.50	$0.18	$0.18	$0.18	$0.19	$0.19
Present Worth of this Option	$10,584,732										

a/ All development options assume existing wells to Edwards Aquifer will continue to operate at reduced capacities as prescribed by SB 1477: 83% of current pumping capacity through 2007 and 74% of capacity thereafter.

Table 7-7
South Bexar County Regional Water Supply Study
Estimated Cost of Proposed Wells to Carrizo Sands
Wells Developed in 2015 (Option 2) a/

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040
Number of Connections	0	19,269	19,269	19,269	19,269	19,269	19,269	19,269	19,269	19,269	19,269
Average Annual Demand, ac-ft	0	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200
Average Day Demand, MGD	0.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Well Capacity Required, MGD	0.0	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
Number of Existing Wells	0	0	19	19	19	19	19	19	19	19	19
Number of Wells Required	0	19	19	19	19	19	19	19	19	19	19
Number of Wells to be Developed	0	0	0	0		19	0	0	0	0	0
Estimated Well Level	0	-500	-510	-520	-530	-540	-550	-560	-570	-580	-590
Pumping Head	100	600	610	620	630	640	650	660	670	680	690
Annual Electricity Consumption, kwh	0	0	0	0	0	9,188,280	9,331,847	9,475,414	9,618,981	9,762,548	9,906,114
Annual Electric Cost	$0	$0	$0	$0	$0	$643,180	$653,229	$663,279	$673,329	$683,378	$693,428
Annual ClO2 Consumption,	0	0	0	0	0	0	0	0	0	0	0
Annual ClO2 Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual PO4 Consumption	0	0	0	0	0	0	0	0	0	0	0
Annual PO4 Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual Cl Consumption	0	0	0	0	0	0	0	0	0	0	0
Annual Cl Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Capital Cost for New Wells Required	$0	$0	$0	$0	$0	$12,350,000	$0	$0	$0	$0	$0
Annual Cost for Wells Constructed in 1995		$0	$0	$0	$0						
Annual Cost for Wells Constructed in 2000			$0	$0	$0	$0					
Annual Cost for Wells Constructed in 2005				$0	$0	$0	$0				
Annual Cost for Wells Constructed in 2010					$0	$0	$0	$0			
Annual Cost for Wells Constructed in 2015						$1,165,717	$1,165,717	$1,165,717	$1,165,717		
Annual Cost for Wells Constructed in 2020							$0	$0	$0	$0	
Annual Cost for Wells Constructed in 2025								$0	$0	$0	$0
Annual Cost for Wells Constructed in 2030									$0	$0	$0
Annual Cost for Wells Constructed in 2035										$0	$0
Annual Cost for Wells Constructed in 2040											$0
Total Annual Operating and Capital Cost	$0	$0	$0	$0	$0	$1,808,896	$1,818,946	$1,828,995	$1,839,045	$683,378	$693,428
Water Production Cost, $/1,000 gall.	$0.00	$0.00	$0.00	$0.00	$0.00	$0.50	$0.50	$0.50	$0.50	$0.19	$0.19
Present Worth of this Option	$3,709,252										

a/ All development options assume existing wells to Edwards Aquifer will continue to operate at reduced capacities as prescribed by SB 1477: 83% of current pumping capacity through 2007 and 74% of capacity thereafter.

Table 7-8
South Bexar County Regional Water Supply Study
Estimated Cost of Proposed Wells to Carrizo Sands
Wells Developed in 2025 (Option 4) a/

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040
Number of Connections	0	19,269	19,269	19,269	19,269	19,269	19,269	19,269	19,269	19,269	19,269
Average Annual Demand, ac-ft	0	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200
Average Day Demand, MGD	0.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Well Capacity Required, MGD	0.0	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
Number of Existing Wells	0	0	19	19	19	19	19	19	19	19	19
Number of Wells Required	0	19	19	19	19	19	19	19	19	19	19
Number of Wells to be Developed	0	0	0	0		0	0	19	0	0	0
Estimated Well Level	0	-500	-510	-520	-530	-540	-550	-560	-570	-580	-590
Pumping Head	100	600	610	620	630	640	650	660	670	680	690
Annual Electricity Consumption, kwh	0	0	0	0	0	0	0	9,475,414	9,618,981	9,762,548	9,906,114
Annual Electric Cost	$0	$0	$0	$0	$0	$0	$0	$663,279	$673,329	$683,378	$693,428
Annual ClO2 Consumption,	0	0	0	0	0	0	0	0	0	0	0
Annual ClO2 Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual PO4 Consumption	0	0	0	0	0	0	0	0	0	0	0
Annual PO4 Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual Cl Consumption	0	0	0	0	0	0	0	0	0	0	0
Annual Cl Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Capital Cost for New Wells Required	$0	$0	$0	$0	$0	$0	$0	$12,350,000	$0	$0	$0
Annual Cost for Wells Constructed in 1995		$0	$0	$0	$0						
Annual Cost for Wells Constructed in 2000			$0	$0	$0	$0					
Annual Cost for Wells Constructed in 2005				$0	$0	$0	$0				
Annual Cost for Wells Constructed in 2010					$0	$0	$0	$0			
Annual Cost for Wells Constructed in 2015						$0	$0	$0	$0		
Annual Cost for Wells Constructed in 2020							$0	$0	$0	$0	
Annual Cost for Wells Constructed in 2025								$1,165,717	$1,165,717	$1,165,717	$1,165,717
Annual Cost for Wells Constructed in 2030									$0	$0	$0
Annual Cost for Wells Constructed in 2035										$0	$0
Annual Cost for Wells Constructed in 2040											$0
Total Annual Operating and Capital Cost	$0	$0	$0	$0	$0	$0	$0	$1,828,995	$1,839,045	$1,849,095	$1,859,145
Water Production Cost, $/1,000 gall.	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.50	$0.50	$0.51	$0.51
Present Worth of this Option	$1,630,217										

a/ All development options assume existing wells to Edwards Aquifer will continue to operate at reduced capacities as prescribed by SB 1477: 83% of current pumping capacity through 2007 and 74% of capacity thereafter.

Table 7-9
South Bexar County Regional Water Supply Study
Estimated Cost of Proposed Wells to Carrizo Sands
Wells Developed in 2040 (Option 5) a/

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040
Number of Connections	0	19,269	19,269	19,269	19,269	19,269	19,269	19,269	19,269	19,269	19,269
Average Annual Demand, ac-ft	0	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200
Average Day Demand, MGD	0.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Well Capacity Required, MGD	0.0	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
Number of Existing Wells	0	0	19	19	19	19	19	19	19	19	19
Number of Wells Required	0	19	19	19	19	19	19	19	19	19	19
Number of Wells to be Developed	0	0	0	0		0	0		0	0	19
Estimated Well Level	0	-500	-510	-520	-530	-540	-550	-560	-570	-580	-590
Pumping Head	100	600	610	620	630	640	650	660	670	680	690
Annual Electricity Consumption, kwh	0	0	0	0	0	0	0	0	0	0	9,906,114
Annual Electric Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$693,428
Annual ClO2 Consumption,	0	0	0	0	0	0	0	0	0	0	0
Annual ClO2 Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual PO4 Consumption	0	0	0	0	0	0	0	0	0	0	0
Annual PO4 Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual Cl Consumption	0	0	0	0	0	0	0	0	0	0	0
Annual Cl Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Capital Cost for New Wells Required	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$12,350,000
Annual Cost for Wells Constructed in 1995		$0	$0	$0	$0						
Annual Cost for Wells Constructed in 2000			$0	$0	$0	$0					
Annual Cost for Wells Constructed in 2005				$0	$0	$0	$0				
Annual Cost for Wells Constructed in 2010					$0	$0	$0	$0			
Annual Cost for Wells Constructed in 2015						$0	$0	$0	$0		
Annual Cost for Wells Constructed in 2020							$0	$0	$0	$0	
Annual Cost for Wells Constructed in 2025								$0	$0	$0	$0
Annual Cost for Wells Constructed in 2030									$0	$0	$0
Annual Cost for Wells Constructed in 2035										$0	$0
Annual Cost for Wells Constructed in 2040											$1,165,717
Total Annual Operating and Capital Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,859,145
Water Production Cost, $/1,000 gall.	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.51
Present Worth of this Option	$63,025										

a/ All development options assume existing wells to Edwards Aquifer will continue to operate at reduced capacities as prescribed by SB 1477: 83% of current pumping capacity through 2007 and 74% of capacity thereafter.

Table 7-10
South Bexar County Regional Water Supply Study
Estimated Cost of Proposed Wells to Carrizo Sands
Wells Developed in 2010 (Option 6) a/

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040
Number of Connections	0	19,269	19,269	19,269	19,269	19,269	19,269	19,269	19,269	19,269	19,269
Average Annual Demand, ac-ft	0	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200	11,200
Average Day Demand, MGD	0.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Well Capacity Required, MGD	0.0	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
Number of Existing Wells	0	0	19	19	19	19	19	19	19	19	19
Number of Wells Required	0	19	19	19	19	19	19	19	19	19	19
Number of Wells to be Developed	0	0	0	0	19	0	0	0	0	0	0
Estimated Well Level	0	-500	-510	-520	-530	-540	-550	-560	-570	-580	-590
Pumping Head	100	600	610	620	630	640	650	660	670	680	690
Annual Electricity Consumption, kwh	0	0	0	0	9,044,713	9,188,280	9,331,847	9,475,414	9,618,981	9,762,548	9,906,114
Annual Electric Cost	$0	$0	$0	$0	$633,130	$643,180	$653,229	$663,279	$673,329	$683,378	$693,428
Annual ClO2 Consumption,	0	0	0	0	0	0	0	0	0	0	0
Annual ClO2 Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual PO4 Consumption	0	0	0	0	0	0	0	0	0	0	0
Annual PO4 Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual Cl Consumption	0	0	0	0	0	0	0	0	0	0	0
Annual Cl Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Capital Cost for New Wells Required	$0	$0	$0	$0	$12,350,000	$0	$0	$0	$0	$0	$0
Annual Cost for Wells Constructed in 1995		$0	$0	$0	$0						
Annual Cost for Wells Constructed in 2000			$0	$0	$0	$0					
Annual Cost for Wells Constructed in 2005				$0	$0	$0	$0				
Annual Cost for Wells Constructed in 2010					$1,165,717	$1,165,717	$1,165,717	$1,165,717			
Annual Cost for Wells Constructed in 2015						$0	$0	$0	$0		
Annual Cost for Wells Constructed in 2020							$0	$0	$0	$0	
Annual Cost for Wells Constructed in 2025								$0	$0	$0	$0
Annual Cost for Wells Constructed in 2030									$0	$0	$0
Annual Cost for Wells Constructed in 2035										$0	$0
Annual Cost for Wells Constructed in 2040											$0
Total Annual Operating and Capital Cost	$0	$0	$0	$0	$1,798,846	$1,808,896	$1,818,946	$1,828,995	$673,329	$683,378	$693,428
Water Production Cost, $/1,000 gall.	$0.00	$0.00	$0.00	$0.00	$0.49	$0.50	$0.50	$0.50	$0.18	$0.19	$0.19
Present Worth of this Option	$5,295,755										

a/ All development options assume existing wells to Edwards Aquifer will continue to operate at reduced capacities as prescribed by SB 1477: 83% of current pumping capacity through 2007 and 74% of capacity thereafter.

Table 7-11
South Bexar County Regional Water Supply Study
Estimated Cost of Proposed Surface Water and Carrizo Sands Groundwater Treatment Facilities
Facilities Constructed Under Option 1 a/

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040
Number of Connections			39,037	49,762	60,485	72,391	84,296	104,096	123,898	144,755	165,612
Average Annual Demand, ac-ft b/			22,690	28,924	35,157	42,077	48,997	60,506	72,016	84,139	96,262
Average Day Demand, MGD			20	26	31	38	44	54	64	75	86
Treatment Plant Capacity Required, MGD c/			30	43	52	63	73	90	107	125	143
Treatment Plant Capacity Provided, MGD			50	50	100	100	100	100	150	150	150
Capital Cost of 50 MGD Treatment Plant			$49,233,000								
Capital Cost of Lake Medina Diversion Structure			$4,800,000								
Capital Cost of Transmission Line from Lake Medina			$35,500,000								
Capital Cost of Carrizo Pump Station			$5,600,000								
Capital Cost of Trans. Line from Carrizo Well Field			$10,000,000								
Annual Cost of Treatment Plant and Pipeline(s)			$9,923,504	$9,923,504	$9,923,504	$9,923,504					
Capital Cost of 50 MGD Treatment Plant Expansion					$41,848,050						
Annual Cost of 50 MGD Treatment Plant Expansion					$3,950,037	$3,950,037	$3,950,037	$3,950,037			
Capital Cost of 50 MGD Treatment Plant Expansion									$41,848,050		
Annual Cost of 50 MGD Treatment Plant Expansion									$3,950,037	$3,950,037	$3,950,037
Capital Cost of 50 MGD Treatment Plant Expansion											$22,154,850
Annual Cost of 50 MGD Treatment Plant Expansion											$2,091,196
Annual Raw Water Pumping Elec. Consumption, kwh			8,254,666	15,940,424	27,550,180	46,064,468	71,616,603	132,829,637	222,045,248	352,148,410	525,443,287
Annual Raw Water Pumping Electrical Cost			$577,827	$1,115,830	$1,928,513	$3,224,513	$5,013,162	$9,298,075	$15,543,167	$24,650,389	$36,781,030
Annual Raw Water Purchase Cost from BMA d/			$680,000	$680,000	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800
Annual Raw Water Purchase Cost from Lindenau e/									$8,960,000	$8,960,000	$8,960,000
Annual Electricity Consumption for Treatment kwh			390,380	497,636	604,875	723,933	842,991	1,041,003	1,239,032	1,447,608	1,656,183
Annual Electricity Cost for Treatment			$27,327	$34,835	$42,341	$50,675	$59,009	$72,870	$86,732	$101,333	$115,933
Annual Coagulant Aid Consumption			924,935	1,179,058	1,433,140	1,715,227	1,997,314	2,466,467	2,935,661	3,429,843	3,924,025
Annual Coagulant Aid Cost			$92,494	$117,906	$143,314	$171,523	$199,731	$246,647	$293,566	$342,984	$392,403
Annual Cl Consumption			123,325	157,208	191,085	228,697	266,309	328,862	391,421	457,312	523,203
Annual Cl Cost			$36,997	$47,162	$57,326	$68,609	$79,893	$98,659	$117,426	$137,194	$156,961
Annual PO4 Consumption			61,662	78,604	95,543	114,348	133,154	164,431	195,711	228,656	261,602
Annual PO4 Cost			$112,842	$143,845	$174,843	$209,258	$243,672	$300,909	$358,151	$418,441	$478,731
Annual Operating and Capital Cost			$11,450,990	$12,063,081	$18,560,678	$19,938,919	$11,886,305	$16,307,997	$31,649,880	$40,901,178	55267091.21
Water Production Cost, $/1,000 gal			$1.55	$1.28	$1.62	$1.45	$0.74	$0.83	$1.35	$1.49	$1.76
Present Worth of this Option	$107,702,979										

a/ Option 1 - Assumes maximum satisfaction of water demands with existing groundwater supplies and pumping capacities; recovery of LM/DR System groundwater losses; full development of the LM/DR System yield, including BMA diversions; development of wells in the Carrizo Formation; and purchase of 40 MGD from the proposed Lindenau Project. Option 1 specifically excludes all use of Effluent from Living Waters Catfish Farm.

b/ Demand to be satisfied by new surface water and Carrizo Sand sources. Does not include projected demands which will be satisfied from existing sources or LM/DR groundwater losses recovered from existing well capacity.

c/ Required treatment capacity is assumed at 1.67 time the Average Day Demand.

d/ Raw water cost assumed at current Canyon Reservoir rate of $55/ac-ft.

e/ Raw water cost from Lindenau Reservoir assumed at $200/ac-ft.

Table 7-12
South Bexar County Regional Water Supply Study
Estimated Cost of Proposed Surface Water and Carrizo Sands Groundwater Treatment Facilities
Facilities Constructed Under Option 2 a/

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040
Number of Connections			39,037	49,762	60,485	72,391	84,296	104,096	123,898	144,755	165,612
Average Annual Demand, ac-ft b/			22,690	28,924	35,157	42,077	48,997	60,506	72,016	84,139	96,262
Average Day Demand, MGD			20	26	31	38	44	54	64	75	86
Treatment Plant Capacity Required, MGD c/			30	43	52	63	73	90	107	125	143
Treatment Plant Capacity Provided, MGD			75	75	75	100	100	100	150	150	150
Capital Cost of 75 MGD Treatment Plant			$73,849,500								
Capital Cost of Lake Medina Diversion Structure			$4,800,000								
Capital Cost of Transmission Line from Lake Medina			$35,500,000								
Capital Cost of Carrizo Pump Station						$5,600,000					
Capital Cost of Trans. Line from Carrizo Well Field						$10,000,000					
Annual Cost of Treatment Plant and Pipeline(s)			$10,774,571	$10,774,571	$10,774,571	$12,247,055	$1,472,484	$1,472,484	$1,472,484		
Capital Cost of 25 MGD Treatment Plant Expansion						$20,924,025					
Annual Cost of 25 MGD Treatment Plant Expansion						$1,975,019	$1,975,019	$1,975,019	$1,975,019		
Capital Cost of 50 MGD Treatment Plant Expansion								$41,848,050			
Annual Cost of 50 MGD Treatment Plant Expansion								$3,950,037	$3,950,037	$3,950,037	$3,950,037
Annual Raw Water Pumping Elec. Consumption, kwh			8,254,666	15,940,424	27,550,180	46,064,468	71,616,603	132,829,637	222,045,248	352,148,410	525,443,287
Annual Raw Water Pumping Electrical Cost			$577,827	$1,115,830	$1,928,513	$3,224,513	$5,013,162	$9,298,075	$15,543,167	$24,650,389	$36,781,030
Annual Raw Water Purchase Cost from BMA d/			$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800
Annual Raw Water Purchase Cost from Lindenau e/								$8,960,000	$8,960,000	$8,960,000	$8,960,000
Annual Electricity Consumption for Treatment kwh			390,380	497,636	604,875	723,933	842,991	1,041,003	1,239,032	1,447,608	1,656,183
Annual Electricity Cost for Treatment			$27,327	$34,835	$42,341	$50,675	$59,009	$72,870	$86,732	$101,333	$115,933
Annual Coagulant Aid Consumption			924,935	1,179,058	1,433,140	1,715,227	1,997,314	2,466,467	2,935,661	3,429,843	3,924,025
Annual Coagulant Aid Cost			$92,494	$117,906	$143,314	$171,523	$199,731	$246,647	$293,566	$342,984	$392,403
Annual Cl Consumption			123,325	157,208	191,085	228,697	266,309	328,862	391,421	457,312	523,203
Annual Cl Cost			$36,997	$47,162	$57,326	$68,609	$79,893	$98,659	$117,426	$137,194	$156,961
Annual PO4 Consumption			61,662	78,604	95,543	114,348	133,154	164,431	195,711	228,656	261,602
Annual PO4 Cost			$112,842	$143,845	$174,843	$209,258	$243,672	$300,909	$358,151	$418,441	$478,731
Annual Operating and Capital Cost			$13,962,858	$14,574,949	$15,461,708	$20,287,452	$11,383,771	$28,715,499	$35,097,383	$40,901,178	$53,175,895
Water Production Cost, $/1,000 gal			$1.89	$1.55	$1.35	$1.48	$0.71	$1.46	$1.50	$1.49	$1.70
Present Worth of this Option	$119,019,231										

a/ Option 2 - Assumes maximum satisfaction of water demands with existing groundwater supplies and pumping capacities; recovery of LM/DR System groundwater losses; full development of the LM/DR System yield, including BMA diversions; development of wells in the Carrizo Formation; and purchase of 40 MGD from the proposed Lindenau Project. Option 2 specifically excludes all use of Effluent from Living Waters Catfish Farm.

b/ Demand to be satisfied by new surface water and Carrizo Sand sources. Does not include projected demands which will be satisfied from existing sources or LM/DR groundwater losses recovered from existing well capacity.

c/ Required treatment capacity is assumed at 1.67 time the Average Day Demand.

d/ Raw water cost assumed at current Canyon Reservoir rate of $55/ac-ft.

e/ Raw water cost from Lindenau Reservoir assumed at $200/ac-ft.

Table 7-13
South Bexar County Regional Water Supply Study
Estimated Cost of Proposed Surface Water and Carrizo Sands Groundwater Treatment Facilities
Facilities Constructed Under Option 3 a/

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040
Number of Connections			39,037	49,762	60,485	72,391	84,296	104,096	123,898	144,755	165,612
Average Annual Demand, ac-ft b/			22,690	28,924	35,157	42,077	48,997	60,506	72,016	84,139	96,262
Average Day Demand, MGD			20	26	31	38	44	54	64	75	86
Treatment Plant Capacity Required, MGD c/			30	43	52	63	73	90	107	125	143
Treatment Plant Capacity Provided, MGD			50	50	75	75	100	100	125	125	150
Capital Cost of 100 MGD Treatment Plant			$98,466,000								
Capital Cost of Lake Medina Diversion Structure			$4,800,000								
Capital Cost of Transmission Line from Lake Medina d/			$35,500,000								
Capital Cost of Carrizo Pump Station			$5,600,000								
Capital Cost of Trans. Line from Carrizo Well Field e/			$10,000,000								
Annual Cost of Treatment Plant and Pipeline(s)			$14,570,607	$14,570,607	$14,570,607	$14,570,607					
Capital Cost of 50 MGD Treatment Plant Expansion								$41,848,050			
Annual Cost of 50 MGD Treatment Plant Expansion								$3,950,037	$3,950,037	$3,950,037	$3,950,037
Annual Raw Water Pumping Elec. Consumption, kwh			8,254,666	15,940,424	27,550,180	46,064,468	71,616,603	132,829,637	222,045,248	352,148,410	525,443,287
Annual Raw Water Pumping Electrical Cost			$577,827	$1,115,830	$1,928,513	$3,224,513	$5,013,162	$9,298,075	$15,543,167	$24,650,389	$36,781,030
Annual Raw Water Purchase Cost from BMA f/			$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800
Annual Raw Water Purchase Cost from Lindenau e/			$0	$0	$0	$0	$0	$8,960,000	$8,960,000	$8,960,000	$8,960,000
Annual Electricity Consumption for Treatment kwh			390,380	497,636	604,875	723,933	842,991	1,041,003	1,239,032	1,447,608	1,656,183
Annual Electricity Cost for Treatment			$27,327	$34,835	$42,341	$50,675	$59,009	$72,870	$86,732	$101,333	$115,933
Annual Coagulant Aid Consumption			924,935	1,179,058	1,433,140	1,715,227	1,997,314	2,466,467	2,935,661	3,429,843	3,924,025
Annual Coagulant Aid Cost			$92,494	$117,906	$143,314	$171,523	$199,731	$246,647	$293,566	$342,984	$392,403
Annual Cl Consumption			123,325	157,208	191,085	228,697	266,309	328,862	391,421	457,312	523,203
Annual Cl Cost			$36,997	$47,162	$57,326	$68,609	$79,893	$98,659	$117,426	$137,194	$156,961
Annual PO4 Consumption			61,662	78,604	95,543	114,348	133,154	164,431	195,711	228,656	261,602
Annual PO4 Cost			$112,842	$143,845	$174,843	$209,258	$243,672	$300,909	$358,151	$418,441	$478,731
Annual Operating and Capital Cost			$17,758,893	$18,370,984	$19,257,743	$20,635,984	$7,936,268	$25,267,997	$31,649,880	$40,901,178	$53,175,895
Water Production Cost, $/1,000 gal			$2.40	$1.95	$1.68	$1.51	$0.50	$1.28	$1.35	$1.49	$1.70
Present Worth of this Option	$132,729,538										

a/ Option 3 - Assumes maximum satisfaction of water demands with existing groundwater supplies and pumping capacities; recovery of LM/DR System groundwater losses; full development of the LM/DR System yield, including BMA diversions; development of wells in the Carrizo Formation; and purchase of 40 MGD from the proposed Lindenau Project. Option 3 specifically excludes all use of Effluent from Living Waters Catfish Farm.

b/ Demand to be satisfied by new surface water and Carrizo Sand sources. Does not include projected demands which will be satisfied from existing sources or LM/DR groundwater losses recovered from existing well capacity.

c/ Required treatment capacity is assumed at 1.67 time the Average Day Demand.

d/ Raw water cost assumed at current Canyon Reservoir rate of $55/ac-ft.

e/ Raw water cost from Lindenau Reservoir assumed at $200/ac-ft.

Table 7-14
South Bexar County Regional Water Supply Study
Estimated Cost of Proposed Surface Water and Carrizo Sands Groundwater Treatment Facilities
Facilities Constructed Under Option 4 a/

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040
Number of Connections			39,037	49,762	60,485	72,391	84,296	104,096	123,898	144,755	165,612
Average Annual Demand, ac-ft b/			22,690	28,924	35,157	42,077	48,997	60,506	72,016	84,139	96,262
Average Day Demand, MGD			20	26	31	38	44	54	64	75	86
Treatment Plant Capacity Required, MGD c/			30	43	52	63	73	90	107	125	143
Treatment Plant Capacity Provided, MGD			100	100	100	100	100	150	150	150	150
Capital Cost of 100 MGD Treatment Plant			$98,466,000								
Capital Cost of LWCF Diversion Structure			$1,600,000								
Capital Cost of Transmission Line from LWCF			$8,610,000								
Capital Cost of Lake Medina Diversion Structure							$4,800,000				
Capital Cost of Transmission Line from Lake Medina							$35,500,000				
Capital Cost of Carrizo Pump Station								$5,600,000			
Capital Cost of Trans. Line from Carrizo Well Field								$10,000,000			
Annual Cost of Treatment Plant and Pipeline(s)			$10,257,928	$10,257,928	$10,257,928	$10,257,928	$3,767,647	$5,226,091	$5,226,091	$5,226,091	$1,458,444
Capital Cost of 50 MGD Treatment Plant Expansion								$41,848,050			
Annual Cost of 50 MGD Treatment Plant Expansion								$3,950,037	$3,950,037	$3,950,037	$3,950,037
Annual Raw Water Pumping Elec. Consumption, kwh			8,254,666	15,940,424	27,550,180	46,064,468	71,616,603	132,829,637	222,045,248	352,148,410	525,443,287
Annual Raw Water Pumping Electrical Cost			$577,827	$1,115,830	$1,928,513	$3,224,513	$5,013,162	$9,298,075	$15,543,167	$24,650,389	$36,781,030
Annual Raw Water Purchase Cost from BMA d/			$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800
Purchase Living Water Catfish Farm Effluent e/			$6,000,000	$0	$0	$0	$0	$0	$0	$0	$0
Annual Electricity Consumption for Treatment kwh			390,380	497,636	604,875	723,933	842,991	1,041,003	1,239,032	1,447,608	1,656,183
Annual Electricity Cost for Treatment			$27,327	$34,835	$42,341	$50,675	$59,009	$72,870	$86,732	$101,333	$115,933
Annual Coagulant Aid Consumption			924,935	1,179,058	1,433,140	1,715,227	1,997,314	2,466,467	2,935,661	3,429,843	3,924,025
Annual Coagulant Aid Cost			$92,494	$117,906	$143,314	$171,523	$199,731	$246,647	$293,566	$342,984	$392,403
Annual Cl Consumption			123,325	157,208	191,085	228,697	266,309	328,862	391,421	457,312	523,203
Annual Cl Cost			$36,997	$47,162	$57,326	$68,609	$79,893	$98,659	$117,426	$137,194	$156,961
Annual PO4 Consumption			61,662	78,604	95,543	114,348	133,154	164,431	195,711	228,656	261,602
Annual PO4 Cost			$112,842	$143,845	$174,843	$209,258	$243,672	$300,909	$358,151	$418,441	$478,731
Annual Operating and Capital Cost			$19,446,214	$14,058,305	$14,945,064	$16,323,305	$11,703,915	$21,534,088	$27,915,971	$37,167,269	$45,674,339
Water Production Cost, $/1,000 gal			$2.63	$1.49	$1.30	$1.19	$0.73	$1.09	$1.19	$1.36	$1.46
Present Worth of this Option	$120,601,639										

a/ Option 4 - Assumes maximum satisfaction of water demands with existing groundwater supplies and pumping capacities; recovery of LM/DR System groundwater losses; full development of the LM/DR System yield, including BMA diversions; development of wells in the Carrizo Formation; and purchase of 40 MGD from the proposed Lindenau Project. Option 4 specifically includes all use of Effluent from Living Waters Catfish Farm as a primary option.

b/ Demand to be satisfied by new surface water and Carrizo Sand sources. Does not include projected demands which will be satisfied from existing sources or LM/DR groundwater losses recovered from existing well capacity.

c/ Required treatment capacity is assumed at 1.67 time the Average Day Demand.

d/ Raw water cost assumed at current Canyon Reservoir rate of $55/ac-ft.

e/ One-time purchase cost of $6,000,000 for all rights to LWCF water and effluent.

Table 7-15
South Bexar County Regional Water Supply Study
Estimated Cost of Proposed Surface Water and Carrizo Sands Groundwater Treatment Facilities
Facilities Constructed Under Option 5 a/

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040
Number of Connections			39,037	49,762	60,485	72,391	84,296	104,096	123,898	144,755	165,612
Average Annual Demand, ac-ft b/			22,690	28,924	35,157	42,077	48,997	60,506	72,016	84,139	96,262
Average Day Demand, MGD			20	26	31	38	44	54	64	75	86
Treatment Plant Capacity Required, MGD c/			30	43	52	63	73	90	107	125	143
Treatment Plant Capacity Provided, MGD			100	100	100	100	150	150	150	150	150
Capital Cost of 100 MGD Treatment Plant			$98,466,000								
Capital Cost of LWCF Diversion Stucture			$1,600,000								
Capital Cost of Transmission Line from LWCF			$8,610,000								
Capital Cost of Lake Medina Diversion Stucture							$4,800,000				
Capital Cost of Transmission Line from Lake Medina							$35,500,000				
Capital Cost of Carrizo Pump Station											$5,600,000
Capital Cost of Trans. Line from Carrizo Well Field											$10,000,000
Annual Cost of Treatment Plant and Pipeline(s)			$10,257,928	$10,257,928	$10,257,928	$10,257,928	$3,767,647	$3,767,647	$3,767,647	$3,767,647	$1,472,484
Capital Cost of 50 MGD Treatment Plant Expansion								$41,848,050			
Annual Cost of 50 MGD Treatment Plant Expansion								$3,950,037	$3,950,037	$3,950,037	$3,950,037
Annual Raw Water Pumping Elec. Consumption, kwh			8,254,666	15,940,424	27,550,180	46,064,468	71,616,603	132,829,637	222,045,248	352,148,410	525,443,287
Annual Raw Water Pumping Electrical Cost			$577,827	$1,115,830	$1,928,513	$3,224,513	$5,013,162	$9,298,075	$15,543,167	$24,650,389	$36,781,030
Annual Raw Water Purchase Cost from BMA d/			$300,000	$300,000	$300,000	$300,000	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800
PurchaseLiving Water Catfish Farm Effluent e/			$6,000,000	$0	$0	$0	$0	$0	$0	$0	$0
Annual Electricity Consumption for Treatment kwh			390,380	497,636	604,875	723,933	842,991	1,041,003	1,239,032	1,447,608	1,656,183
Annual Electricity Cost for Treatment			$27,327	$34,835	$42,341	$50,675	$59,009	$72,870	$86,732	$101,333	$115,933
Annual Coagulant Aid Consumption			924,935	1,179,058	1,433,140	1,715,227	1,997,314	2,466,467	2,935,661	3,429,843	3,924,025
Annual Coagulant Aid Cost			$92,494	$117,906	$143,314	$171,523	$199,731	$246,647	$293,566	$342,984	$392,403
Annual Cl Consumption			123,325	157,208	191,085	228,697	266,309	328,862	391,421	457,312	523,203
Annual Cl Cost			$36,997	$47,162	$57,326	$68,609	$79,893	$98,659	$117,426	$137,194	$156,961
Annual PO4 Consumption			61,662	78,604	95,543	114,348	133,154	164,431	195,711	228,656	261,602
Annual PO4 Cost			$112,842	$143,845	$174,843	$209,258	$243,672	$300,909	$358,151	$418,441	$478,731
Annual Operating and Capital Cost			$17,405,414	$12,017,505	$12,904,264	$14,282,505	$11,703,915	$20,075,644	$26,457,527	$35,708,825	$45,688,379
Water Production Cost, $/1,000 gal			$2.35	$1.28	$1.13	$1.04	$0.73	$1.02	$1.13	$1.30	$1.46
Present Worth of this Option	$108,369,007										

a/ Option 5 - Assumes maximum satisfaction of water demands with existing groundwater supplies and pumping capacities; recovery of LM/DR System groundwater losses; full development of the LM/DR System yield, including BMA diversions; development of wells in the Carrizo Formation; and purchase of 40 MGD from the proposed Lindenau Project. Option 5 specifically includes all use of Effluent from Living Waters Catfish Farm as a primary option.

b/ Demand to be satisfied by new surface water and Carrizo Sand sources. Does not include projected demands which will be satisfied from existing sources or LM/DR groundwater losses recovered from existing well capacity.

c/ Required treatment capacity is assumed at 1.67 time the Average Day Demand.

d/ Raw water cost assumed at current Canyon Reservoir rate of $55/ac-ft.

e/ One-time purchase cost of $6,000,000 for all rights to LWCF water and effluent.

Table 7-16
South Bexar County Regional Water Supply Study
Estimated Cost of Proposed Surface Water and Carrizo Sands Groundwater Treatment Facilities
Facilities Constructed Under Option 6 a/

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040
Number of Connections			39,037	49,762	60,485	72,391	84,296	104,096	123,898	144,755	165,612
Average Annual Demand, ac-ft b/			22,690	28,924	35,157	42,077	48,997	60,506	72,016	84,139	96,262
Average Day Demand, MGD			20	26	31	38	44	54	64	75	86
Treatment Plant Capacity Required, MGD c/			30	43	52	63	73	90	107	125	143
Treatment Plant Capacity Provided, MGD			100	100	100	100	150	150	150	150	150
Capital Cost of 100 MGD Treatment Plant			$98,466,000								
Capital Cost of LWCF Diversion Structure			$1,600,000								
Capital Cost of Transmission Line from LWCF			$8,610,000								
Capital Cost of Lake Medina Diversion Structure							$4,800,000				
Capital Cost of Transmission Line from Lake Medina							$35,500,000				
Capital Cost of Carrizo Pump Station					$5,600,000						
Capital Cost of Trans. Line from Carrizo Well Field					$10,000,000						
Annual Cost of Treatment Plant and Pipeline(s)			$10,257,928	$10,257,928	$11,730,412	$11,730,412	$4,791,379	$4,791,379	$3,767,647	$3,767,647	$0
Capital Cost of 50 MGD Treatment Plant Expansion									$41,848,050		
Annual Cost of 50 MGD Treatment Plant Expansion									$3,950,037	$3,950,037	$3,950,037
Annual Raw Water Pumping Elec. Consumption, kwh			8,254,666	15,940,424	27,550,180	46,064,468	71,616,603	132,829,637	222,045,248	352,148,410	525,443,287
Annual Raw Water Pumping Electrical Cost			$577,827	$1,115,830	$1,928,513	$3,224,513	$5,013,162	$9,298,075	$15,543,167	$24,650,389	$36,781,030
Annual Raw Water Purchase Cost from BMA d/			$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800	$2,340,800
Purchase Living Water Catfish Farm Effluent e/			$6,000,000	$0	$0	$0	$0	$0	$0	$0	$0
Annual Electricity Consumption for Treatment kwh			390,380	497,636	604,875	723,933	842,991	1,041,003	1,239,032	1,447,608	1,656,183
Annual Electricity Cost for Treatment			$27,327	$34,835	$42,341	$50,675	$59,009	$72,870	$86,732	$101,333	$115,933
Annual Coagulant Aid Consumption			924,935	1,179,058	1,433,140	1,715,227	1,997,314	2,466,467	2,935,661	3,429,843	3,924,025
Annual Coagulant Aid Cost			$92,494	$117,906	$143,314	$171,523	$199,731	$246,647	$293,566	$342,984	$392,403
Annual Cl Consumption			123,325	157,208	191,085	228,697	266,309	328,862	391,421	457,312	523,203
Annual Cl Cost			$36,997	$47,162	$57,326	$68,609	$79,893	$98,659	$117,426	$137,194	$156,961
Annual PO4 Consumption			61,662	78,604	95,543	114,348	133,154	164,431	195,711	228,656	261,602
Annual PO4 Cost			$112,842	$143,845	$174,843	$209,258	$243,672	$300,909	$358,151	$418,441	$478,731
Annual Operating and Capital Cost			$19,446,214	$14,058,305	$16,417,548	$17,795,789	$12,727,647	$17,149,338	$26,457,527	$35,708,825	$44,215,895
Water Production Cost, $/1,000 gal			$2.63	$1.49	$1.43	$1.30	$0.80	$0.87	$1.13	$1.30	$1.41
Present Worth of this Option	$121,407,223										

a/ Option 5 - Assumes maximum satisfaction of water demands with existing groundwater supplies and pumping capacities; recovery of LM/DR System groundwater losses; full development of the LM/DR System yield, including BMA diversions; development of wells in the Carrizo Formation; and purchase of 40 MGD from the proposed Lindenau Project. Option 5 specifically includes all use of Effluent from Living Waters Catfish Farm as a primary option.

b/ Demand to be satisfied by new surface water and Carrizo Sand sources. Does not include projected demands which will be satisfied from existing sources or LM/DR groundwater losses recovered from existing well capacity.

c/ Required treatment capacity is assumed at 1.67 time the Average Day Demand.

d/ Raw water cost assumed at current Canyon Reservoir rate of $55/ac-ft.

e/ One-time purchase cost of $6,000,000 for all rights to LWCF water and effluent.

Table 7-17
South Bexar County Regional Water Supply Study
Estimated Cost of Proposed Surface Water and Groundwater Treatment Facilities
Facilities Constructed Under Option 7 a/

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040
Number of Connections			39,037	49,762	60,485	72,391	84,296	104,096	123,898	144,755	165,612
Average Annual Demand, ac-ft b/			22,690	28,924	35,157	42,077	48,997	60,506	72,016	84,139	96,262
Average Day Demand, MGD			20	26	31	38	44	54	64	75	86
Treatment Plant Capacity Required, MGD c/			30	43	52	63	73	90	107	125	143
Treatment Plant Capacity Provided, MGD			100	100	100	100	100	150	150	150	150
Capital Cost of 100 MGD Treatment Plant			$98,466,000								
Capital Cost of LWCF Diversion Structure			$1,600,000								
Capital Cost of Transmission Line from LWCF to LM			$28,000,000								
Capital Cost of Lake Medina Diversion Structure			$4,800,000								
Capital Cost of Transmission Line from Lake Medina			$35,500,000								
Annual Cost of Treatment Plant and Pipeline(s)			$15,892,067	$15,892,067	$15,892,067	$15,892,067					
Capital Cost of 50 MGD Treatment Plant Expansion								$41,848,050			
Annual Cost of 50 MGD Treatment Plant Expansion								$3,950,037	$3,950,037	$3,950,037	$3,950,037
Annual Raw Water Pumping Elec. Consumption, kwh			8,254,666	15,940,424	27,550,180	46,064,468	71,616,603	132,829,637	222,045,248	352,148,410	525,443,287
Annual Raw Water Pumping Electrical Cost			$577,827	$1,115,830	$1,928,513	$3,224,513	$5,013,162	$9,298,075	$15,543,167	$24,650,389	$36,781,030
Annual Raw Water Purchase Cost from BMA d/			$2,340,800	$2,340,800	$2,340,800	$3,564,000	$3,564,000	$3,564,000	$3,564,000	$3,564,000	$3,564,000
Purchase Living Water Catfish Farm Effluent e/			$6,000,000								
Annual Electricity Consumption for Treatment kwh			390,380	497,636	604,875	723,933	842,991	1,041,003	1,239,032	1,447,608	1,656,183
Annual Electricity Cost for Treatment			$27,327	$34,835	$42,341	$50,675	$59,009	$72,870	$86,732	$101,333	$115,933
Annual Coagulant Aid Consumption			924,935	1,179,058	1,433,140	1,715,227	1,997,314	2,466,467	2,935,661	3,429,843	3,924,025
Annual Coagulant Aid Cost			$92,494	$117,906	$143,314	$171,523	$199,731	$246,647	$293,566	$342,984	$392,403
Annual Cl Consumption			123,325	157,208	191,085	228,697	266,309	328,862	391,421	457,312	523,203
Annual Cl Cost			$36,997	$47,162	$57,326	$68,609	$79,893	$98,659	$117,426	$137,194	$156,961
Annual PO4 Consumption			61,662	78,604	95,543	114,348	133,154	164,431	195,711	228,656	261,602
Annual PO4 Cost			$112,842	$143,845	$174,843	$209,258	$243,672	$300,909	$358,151	$418,441	$478,731
Annual Operating and Capital Cost			$25,080,353	$19,692,444	$20,579,203	$23,180,644	$9,159,468	$17,531,197	$23,913,080	$33,164,378	$45,439,095
Water Production Cost, $/1,000 gal			$3.39	$2.09	$1.80	$1.69	$0.57	$0.89	$1.02	$1.21	$1.45
Present Worth of this Option	$147,068,538										

a/ Option 7 - Assumes maximum satisfaction of water demands with existing groundwater supplies and pumping capacities; recovery of LM/DR System groundwater losses; full development of the LM/DR System yield, including BMA diversions; and pump-back of LWCF effluent to Lake Medina @ 60,000 ac-ft/yr (50 MGD).

b/ Demand to be satisfied by new surface water sources. Does not include projected demands which will be satisfied from existing sources or LM/DR groundwater losses recovered from existing well capacity.

c/ Required treatment capacity is assumed at 1.67 time the Average Day Demand.

d/ Raw water cost assumed at current Canyon Reservoir rate of $55/ac-ft.

e/ One-time purchase cost of $6,000,000 for all rights to LWCF water and effluent.

Table 7-18
South Bexar County Water Supply Study
Present Worth and Water Production Costs of Phased Development Options

		Present Worth						
		Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
	Water Treatment Facilities (including pipelines, pump stations, etc.)	$95,445,811	$115,844,531	$119,611,829	$113,015,624	$101,548,458	$112,565,133	$147,068,538
	Carrizo Sands Wells	$10,584,732	$3,709,252	$10,584,732	$1,630,217	$1,630,217	$5,295,755	0
	Total Present Worth of Option	*$107,702,979*	$119,019,231	$132,729,538	$120,601,639	*$108,369,007*	$121,407,223	$147,068,538
		Water Production Cost						
1995	Water Treatment Facilities (including pipelines, pump stations, etc.)							
	Carrizo Sands Wells							
	Total	Current	Current	Current	Current	Current	Current	Current
2000	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.55	$1.89	$2.40	$2.63	$2.35	$2.63	$3.39
	Carrizo Sands Wells	$0.49	$0.00	$0.49	$0.00	$0.00	$0.00	$0.00
	Total	*$2.04*	*$1.89*	$2.89	$2.63	$2.35	$2.63	$3.39
2005	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.26	$1.55	$1.95	$1.49	$1.28	$1.49	$2.09
	Carrizo Sands Wells	$0.49	$0.00	$0.49	$0.00	$0.00	$0.00	$0.00
	Total	$1.75	$1.55	$2.44	$1.49	$1.28	$1.49	$2.09
2010	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.62	$1.35	$1.68	$1.30	$1.13	$1.43	$1.80
	Carrizo Sands Wells	$0.49	$0.00	$0.49	$0.00	$0.00	$0.49	$0.49
	Total	$2.11	$1.35	$2.17	$1.30	$1.13	$1.92	$2.29
2015	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.45	$1.48	$1.51	$1.19	$1.04	$1.30	$1.69
	Carrizo Sands Wells	$0.50	$0.50	$0.50	$0.00	$0.00	$0.50	$0.50
	Total	$1.95	$1.98	$2.01	$1.19	$1.04	$1.80	$2.19
2020	Water Treatment Facilities (including pipelines, pump stations, etc.)	$0.74	$0.71	$0.50	$0.73	$0.73	$0.80	$0.57
	Carrizo Sands Wells	$0.18	$0.50	$0.18	$0.00	$0.00	$0.50	$0.50
	Total	$0.92	$1.21	$0.68	$0.73	$0.73	$1.30	$1.07
2025	Water Treatment Facilities (including pipelines, pump stations, etc.)	$0.83	$1.46	$1.28	$1.09	$1.02	$0.87	$0.89
	Carrizo Sands Wells	$0.18	$0.50	$0.18	$0.50	$0.00	$0.50	$0.50
	Total	$1.01	$1.96	$1.46	$1.59	$1.02	$1.37	$1.39
2030	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.35	$1.50	$1.35	$1.19	$1.13	$1.13	$1.02
	Carrizo Sands Wells	$0.18	$0.50	$0.18	$0.50	$0.00	$0.18	$0.18
	Total	$1.53	$2.00	$1.53	$1.69	$1.13	$1.31	$1.20
2035	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.49	$1.49	$1.49	$1.36	$1.30	$1.30	$1.21
	Carrizo Sands Wells	$0.19	$0.19	$0.19	$0.51	$0.00	$0.19	$0.19
	Total	$1.68	$1.68	$1.68	$1.87	$1.30	$1.49	$1.40
2040	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.76	$1.70	$1.70	$1.49	$1.46	$1.41	$1.45
	Carrizo Sands Wells	$0.19	$0.19	$0.19	$0.51	$0.51	$0.19	$0.19
	Total	$1.95	$1.89	$1.89	$2.00	$1.97	$1.60	$1.64
	Average	$1.66	$1.72	$1.86	$1.61	*$1.33*	$1.66	$1.85

Table 8-1
Bexar Metropolitan Water District
Future Water Supply Development Options
Institutional, Legal, and Financial Considerations

Development Option	Institutional	Legal	Financial	Required Permits
1. ***Limited/No Action Alternative***				
a. Continue on Existing Wells	• No change in existing entities	• Senate Bill 1477 imposes pumping limits on the Edwards Aquifer. From 9/1/93 to 12/31/2007 permitted withdrawals are limited to 450,000 ac-ft/yr. After 12/31/2007 permitted withdrawals are limited to 400,000 ac-ft/yr.	• None Required	• Initial regular permit required by March 1, 1994 from Edwards Aquifer Authority
b. Develop New Wells (1) Well to Edwards Aquifer	• No change in existing entities	• Senate Bill 1477 imposes pumping limits on the Edwards Aquifer. From 9/1/93 to 12/31/2007 permitted withdrawals are limited to 450,000 ac-ft/yr. After 12/31/2007 permitted withdrawals are limited to 400,000 ac-ft/yr.	• Pumping limits increase risk for revenue bonds; may result in higher interest rates	• Pumping permit required from Edward Aquifer Authority
(2) Wells to Carrizo Sands	• No change in existing entities	• No new authorization needed • Possible land and right-of-way acquisition	• Readily available in private market	• Environmental Impact Study need to determine if any environmental permits necessary
(3) Other Formations	• No change in existing entities	• No new authorization needed • Possible land and right-of-way acquisition	• Readily available in private market	• Environmental Impact Study need to determine if any environmental permits necessary
2. ***Medina River Surface Water Source***				
a. Medina Lake (1) Without Living Waters Catfish	• Arrangement with other entities handled by inter-local agreement	• Possible wholesale contracts with other entities • Right-of-way acquisition	• Because of low yield, market will view this as higher risk, could see higher interest rate	• Water Rights Permit, either an appropriative right subject to water necessary for Applewhite, or a change in the diversion point • If water rights permit for over 66,000 ac-ft/yr, the permit will be conditional for all yields above 66,000 ac-ft/yr • Dam safety evaluation • Environmental Impact Statement for right of way
(2) With Living Waters Catfish	• Options: 1) Purchase wastewater, 2) Purchase permitted well, or 3) Purchase catfish farm and lease farm to catfish operator	• Purchase or Lease to be negotiated		• Environmental Impact Statement for right of way • New discharge permit from TWC • Water Supply must meet standards of Safe Drinking Water Act

Table 8-1 (Continued)
Bexar Metropolitan Water District
Future Water Supply Development Options
Institutional, Legal, and Financial Considerations

Development Option	Institutional	Legal	Financial	Required Permits
2. Medina River Surface Water Source b. Diversion Lake (1) Without Living Waters Catfish		• Some right of way acquisition	• Lower yield would be viewed as higher risk; possible higher interest rate from private market	• TWC water rights permit required • Environmental Impact study on right of way
(2) With Living Waters Catfish	• Options: 1) Purchase wastewater, 2) Purchase permitted well, or 3) Purchase catfish farm and lease farm to catfish operator	• Purchase and Lease to be negotiated		• Environmental Impact Statement for right of way • New discharge permit from TWC • Water Supply must meet standards of the Safe Drinking Water Act • TWC Water right permit required
3. Medina River Below Diversion Lake	• No change to existing entities	• Minimum right of way acquisition	• Funding readily available from a variety of sources	• Water rights permit • Environment Impact Study on right of way
4. Medina/Applewhite Reservoir Combination	• Options: 1) SAWS builds dam and BMWD leases storage capacity, 2) BMWD buys raw water, or 3) BMWD buys permit and builds dam • Possible increase in staff and training to operate reservoir	• Negotiation or contracts or purchase of Applewhite permit	• Private bond market	• SAWS holds TWC permit • SAWS obtained environmental permits
5. Lake Medina/Cibolo Reservoir Combination	• Bureau of Reclamation to Operate	• Major land acquisition	• Federal funding authorized; would have to be budgeted and appropriated	• TWC permits required for construction and for diversion • NEPA process • Corp 404 permit
6. Edwards Underground Aquifer - New Wells	• No change to existing entities	• Senate Bill 1477 imposes pumping limits on the Edwards Aquifer. From 9/1/93 to 12/31/2007 permitted withdrawals are limited to 450,000 ac-ft/yr. After 12/31/2007 permitted withdrawals are limited to 400,000 ac-ft/yr.	• Pumpage limitations could increase risk in a revenue bond resulting in higher interest rates	• Pumping permit required from Edward Aquifer Authority

Table 8-1 (Continued)
Bexar Metropolitan Water District
Future Water Supply Development Options
Institutional, Legal, and Financial Considerations

Development Option	Institutional	Legal	Financial	Required Permits
7. Living Waters Catfish Farm Effluent - Direct Use				
a. Without Off-channel Storage		• Major permit hearing		• Subject to TWC permit issuance • USCOE 404 permit • Environmental Assessment
b. With Off-channel Storage		• Major permit hearing • Major land acquisition		• Subject to TWC permit issuance • USCOE 404 permit • Environmental Assessment
8. Purchase and Convert BMA Irrigation Rights	• Handled by contract with BMA • Options include: 1) Purchase or 2) Lease	• Purchase contracts to be negotiated • Water rights hearings	• Can be financed through TWDB	• Requires TWC approval for conversion of agricultural water rights to municipal priority • TWC approval to change operation of reservoir • Discharge permit from TWC
9. Develop Cibolo Reservoir				
a. Without Living Waters Catfish	• Bureau of Reclamation to Operate	• Major land acquisition	• Federal funding authorized; would have to be budgeted and appropriated	• NEPA process • USCOE 404 permit • State Permit from TWC required
b. With Living Waters Catfish	• Bureau of Reclamation to Operate	• Purchase of Living Waters Catfish farm to be negotiated • Major land acquisition	• Federal funding authorized; would have to be budgeted and appropriated	• NEPA process • USCOE 404 permit • State permit from TWC required
10. Wastewater Reuse				
a. BMWD Service Area Wastewater	• Would require BMWD to develop staff handle wastewater treatment	• Wastewater CCN's would have to be acquired. • Contract to buy SAWS WWTPs to be negotiated. • SAWS is asserting their right to control wastewater that originated as groundwater • Edwards Aquifer Authority must give credit for reuse • Right of Way acquisition	• Funding of loans for this purpose available from variety of sources	• TWC and NPDES discharge permits required

Table 8-1 (Continued)
Bexar Metropolitan Water District
Future Water Supply Development Options
Institutional, Legal, and Financial Considerations

Development Option	Institutional	Legal	Financial	Required Permits
10. ***Wastewater Reuse***				
b. Regional Wastewater	• Would require BMWA to develop staff handle wastewater treatment	• Wastewater CCN's would have to be acquired. • Contract to sell SAWS WWTPs to be negotiated.	• Funding of loans for this purpose available from variety of sources	• TWC and NPDES discharge permit required
11. ***Purchase Supplies from Other Entities***				
a. San Antonio Water System (SAWS)	• Handled by wholesale water contracts	• Senate Bill 1477 imposes pumping limits on the Edwards Aquifer. From 9/1/93 to 12/31/2007 permitted withdrawals are limited to 450,000 ac-ft/yr. After 12/31/2007 permitted withdrawals are limited to 400,000 ac-ft/yr.		• Pumping permit required from Edwards Aquifer Authority
b. Canyon Regional Water Authority	• BMWD is part of CRWA. Contracts may be two way. When BMWD has excess water, it would sell the excess to CRWA. When BMWD is water short, it would purchase water from CRWA	• Contracts for water rights to be negotiated		• Interbasin transfer permit from water commission; they will consider if it impairs existing water rights, that applicant will avoid waste and will implement water conservation, applicant will include environmental, social, and economic impacts statement
c. Other		• Pumping limits will be in effect on Edwards water		• Pumping permit required from Edward Aquifer Authority
12. Recharge Enhancement	• Encouraged by TWC and Senate Bill 1477	• Subject to regulation by Edwards Aquifer Authority (EAA). • Edwards Aquifer Authority might reduce pumping of water injected by portion discharged to springs.	• Private bond market will view as story bond project; higher interest rates	• Pumping permit required from Edward Aquifer Authority
13. Inter-aquifer Transfer	• Unknown because of regulatory uncertainty	• Subject to regulation by Edwards Aquifer Authority (EAA) • EAA may view as artificial recharge and offset by portion discharged through springs • Should anticipate new TWC regulations	• Because of technological difficulties and environmental concerns, TWDB funding is unlikely • Because of environmental concerns, federal funding is unlikely • Private bond market will view as story bond project; high interest rates	• If financed in part with Federal funds, NEPA process • Fish and Wildlife and Parks and Wildlife permits

Table 9-1
Future BMWD Water Supply Development Options and Phased Buildout With and Without Consideration of Living Waters Catfish Farm Effluent as a Potential Source a/

		Development Options Which Do Not Include Use of Living Waters Catfish Farm Effluent					
Year	**Average Annual Demand (MGD)**	**Option 1 and Yield (MGD)**		**Option 2 and Yield (MGD)**		**Option 3 and Yield (MGD)**	
1995	**54**	Continue to utilize existing wells at the reduced capacities specified in 1993 Edwards Aquifer legislation (30 MGD maximum pumpage for entire study area).	**30**	Continue to utilize existing wells at the reduced capacities specified in 1993 Edwards Aquifer legislation (30 MGD maximum pumpage for entire study area).	**30**	Continue to utilize existing wells at the reduced capacities specified in 1993 Edwards Aquifer legislation (30 MGD maximum pumpage for entire study area).	**30**
		Utilize existing excess well capacity of BMWD (37 MGD) and local Airforce Bases (30 MGD) to recover LM/DR losses to Edwards Aquifer up to a total of 27 MGD (59 MGD LM/DR permitted yield - 32 MGD BMA diversions).	22	Utilize existing excess well capacity of BMWD (37 MGD) and local Airforce Bases (30 MGD) to recover LM/DR losses to Edwards Aquifer up to a total of 27 MGD (59 MGD LM/DR permitted yield - 32 MGD BMA diversions).	22	Utilize existing excess well capacity of BMWD (37 MGD) and local Airforce Bases (30 MGD) to recover LM/DR losses to Edwards Aquifer up to a total of 27 MGD (59 MGD LM/DR permitted yield - 32 MGD BMA diversions).	22
2000	72	Build 60 MGD pipeline between Lake Medina and BMWD (maximum permitted LM/DR System diversions). Maximum diversion is 60 MGD - 30 MGD BMA diversion - LM/DR loss recovery pumping.	10	Build 60 MGD pipeline between Lake Medina and BMWD (maximum permitted LM/DR System diversions). Maximum diversion is 60 MGD - 30 MGD BMA diversion - LM/DR loss recovery pumping.	10	Build 60 MGD pipeline between Lake Medina and BMWD (maximum permitted LM/DR System diversions). Maximum diversion is 60 MGD - 30 MGD BMA diversion - LM/DR loss recovery pumping.	10
		Drill new 10 MGD well field into Carrizo Sands in northern Atascosa County.	10	Purchase remaining BMA Irrigation rights and eliminate diversions.	30	Drill new 10 MGD well field into Carrizo Sands in northern Atascosa County.	10
		Purchase remaining BMA Irrigation rights and eliminate diversions.	30	Build 75 MGD surface water treatment plant and groundwater blending capabilities.		Purchase remaining BMA Irrigation rights and eliminate diversions.	30
		Build 50 MGD surface water treatment plant and groundwater blending capabilities.				Build 100 MGD surface water treatment plant and groundwater blending capabilities.	
2005	78	Continue to utilize existing wells, but at the reduced capacities specified in 1993 Edwards Aquifer legislation (27 MGD maximum pumpage for entire study area).		Continue to utilize existing wells, but at the reduced capacities specified in 1993 Edwards Aquifer legislation (27 MGD maximum pumpage for entire study area).			
2010	83	Expand water treatment plant to 100 MGD.					
2015	90			Drill new well field into Carrizo Sands in northern Atascosa County	10		
				Expand water treatment plant to 100 MGD.			
2020	96						
2025	106			Purchase additional water supplies (30 MGD) from Lindenau or Goliad Reservoir Projects.	40	Purchase additional water supplies (30 MGD) from Lindenau or Goliad Reservoir Projects.	40
				Expand water treatment plant to 150 MGD.		Expand water treatment plant to 150 MGD.	
2030	116	Purchase additional water supplies (30 MGD) from Lindenau or Goliad Reservoir Projects.	40				
		Expand water treatment plant to 150 MGD.					
2035	127						
2040	138						

a/ All options assumed continued use of groundwater supplies, reduced to 83% of current pumpage rate by 2007 and 74% of current rate thereafter.

Table 9-1 (continued)
Future BMWD Water Supply Development Options and Phased Buildout Without Consideration of Living Waters Catfish Farm Effluent as a Potential Source a/

		Development Options Which Do Not Include Use of Living Waters Catfish Farm Effluent					
Year	Average Annual Demand (MGD)	Option 4 and Yield (MGD)		Option 5 and Yield (MGD)		Option 6 and Yield (MGD)	
1995	54	Continue to utilize existing wells at the reduced capacities specified in 1993 Edwards Aquifer legislation (30 MGD maximum pumpage for entire study area).	30	Continue to utilize existing wells at the reduced capacities specified in 1993 Edwards Aquifer legislation (30 MGD maximum pumpage for entire study area).	30	Continue to utilize existing wells at the reduced capacities specified in 1993 Edwards Aquifer legislation (30 MGD maximum pumpage for entire study area).	30
		Utilize existing excess well capacity of BMWD (37 MGD) and local Airforce Bases (30 MGD) to recover LM/DR losses to Edwards Aquifer up to a total of 27 MGD (59 MGD LM/DR permitted yield - 32 MGD BMA diversions).	22	Utilize existing excess well capacity of BMWD (37 MGD) and local Airforce Bases (30 MGD) to recover LM/DR losses to Edwards Aquifer up to a total of 27 MGD (59 MGD LM/DR permitted yield - 32 MGD BMA diversions).	22	Utilize existing excess well capacity of BMWD (37 MGD) and local Airforce Bases (30 MGD) to recover LM/DR losses to Edwards Aquifer up to a total of 27 MGD (59 MGD LM/DR permitted yield - 32 MGD BMA diversions).	22
2000	72	Purchase Living Waters Catfish Farm Effluent.	50	Purchase Living Waters Catfish Farm Effluent.	50	Purchase Living Waters Catfish Farm Effluent.	50
		Construct an approximate 32,000 ft pipeline between LWCF and BMWD.		Construct an approximate 32,000 ft pipeline between LWCF and BMWD.		Construct an approximate 32,000 ft pipeline between LWCF and BMWD.	
		Build 100 MGD surface water treatment plant and groundwater blending capabilities.		Build 100 MGD surface water treatment plant and groundwater blending capabilities.		Build 100 MGD surface water treatment plant and groundwater blending capabilities.	
2005	78						
2010	83					Develop new wells to Carrizo Sands.	10
						Construct an approximate 100,000 ft pipeline between well fields and BMWD.	
2015	90						
2020	96	Build 60 MGD pipeline between Lake Medina and BMWD (maximum permitted LM/DR System diversions). Maximum diversion is 60 MGD - 30 MGD BMA diversion - LM/DR loss recovery pumping.	10	Build 60 MGD pipeline between Lake Medina and BMWD (maximum permitted LM/DR System diversions). Maximum diversion is 60 MGD - 30 MGD BMA diversion - LM/DR loss recovery pumping.	10		
		Expand surface water treatment plant to 150 MGD.		Purchase remaining BMA Irrigation rights and eliminate diversions.	30		
				Expand surface water treatment plant to 150 MGD.			
2025	106	Drill new 10 MGD well field into Carrizo Sands in northern Atascosa County.	10			Build 60 MGD pipeline between Lake Medina and BMWD (maximum permitted LM/DR System diversions). Maximum diversion is 60 MGD - 30 MGD BMA diversion - LM/DR loss recovery pumping.	10
2030	116					Expand surface water treatment plant to 150 MGD.	
2035	127	Purchase remaining BMA Irrigation rights and eliminate diversions.	30			Purchase remaining BMA Irrigation rights and eliminate diversions.	30
2040	138			Drill new 10 MGD well field into Carrizo Sands in northern Atascosa County.	10		

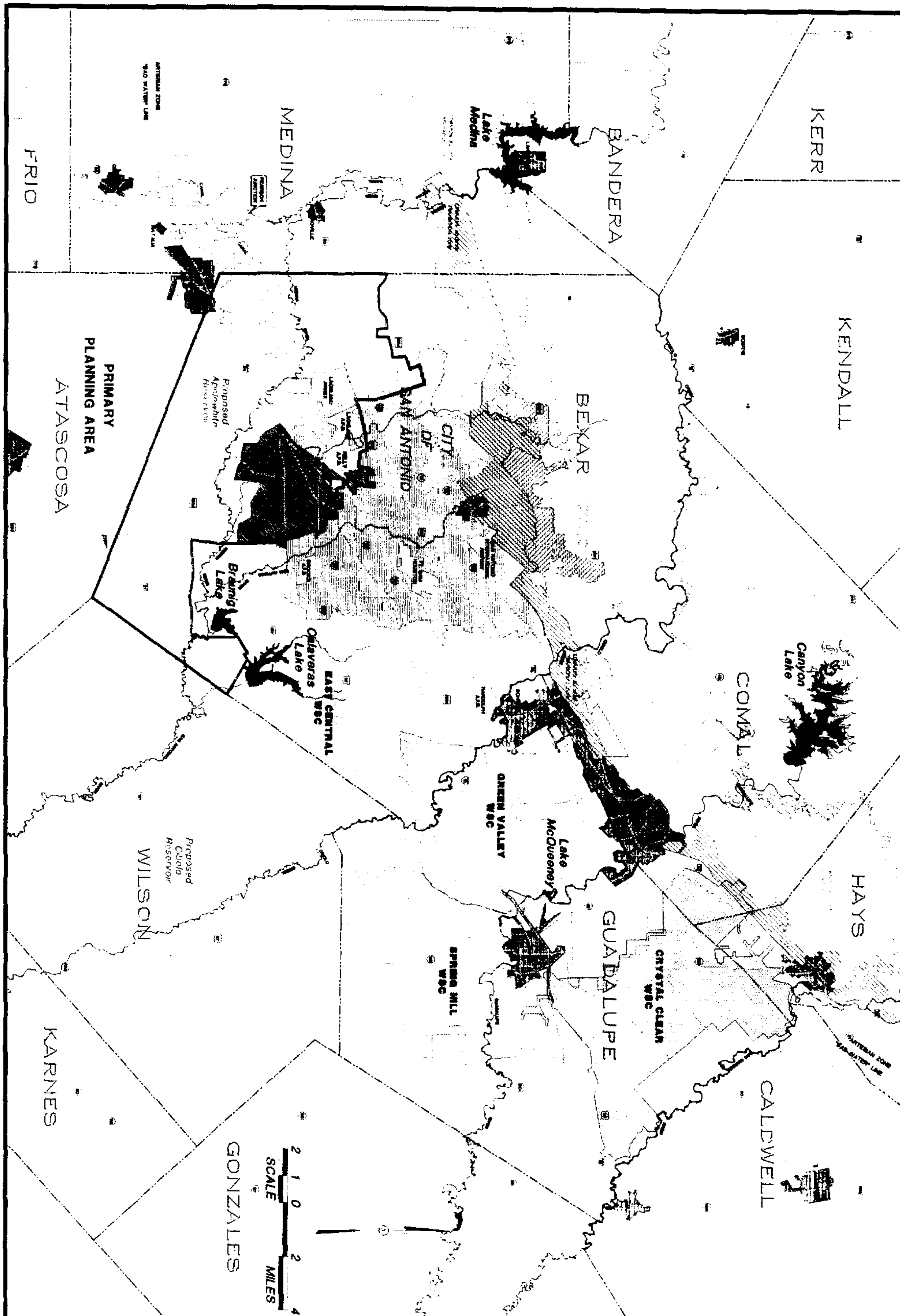
a/ All options assumed continued use of groundwater supplies, reduced to 83% of current pumpage rate by 2007 and 74% of current rate thereafter.

Table 9-2
South Bexar County Water Supply Study
Present Worth and Water Production Costs of Phased Development Options

		Present Worth						
		Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
	Water Treatment Facilities (including pipelines, pump stations, etc.)	$95,445,811	$115,844,531	$119,611,829	$113,015,624	$101,548,458	$112,565,133	$147,068,538
	Carrizo Sands Wells	$10,584,732	$3,709,252	$10,584,732	$1,630,217	$1,630,217	$5,295,755	0
	Total Present Worth of Option	*$107,702,979*	$119,019,231	$132,729,538	$120,601,639	*$108,369,007*	$121,407,223	$147,068,538
		Water Production Cost						
1995	Water Treatment Facilities (including pipelines, pump stations, etc.)							
	Carrizo Sands Wells							
	Total	Current	Current	Current	Current	Current	Current	Current
2000	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.55	$1.89	$2.40	$2.63	$2.35	$2.63	$3.39
	Carrizo Sands Wells	$0.49	$0.00	$0.49	$0.00	$0.00	$0.00	$0.00
	Total	*$2.04*	*$1.89*	$2.89	$2.63	$2.35	$2.63	$3.39
2005	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.26	$1.55	$1.95	$1.49	$1.28	$1.49	$2.09
	Carrizo Sands Wells	$0.49	$0.00	$0.49	$0.00	$0.00	$0.00	$0.00
	Total	$1.75	$1.55	$2.44	$1.49	$1.28	$1.49	$2.09
2010	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.62	$1.35	$1.68	$1.30	$1.13	$1.43	$1.80
	Carrizo Sands Wells	$0.49	$0.00	$0.49	$0.00	$0.00	$0.49	$0.49
	Total	$2.11	$1.35	$2.17	$1.30	$1.13	$1.92	$2.29
2015	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.45	$1.48	$1.51	$1.19	$1.04	$1.30	$1.69
	Carrizo Sands Wells	$0.50	$0.50	$0.50	$0.00	$0.00	$0.50	$0.50
	Total	$1.95	$1.98	$2.01	$1.19	$1.04	$1.80	$2.19
2020	Water Treatment Facilities (including pipelines, pump stations, etc.)	$0.74	$0.71	$0.50	$0.73	$0.73	$0.80	$0.57
	Carrizo Sands Wells	$0.18	$0.50	$0.18	$0.00	$0.00	$0.50	$0.50
	Total	$0.92	$1.21	$0.68	$0.73	$0.73	$1.30	$1.07
2025	Water Treatment Facilities (including pipelines, pump stations, etc.)	$0.83	$1.46	$1.28	$1.09	$1.02	$0.87	$0.89
	Carrizo Sands Wells	$0.18	$0.50	$0.18	$0.50	$0.00	$0.50	$0.50
	Total	$1.01	$1.96	$1.46	$1.59	$1.02	$1.37	$1.39
2030	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.35	$1.50	$1.35	$1.19	$1.13	$1.13	$1.02
	Carrizo Sands Wells	$0.18	$0.50	$0.18	$0.50	$0.00	$0.18	$0.18
	Total	$1.53	$2.00	$1.53	$1.69	$1.13	$1.31	$1.20
2035	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.49	$1.49	$1.49	$1.36	$1.30	$1.30	$1.21
	Carrizo Sands Wells	$0.19	$0.19	$0.19	$0.51	$0.00	$0.19	$0.19
	Total	$1.68	$1.68	$1.68	$1.87	$1.30	$1.49	$1.40
2040	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.76	$1.70	$1.70	$1.49	$1.46	$1.41	$1.45
	Carrizo Sands Wells	$0.19	$0.19	$0.19	$0.51	$0.51	$0.19	$0.19
	Total	$1.95	$1.89	$1.89	$2.00	$1.97	$1.60	$1.64
	Average	$1.66	$1.72	$1.86	$1.61	*$1.33*	$1.66	$1.85

Table 9-2
South Bexar County Water Supply Study
Present Worth and Water Production Costs of Phased Development Options

		Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
	Present Worth							
	Water Treatment Facilities (including pipelines, pump stations, etc.)	$95,445,811	$115,844,531	$119,611,829	$113,015,624	$101,548,458	$112,565,133	$147,068,538
	Carrizo Sands Wells	$10,584,732	$3,709,252	$10,584,732	$1,630,217	$1,630,217	$5,295,755	0
	Total Present Worth of Option	*$107,702,979*	$119,019,231	$132,729,538	$120,601,639	*$108,369,007*	$121,407,223	$147,068,538
	Water Production Cost							
1995	Water Treatment Facilities (including pipelines, pump stations, etc.)							
	Carrizo Sands Wells							
	Total	Current	Current	Current	Current	Current	Current	Current
2000	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.55	$1.89	$2.40	$2.63	$2.35	$2.63	$3.39
	Carrizo Sands Wells	$0.49	$0.00	$0.49	$0.00	$0.00	$0.00	$0.00
	Total	*$2.04*	*$1.89*	$2.89	$2.63	$2.35	$2.63	$3.39
2005	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.26	$1.55	$1.95	$1.49	$1.28	$1.49	$2.09
	Carrizo Sands Wells	$0.49	$0.00	$0.49	$0.00	$0.00	$0.00	$0.00
	Total	$1.75	$1.55	$2.44	$1.49	$1.28	$1.49	$2.09
2010	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.62	$1.35	$1.68	$1.30	$1.13	$1.43	$1.80
	Carrizo Sands Wells	$0.49	$0.00	$0.49	$0.00	$0.00	$0.49	$0.49
	Total	$2.11	$1.35	$2.17	$1.30	$1.13	$1.92	$2.29
2015	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.45	$1.48	$1.51	$1.19	$1.04	$1.30	$1.69
	Carrizo Sands Wells	$0.50	$0.50	$0.50	$0.00	$0.00	$0.50	$0.50
	Total	$1.95	$1.98	$2.01	$1.19	$1.04	$1.80	$2.19
2020	Water Treatment Facilities (including pipelines, pump stations, etc.)	$0.74	$0.71	$0.50	$0.73	$0.73	$0.80	$0.57
	Carrizo Sands Wells	$0.18	$0.50	$0.18	$0.00	$0.00	$0.50	$0.50
	Total	$0.92	$1.21	$0.68	$0.73	$0.73	$1.30	$1.07
2025	Water Treatment Facilities (including pipelines, pump stations, etc.)	$0.83	$1.46	$1.28	$1.09	$1.02	$0.87	$0.89
	Carrizo Sands Wells	$0.18	$0.50	$0.18	$0.50	$0.00	$0.50	$0.50
	Total	$1.01	$1.96	$1.46	$1.59	$1.02	$1.37	$1.39
2030	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.35	$1.50	$1.35	$1.19	$1.13	$1.13	$1.02
	Carrizo Sands Wells	$0.18	$0.50	$0.18	$0.50	$0.00	$0.18	$0.18
	Total	$1.53	$2.00	$1.53	$1.69	$1.13	$1.31	$1.20
2035	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.49	$1.49	$1.49	$1.36	$1.30	$1.30	$1.21
	Carrizo Sands Wells	$0.19	$0.19	$0.19	$0.51	$0.00	$0.19	$0.19
	Total	$1.68	$1.68	$1.68	$1.87	$1.30	$1.49	$1.40
2040	Water Treatment Facilities (including pipelines, pump stations, etc.)	$1.76	$1.70	$1.70	$1.49	$1.46	$1.41	$1.45
	Carrizo Sands Wells	$0.19	$0.19	$0.19	$0.51	$0.51	$0.19	$0.19
	Total	$1.95	$1.89	$1.89	$2.00	$1.97	$1.60	$1.64
	Average	$1.66	$1.72	$1.86	$1.61	*$1.33*	$1.56	$1.65



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Engineering & Environmental Consultants
Air - Water Quality - Water Resources

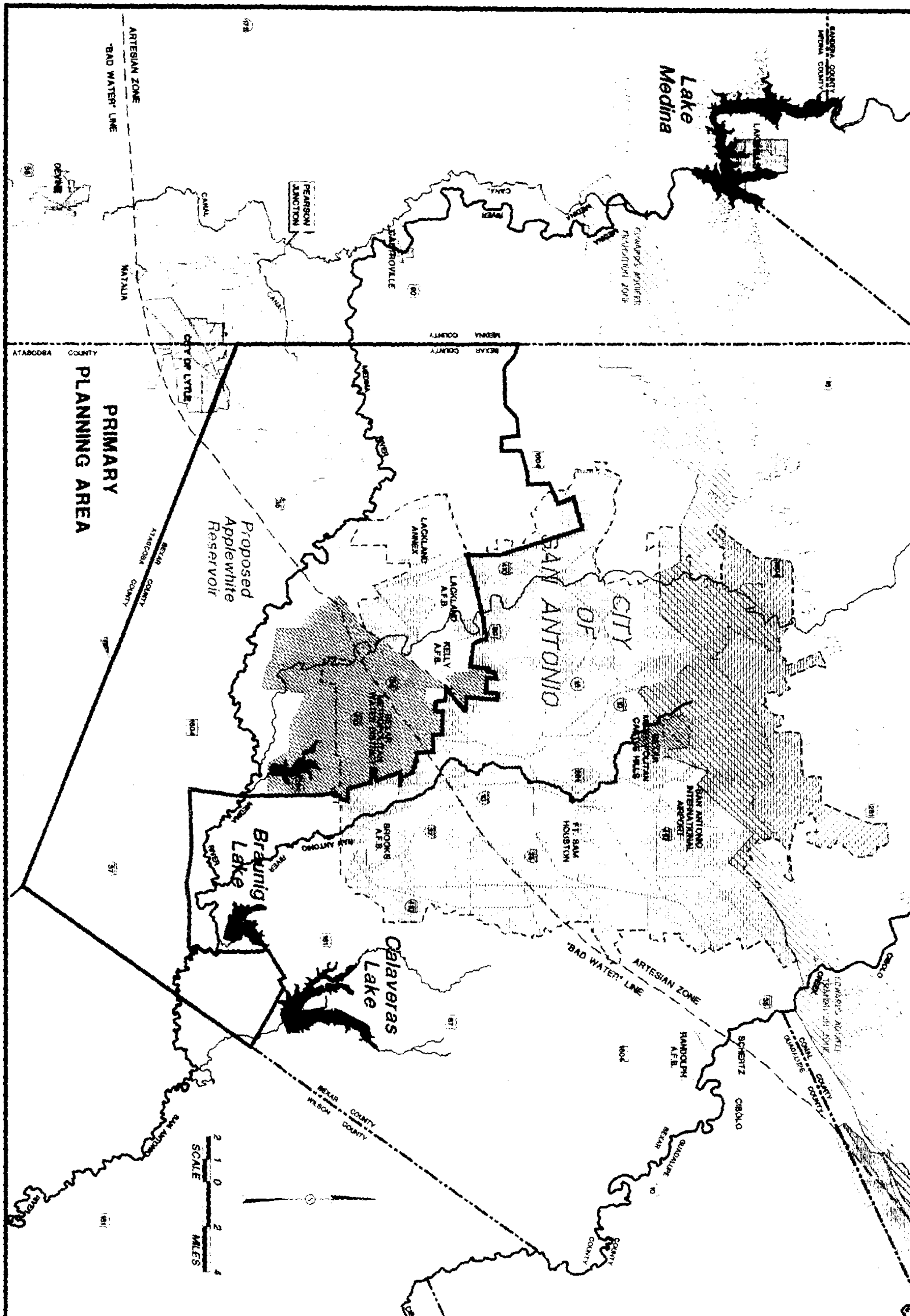
FIGURE 1-1

REGION MAP

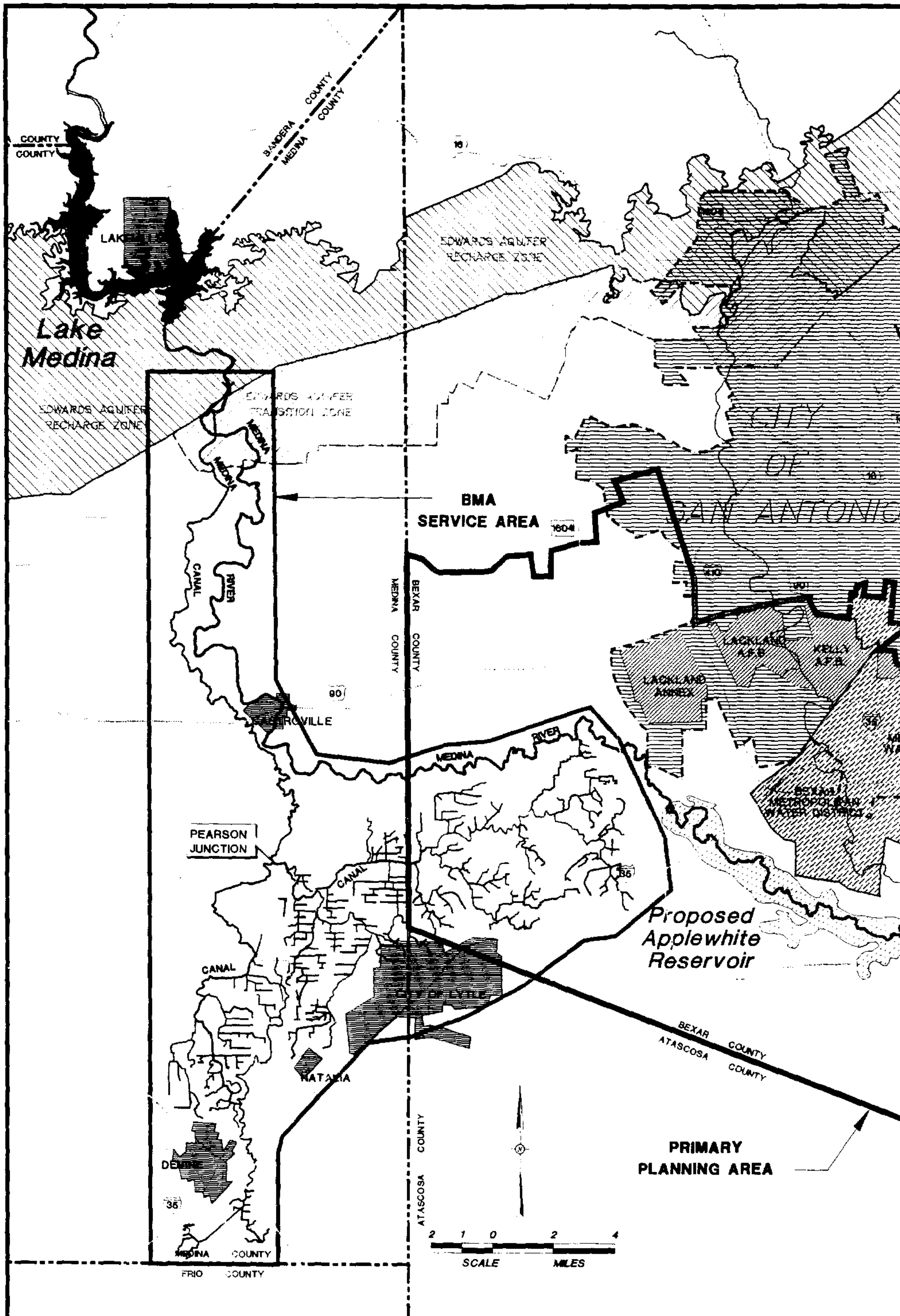
SUBMITTED TO:
Bexar Metropolitan Water District
FOR:
Southern Bexar County
Medina Valley Surface Water Supply Study

DATE:
AUGUST 1992

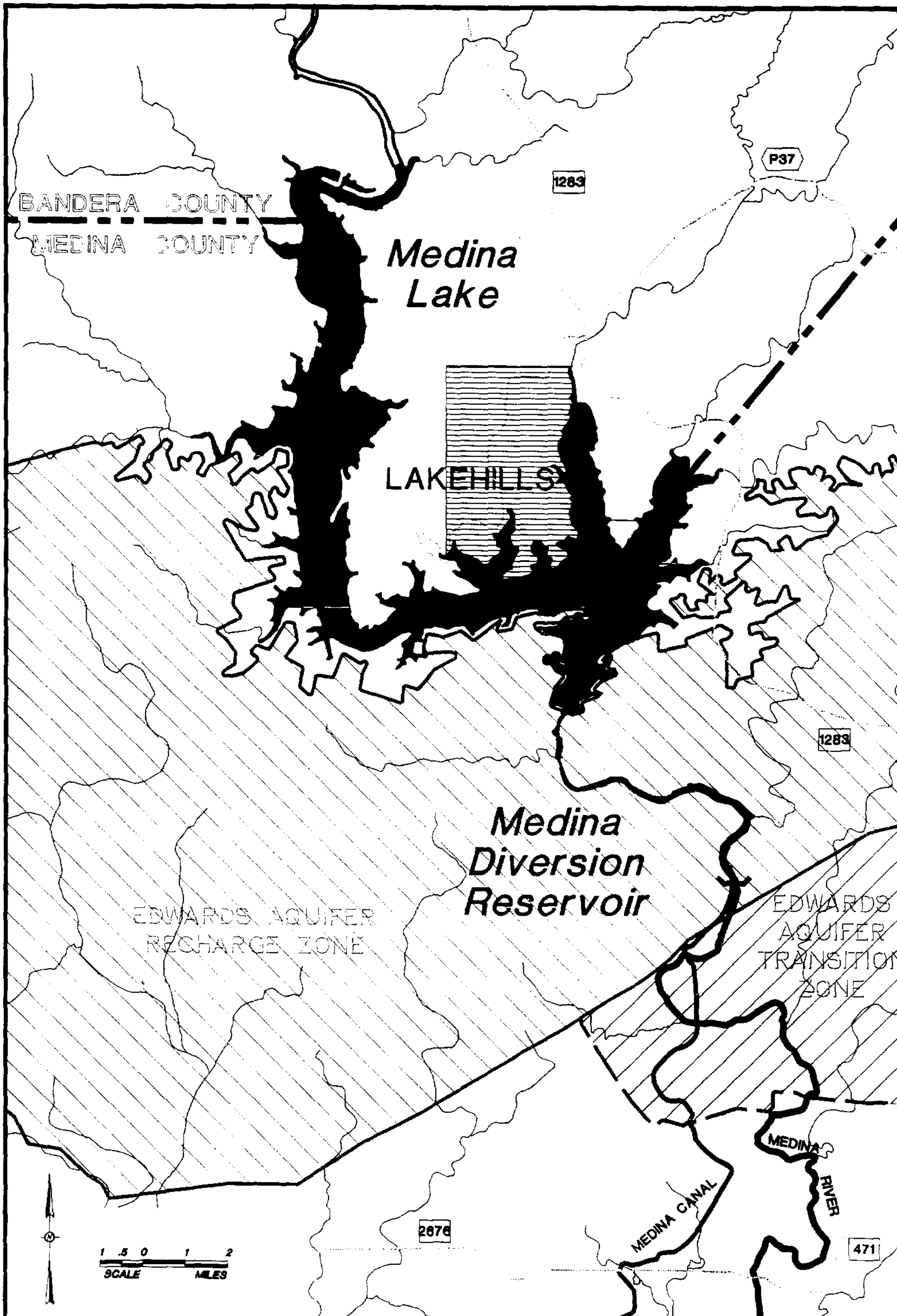
DRAWN BY:
DWS



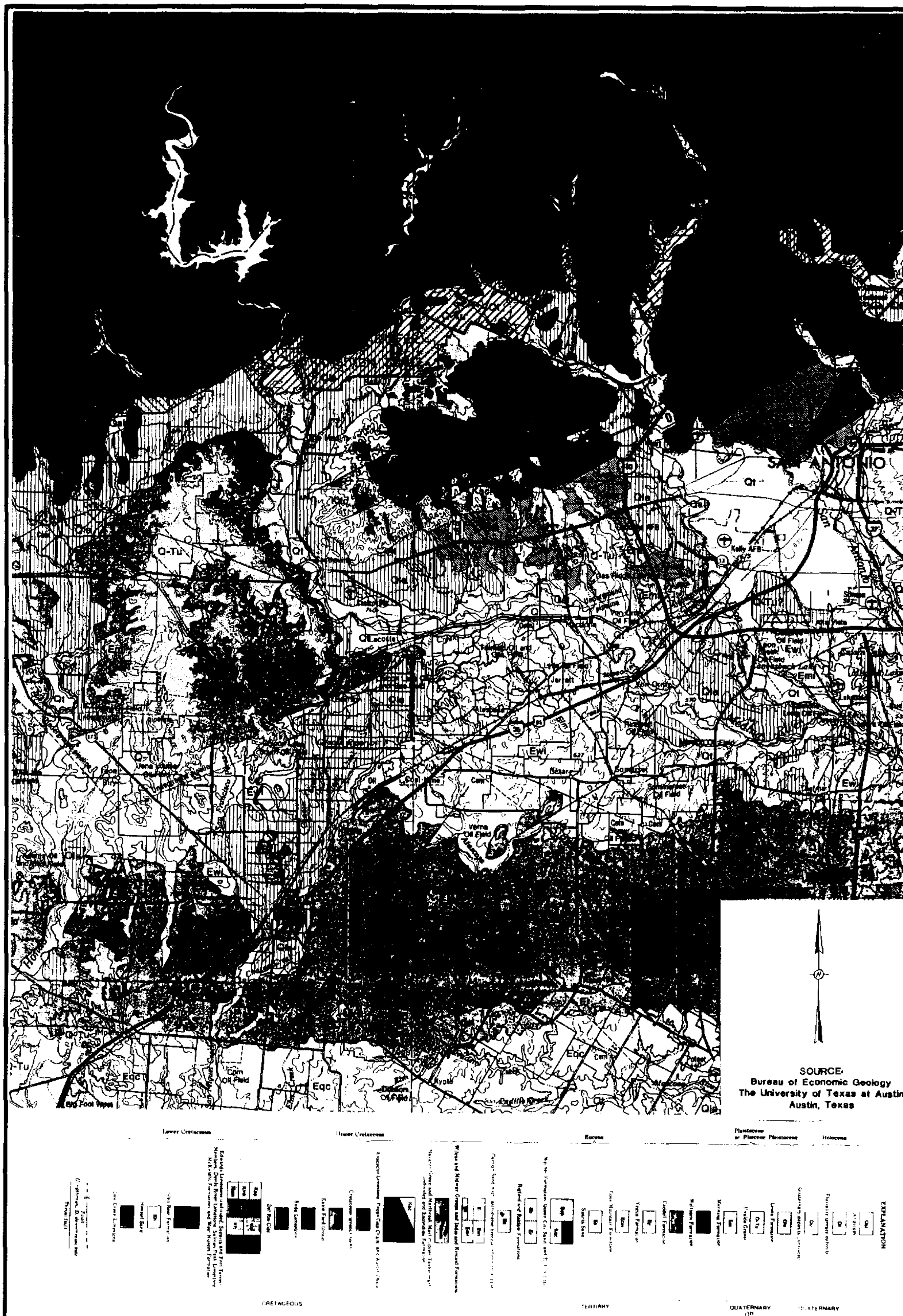
MICHAEL SULLIVAN & ASSOC., INC. Engineering & Environmental Consultants Air - Water Quality - Water Resources	FIGURE 1-2 STUDY AREA MAP	SUBMITTED TO: Bexar Metropolitan Water District FOR: Southern Bexar County Medina Valley Surface Water Supply Study	DATE: AUGUST 1992 DRAWN BY: DWS



MICHAEL SULLIVAN & ASSOC., INC. Engineering & Environmental Consultants Air - Water Quality - Water Resources	FIGURE 1-3 BMA SERVICE AREA MAP	SUBMITTED TO: Bexar Metropolitan Water District FOR: Southern Bexar County Medina Valley Surface Water Supply Study	DATE: AUGUST 1992 DRAWN BY: DWS



MICHAEL SULLIVAN & ASSOC., INC. Engineering & Environmental Consultants Air - Water Quality - Water Resources	FIGURE 1-4 MEDINA/DIVERSION LAKE SCHEMATIC	SUBMITTED TO: Bexar Metropolitan Water District FOR: Southern Bexar County Medina Valley Surface Water Supply Study	DATE: AUGUST 1992 DRAWN BY: DWS



MICHAEL SULLIVAN & ASSOC., INC. Engineering & Environmental Consultants Air - Water Quality - Water Resources	FIGURE 2-1 Regional Geologic Map	SUBMITTED TO: Bexar Metropolitan Water District FOR: Southern Bexar County Medina Valley Surface Water Supply Study	DATE: AUGUST 1992 DRAWN BY: DWS

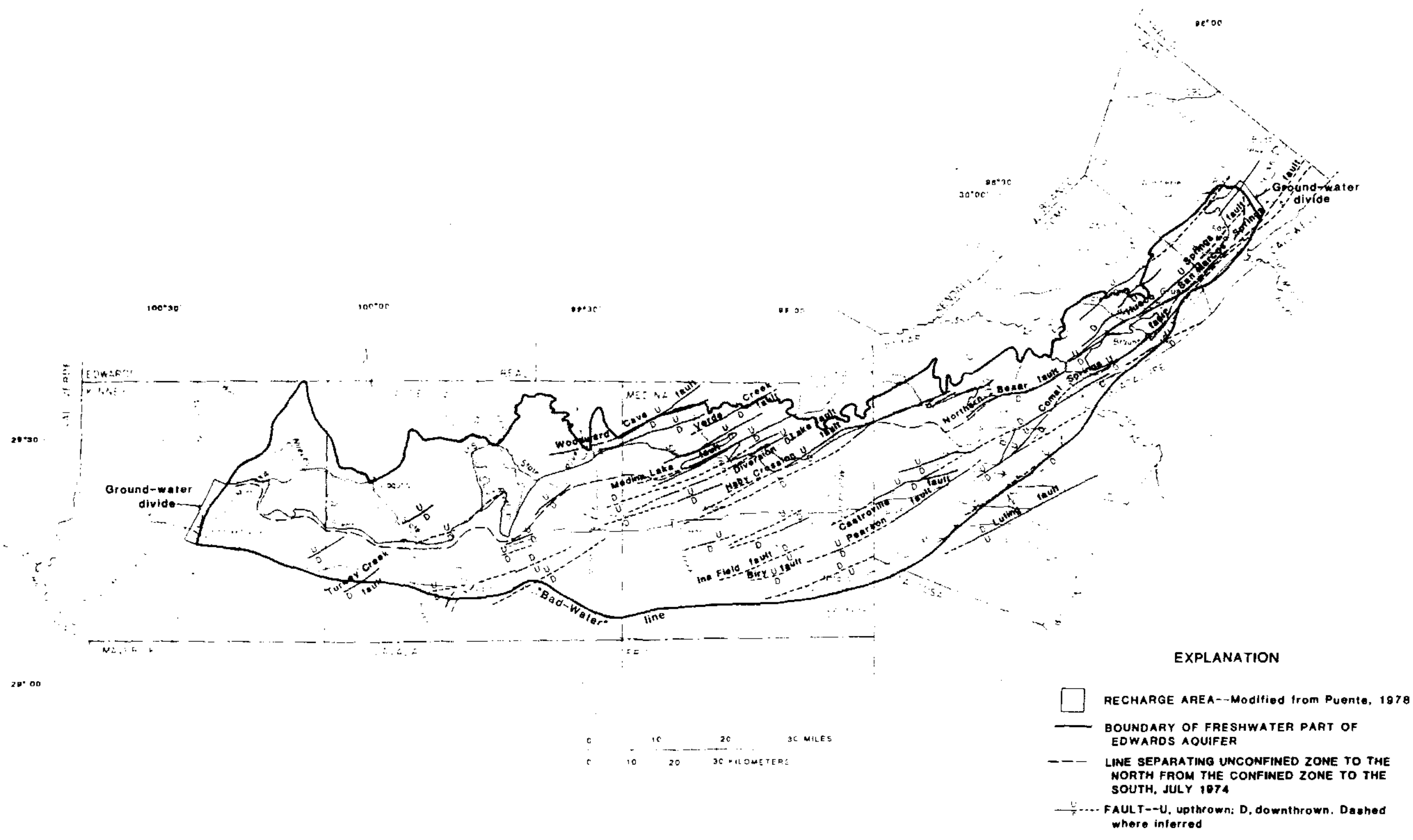


FIGURE 2-2

MAJOR FAULTS OF THE SAN ANTONIO REGION OF THE EDWARDS AQUIFER

SOURCE, USGS 1986

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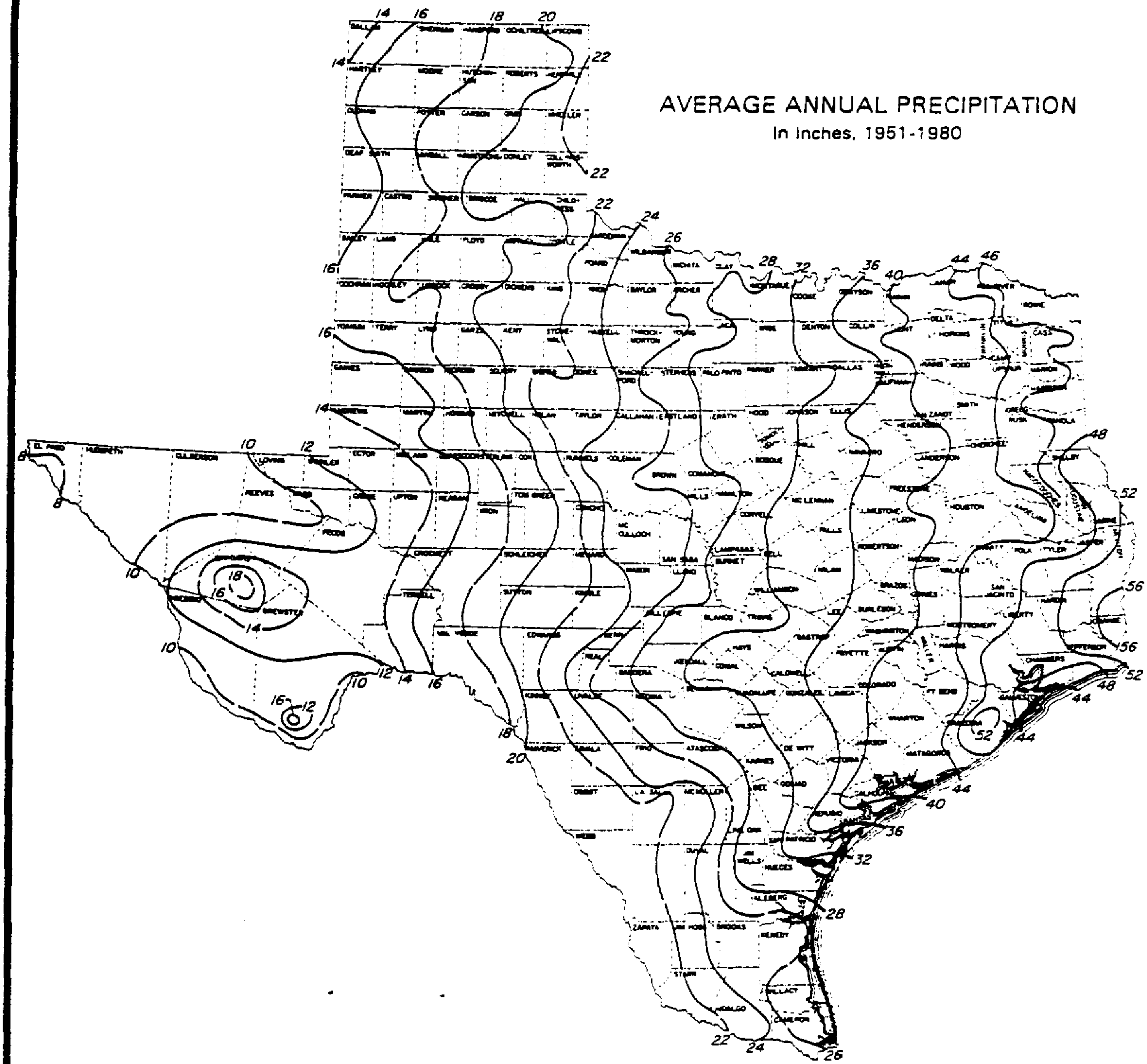
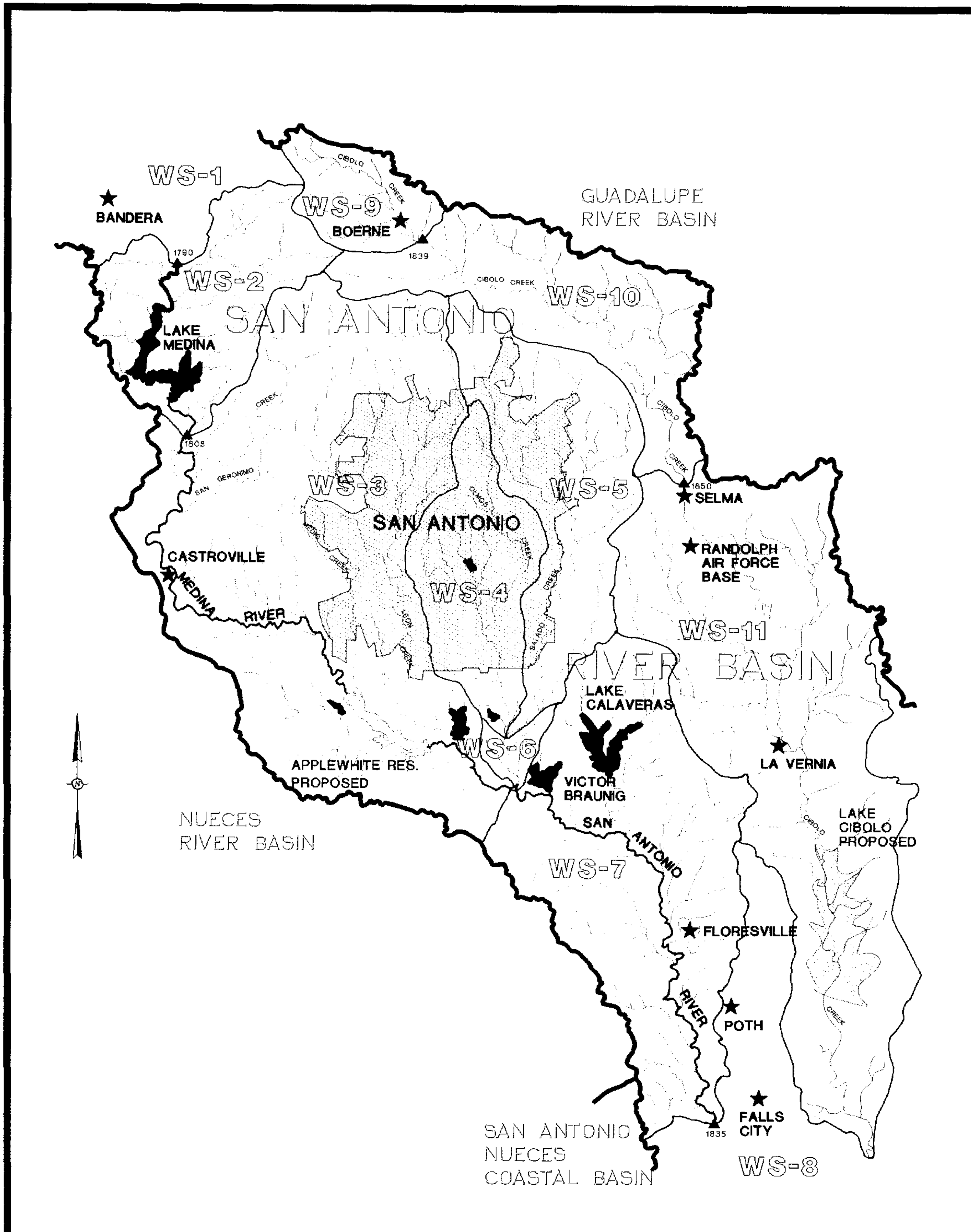
Southern Bexar County
Medina Valley Surface Water Supply Study

DATE: AUGUST 1992

DRAWN BY: DWS



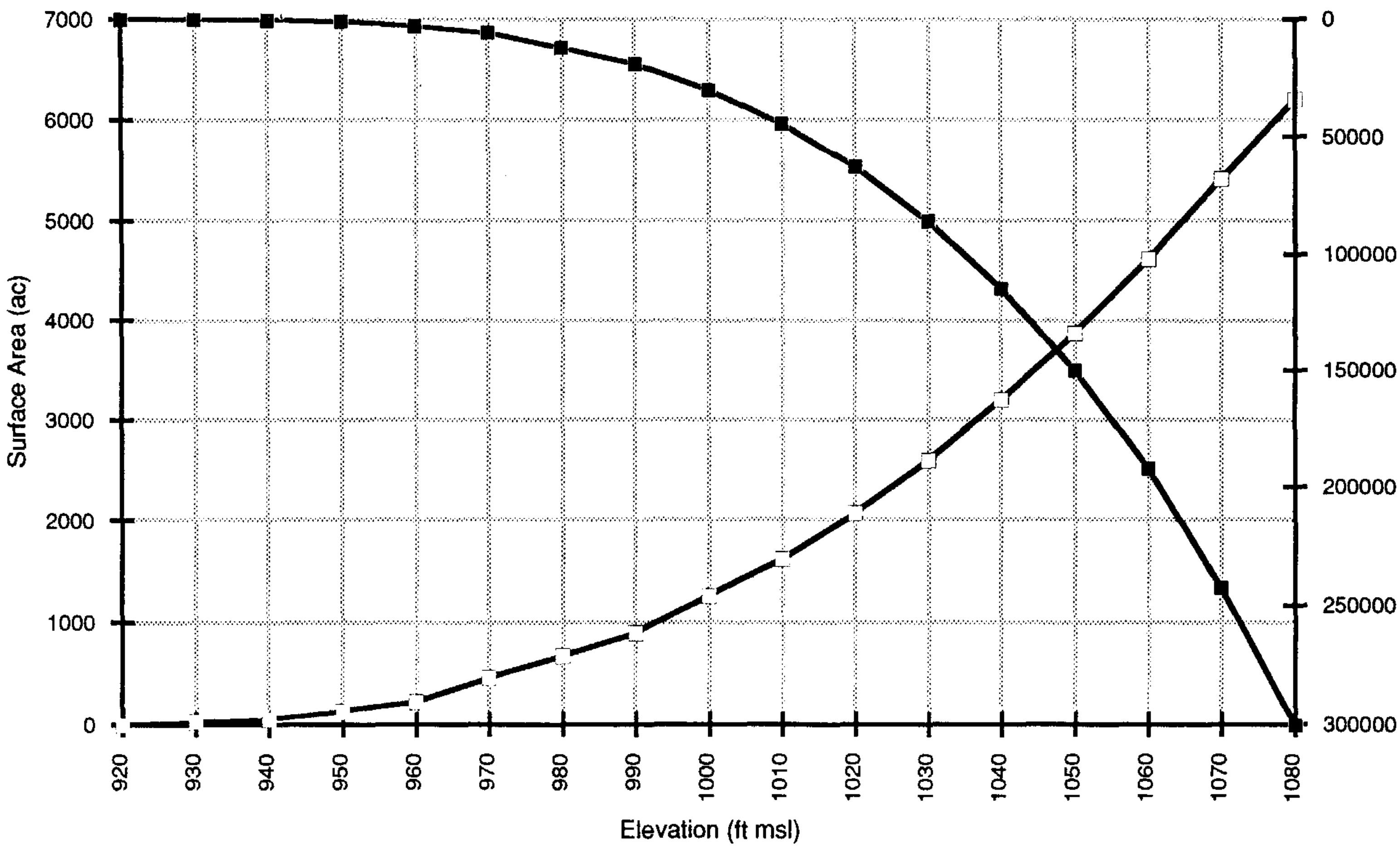
MICHAEL SULLIVAN & ASSOC., INC, Engineering & Environmental Consultants Air - Water Quality - Water Resources	FIGURE 2-3 AVERAGE ANNUAL PRECIPITATION MAP	SUBMITTED TO: **Bexar Metropolitan Water District** FOR: **Southern Bexar County Medina Valley Surface Water Supply Study**	DATE: AUGUST 1992 DRAWN BY: DWS



MICHAEL SULLIVAN & ASSOC., INC. Engineering & Environmental Consultants Air - Water Quality - Water Resources	FIGURE 2-4 Surface Water Drainage Area Map TWC Adjudication Base Source: Texas Water Commision	SUBMITTED TO: Bexar Metropolitan Water District FOR: Southern Bexar County Medina Valley Surface Water Supply Study	DATE: AUGUST 1992 DRAWN BY: DWS

MSA

Figure 2-5
Medina Lake
Elevation-Area-Capacity Curves



MSA

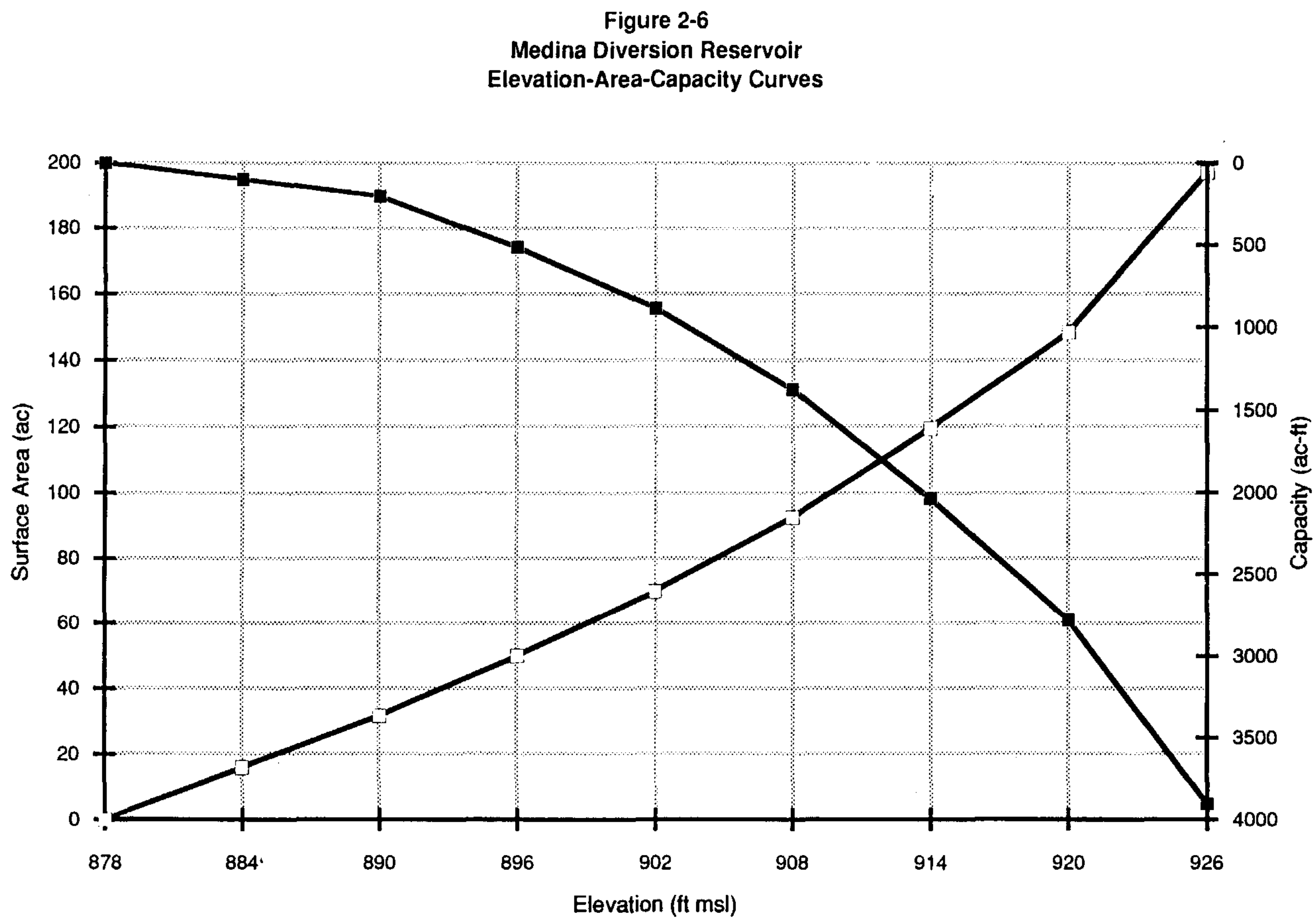
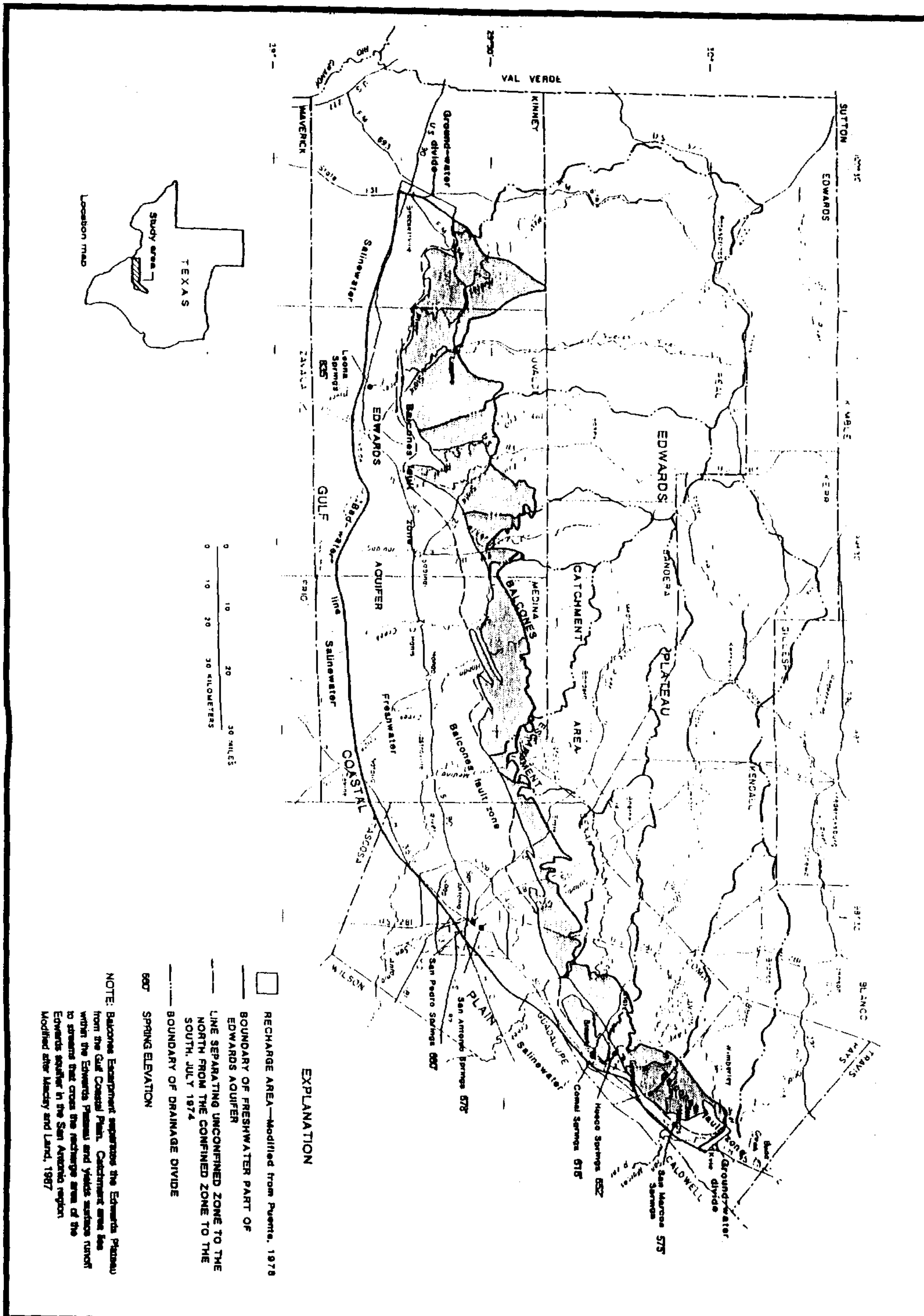
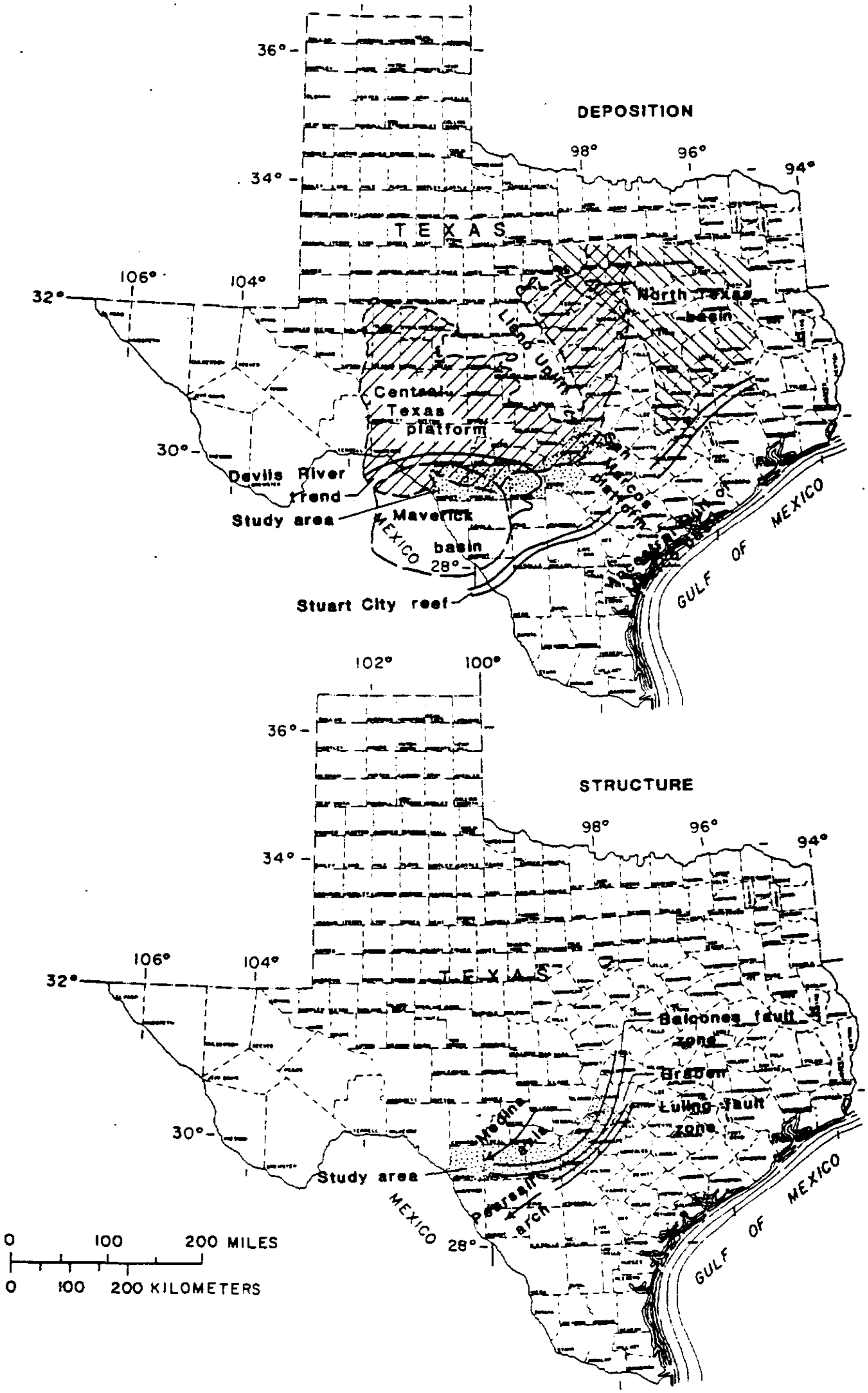


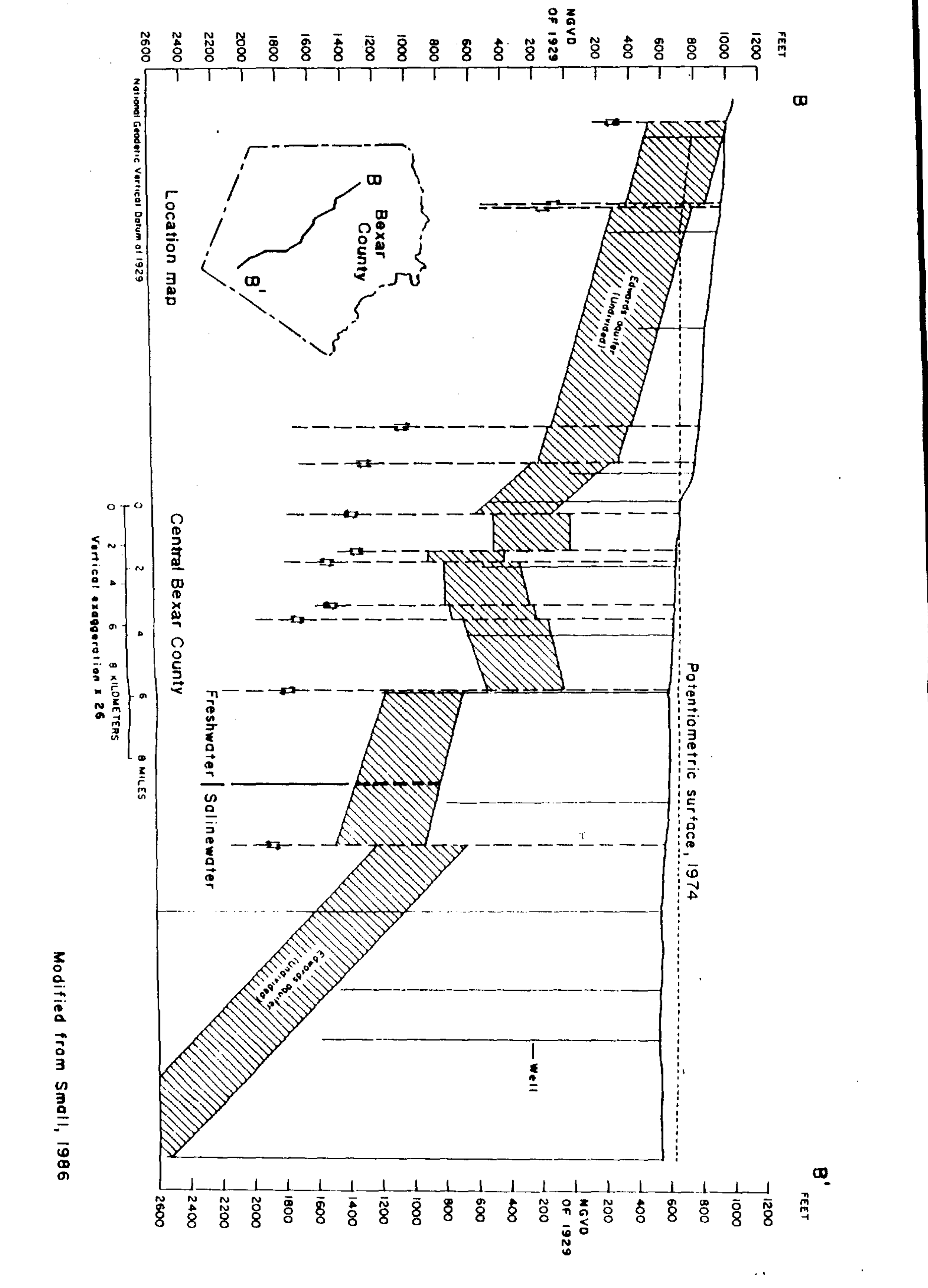
Figure 2-6
Medina Diversion Reservoir
Elevation-Area-Capacity Curves
Surface Area (ac)
200
180
160
140
120
100
80
60
40
20
0
Capacity (ac-ft)
0
500
1000
1500
2000
2500
3000
3500
4000
878
884
890
896
902
908
914
920
926
Elevation (ft msl)



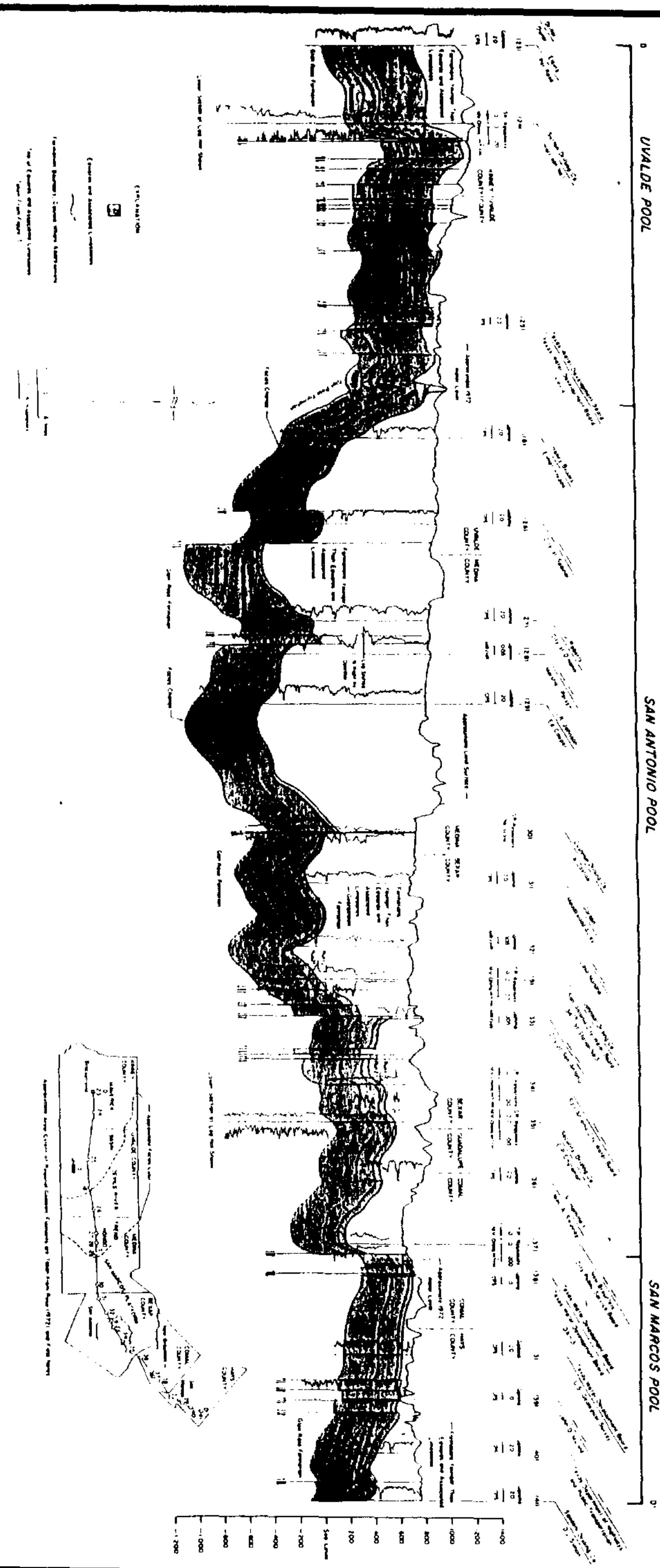
MICHAEL SULLIVAN & ASSOC., INC. Engineering & Environmental Consultants Air - Water Quality - Water Resources	**FIGURE 2-7** SAN ANTONIO REGION OF THE EDWARDS AQUIFER	SUBMITTED TO: **Bexar Metropolitan Water District** FOR: **Southern Bexar County Medina Valley Surface Water Supply Study**	DATE: AUGUST 1992 DRAWN BY: DWS



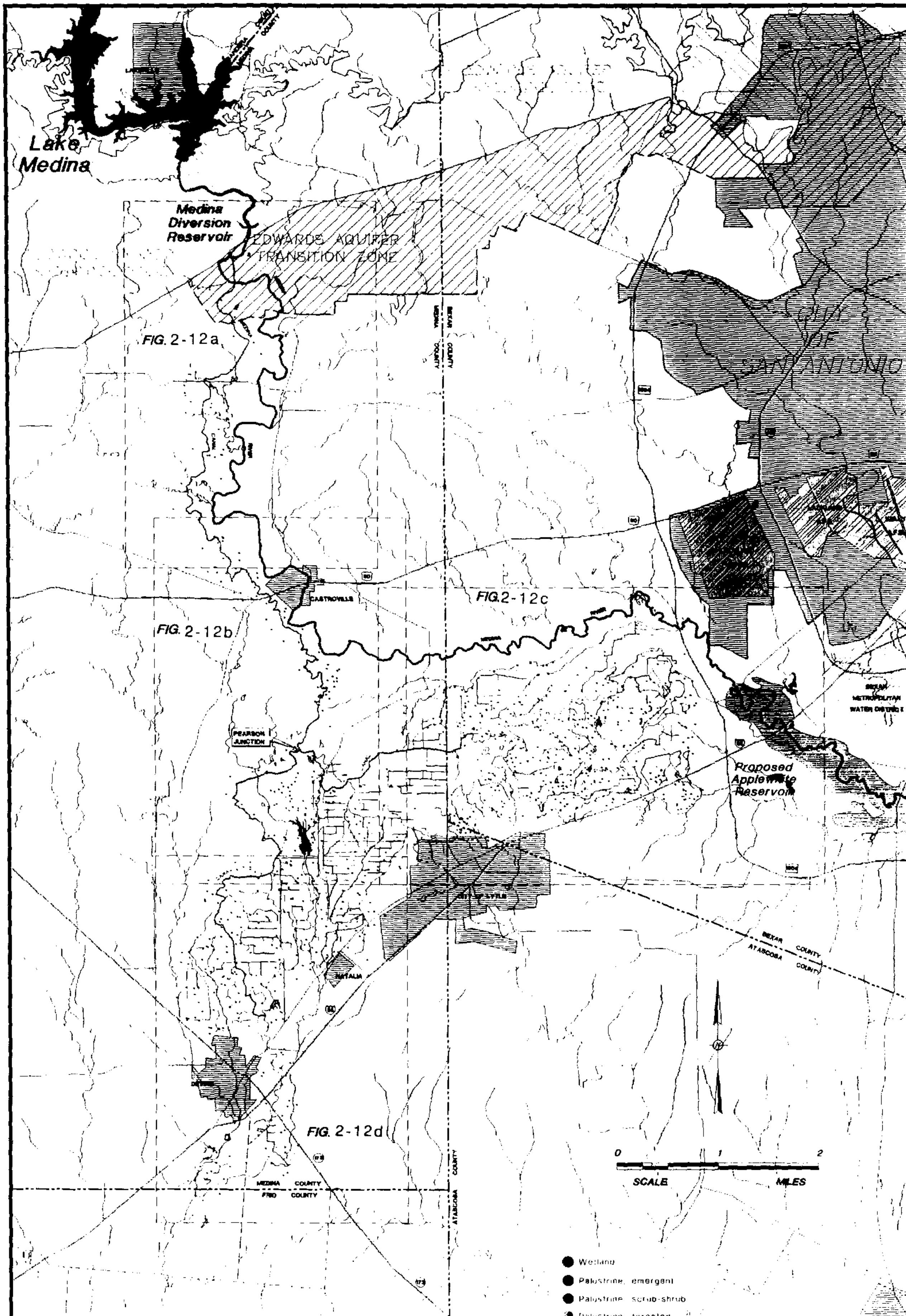
MICHAEL SULLIVAN & ASSOC., INC. Engineering & Environmental Consultants Air - Water Quality - Water Resources	FIGURE 2-8 GENERAL GEOLOGIC MAP OF CENTRAL TEXAS	SUBMITTED TO: Bexar Metropolitan Water District FOR: Southern Bexar County Medina Valley Surface Water Supply Study	DATE: AUGUST 1992 DRAWN BY: DWS



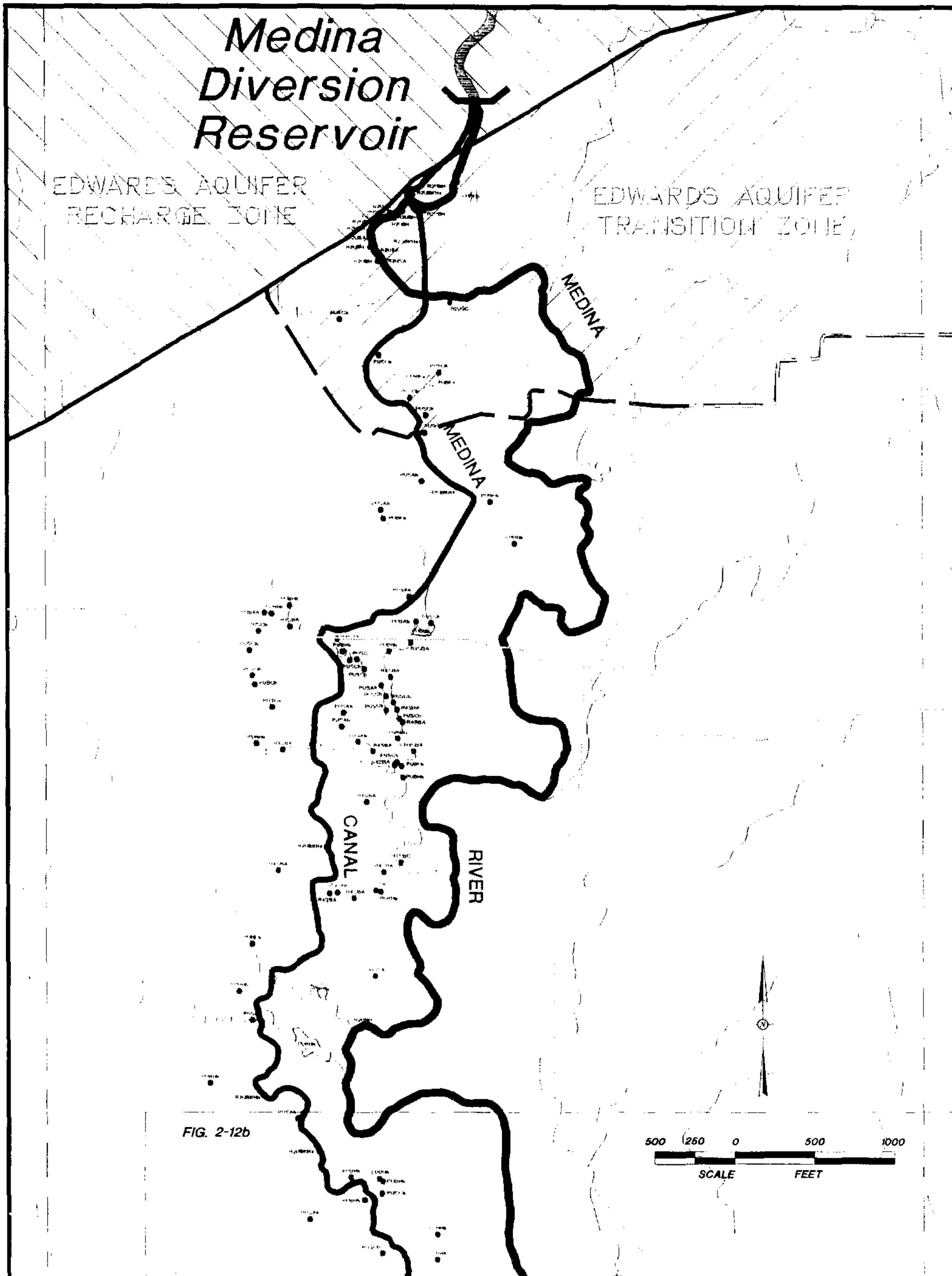
MICHAEL SULLIVAN & ASSOC., INC. Engineering & Environmental Consultants Air - Water Quality - Water Resources	FIGURE 2-9 SCHEMATIC CROSS-SECTION OF THE EDWARDS AQUIFER IN BEXAR COUNTY	SUBMITTED TO: Bexar Metropolitan Water District FOR: Southern Bexar County Medina Valley Surface Water Supply Study	DATE: AUGUST 1992 DRAWN BY: DWS



MICHAEL SULLIVAN & ASSOC., INC. Engineering & Environmental Consultants Air - Water Quality - Water Resources	**FIGURE 2-10** HYDROGEOLOGIC SECTIONS OR "POOLS" OF THE SAN ANTONIO REGION OF THE EDWARDS AQUIFER SOURCE: TWC 1991	SUBMITTED TO: **Bexar Metropolitan Water District** FOR: **Southern Bexar County Medina Valley Surface Water Supply Study**	DATE: AUGUST 1992 DRAWN BY: DWS



MICHAEL SULLIVAN & ASSOC., INC, Engineering & Environmental Consultants Air - Water Quality - Water Resources	FIGURE 2-11 Regional Wetlands Inventory Map	SUBMITTED TO: Bexar Metropolitan Water District FOR: Southern Bexar County Medina Valley Surface Water Supply Study	DATE: AUGUST 1992 DRAWN BY: DWS

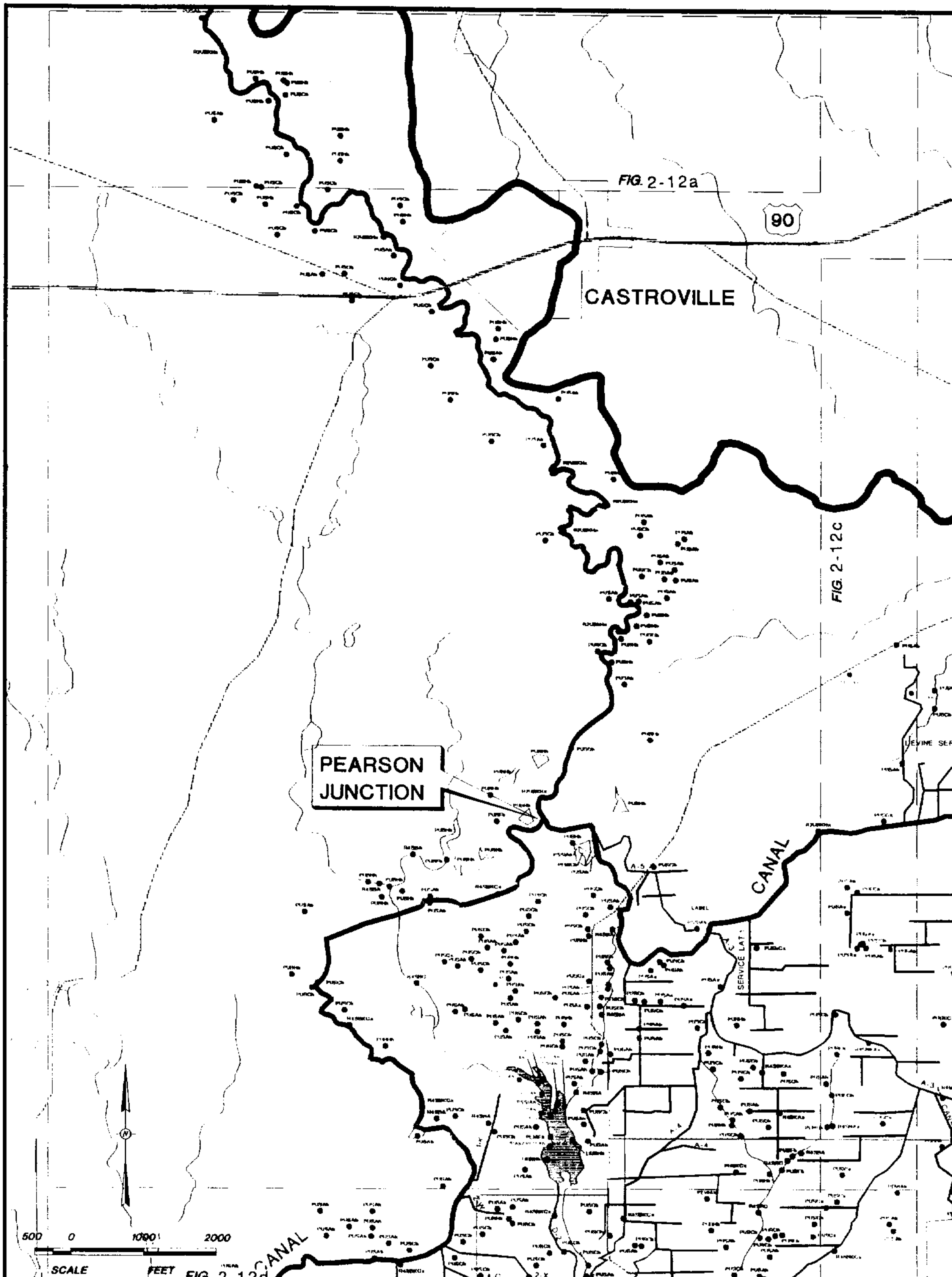


Lacustrine, limnetic unconsolidated bottom	Riverine, lower perennial unconsolidated bottom	Palustrine, emergent
Riverine, intermittent streambed	Palustrine, unconsolidated shore	Palustrine, scrub-shrub
Riverine, lower perennial unconsolidated shore	Palustrine, unconsolidated bottom	Palustrine, forested

MODIFIERS

A	Temporarily flooded	B	Saturated
C	Seasonally flooded	K	Artificially flooded
H	Permanently flooded	h	Diked/Impounded
F	Semipermanently flooded	x	Excavated

MICHAEL SULLIVAN & ASSOC., INC. Engineering & Environmental Consultants Air - Water Quality - Water Resources	**FIGURE 2-12a** BMA Canal System Inventory Map - Panel I	SUBMITTED TO: **Bexar Metropolitan Water District** FOR: **Southern Bexar County Medina Valley Surface Water Supply Study**	DATE: AUGUST 1992 DRAWN BY: DWS



L1UB	Lacustrine, limnetic unconsolidated bottom	R2UB	Riverine lower perennial unconsolidated bottom	PEM	Palustrine emergent
R4SB	Riverine intermittent streambed	PUS	Palustrine, unconsolidated shore		Palustrine scrub shrub
R2US	Riverine, lower perennial unconsolidated shore	PUB	Palustrine unconsolidated bottom		Palustrine forested

MODIFIERS

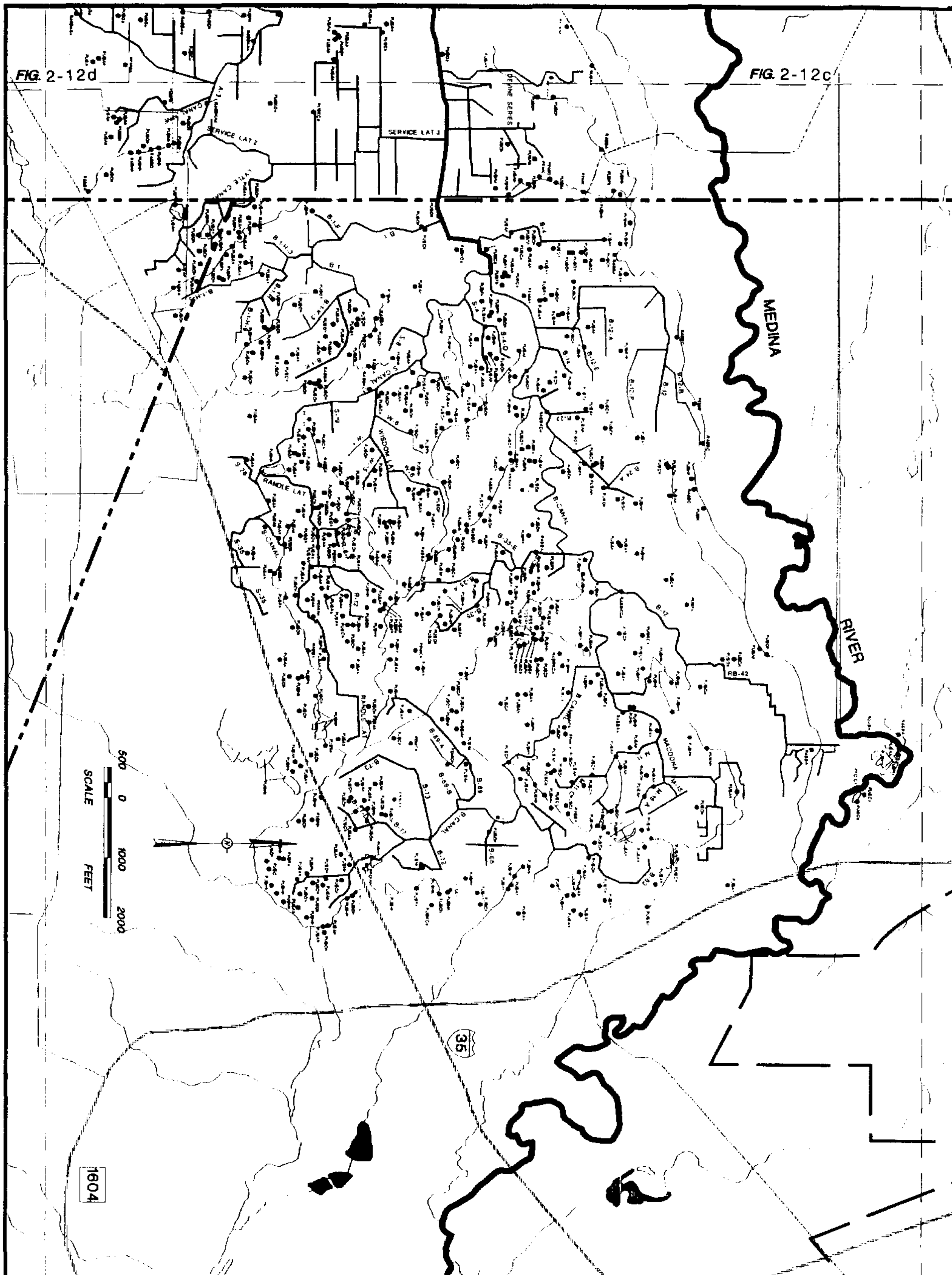
A	Temporarily flooded	B	Saturated
C	Seasonally flooded	K	Artificially flooded
H	Permanently flooded	h	Diked/Impounded
F	Semipermanently flooded	x	Excavated

MICHAEL SULLIVAN & ASSOC., INC,
Engineering & Environmental Consultants
Air - Water Quality - Water Resources

FIGURE 2-12b
BMA Canal System Inventory Map - Panel II

SUBMITTED TO:
Bexar Metropolitan Water District
FOR:
Southern Bexar County Medina Valley Surface Water Supply Study

DATE: AUGUST 1992
DRAWN BY: DWS

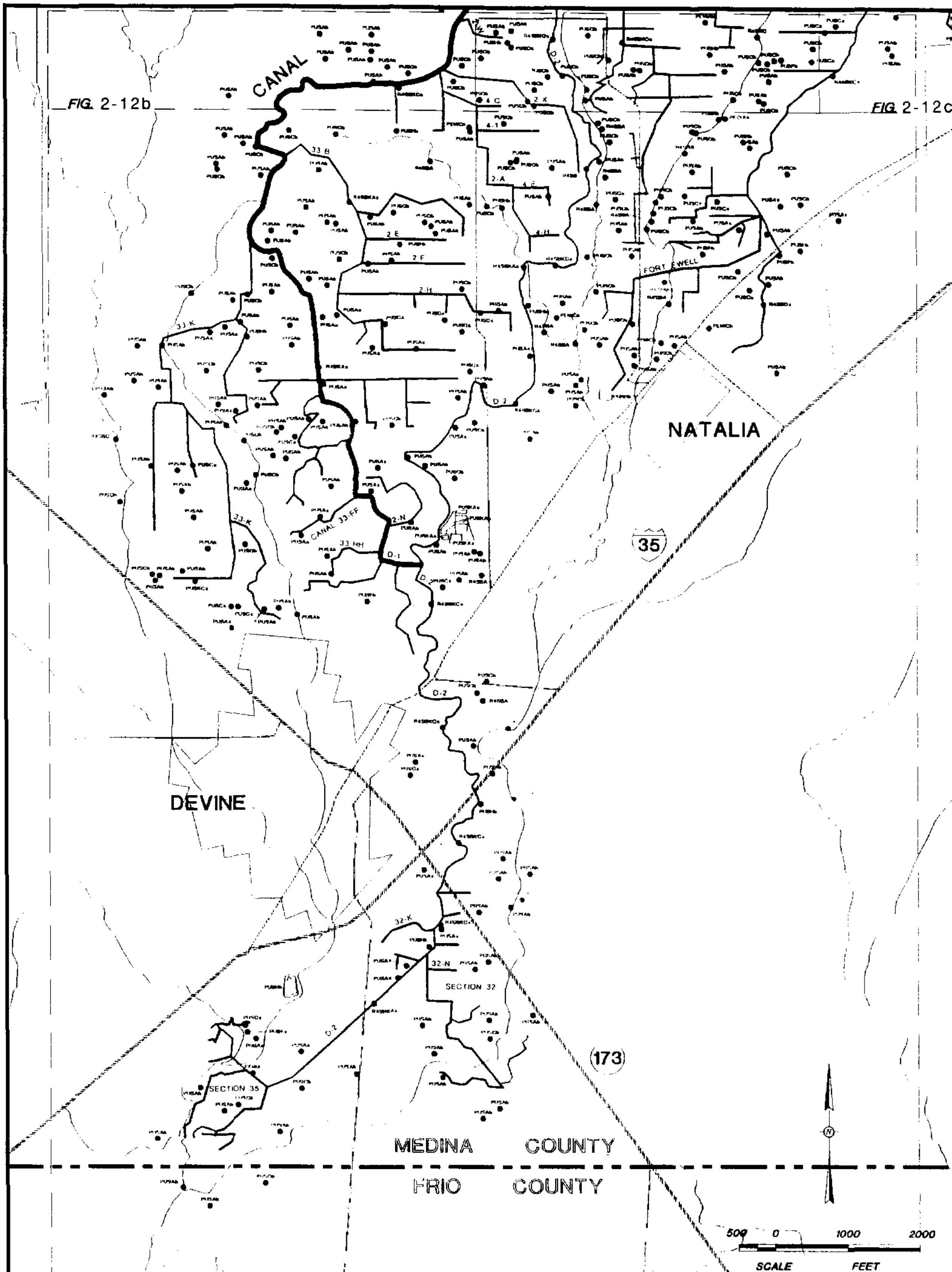


L1UB ● Lacustrine, limnetic unconsolidated bottom	R2UB ● Riverine, lower perennial unconsolidated bottom	PEM ● Palustrine, emergent
R4SB ● Riverine intermittent streambed	PUS ● Palustrine, unconsolidated shore	● Palustrine, scrub shrub
R2US ● Riverine lower perennial unconsolidated shore	PUB ● Palustrine, unconsolidated bottom	● Palustrine forested

MODIFIERS

A	Temporarily flooded	B	Saturated
C	Seasonally flooded	K	Artificially flooded
H	Permanently flooded	h	Diked/Impounded
F	Semipermanently flooded	x	Excavated

MICHAEL SULLIVAN & ASSOC., INC, Engineering & Environmental Consultants Air - Water Quality - Water Resources	**FIGURE 2-12c** **BMA Canal System Inventory Map - Panel III**	SUBMITTED TO: **Bexar Metropolitan Water District** FOR: **Southern Bexar County Medina Valley Surface Water Supply Study**	DATE: AUGUST 1992 DRAWN BY: DWS



L1UB	Lacustrine, limnetic unconsolidated bottom	R2UB	Riverine, lower perennial unconsolidated bottom	PEM	Palustrine, emergent
R4SB	Riverine, intermittent streambed	PUS	Palustrine, unconsolidated shore		Palustrine, scrub-shrub
R2US	Riverine, lower perennial unconsolidated shore	PUB	Palustrine unconsolidated bottom		Palustrine, forested

MODIFIERS

A	Temporarily flooded	B	Saturated
C	Seasonally flooded	K	Artificially flooded
H	Permanently flooded	h	Diked/Impounded
F	Semipermanently flooded	x	Excavated

MICHAEL SULLIVAN & ASSOC., INC,
Engineering & Environmental Consultants
Air - Water Quality - Water Resources

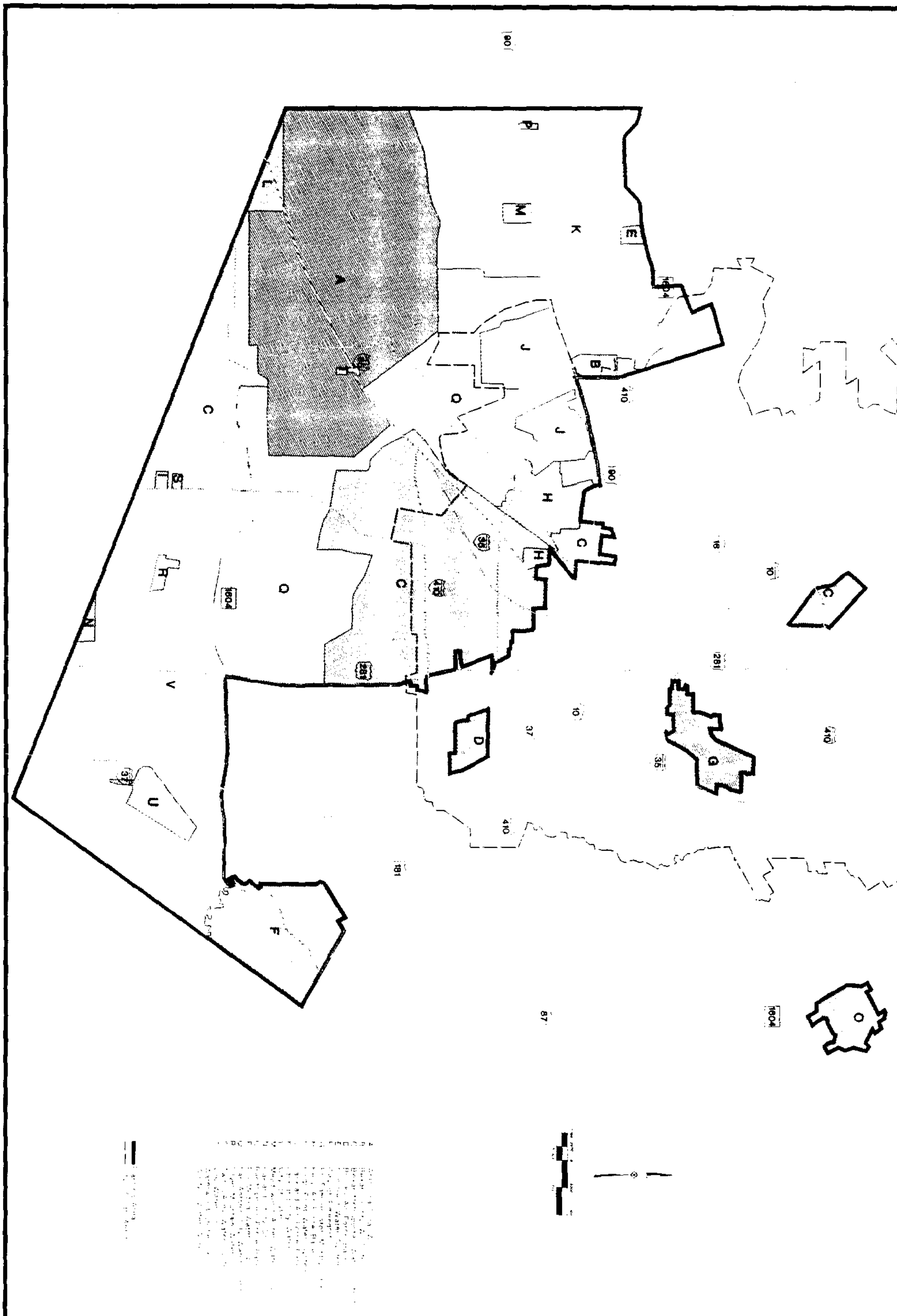
FIGURE 2-12d

BMA Canal System Inventory Map - Panel IV

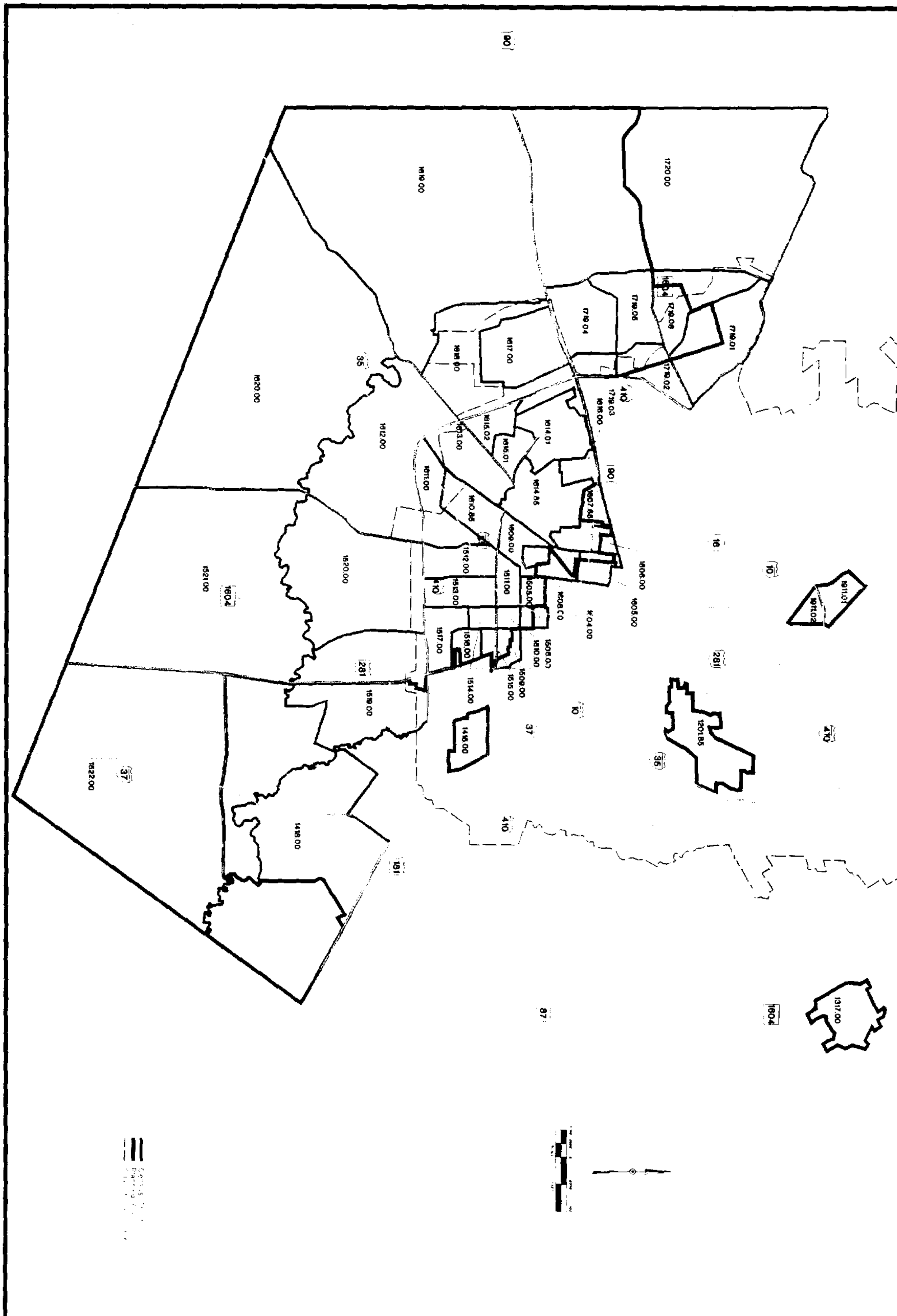
SUBMITTED TO:
Bexar Metropolitan Water District
FOR:
Southern Bexar County Medina Valley Surface Water Supply Study

DATE: AUGUST 1992

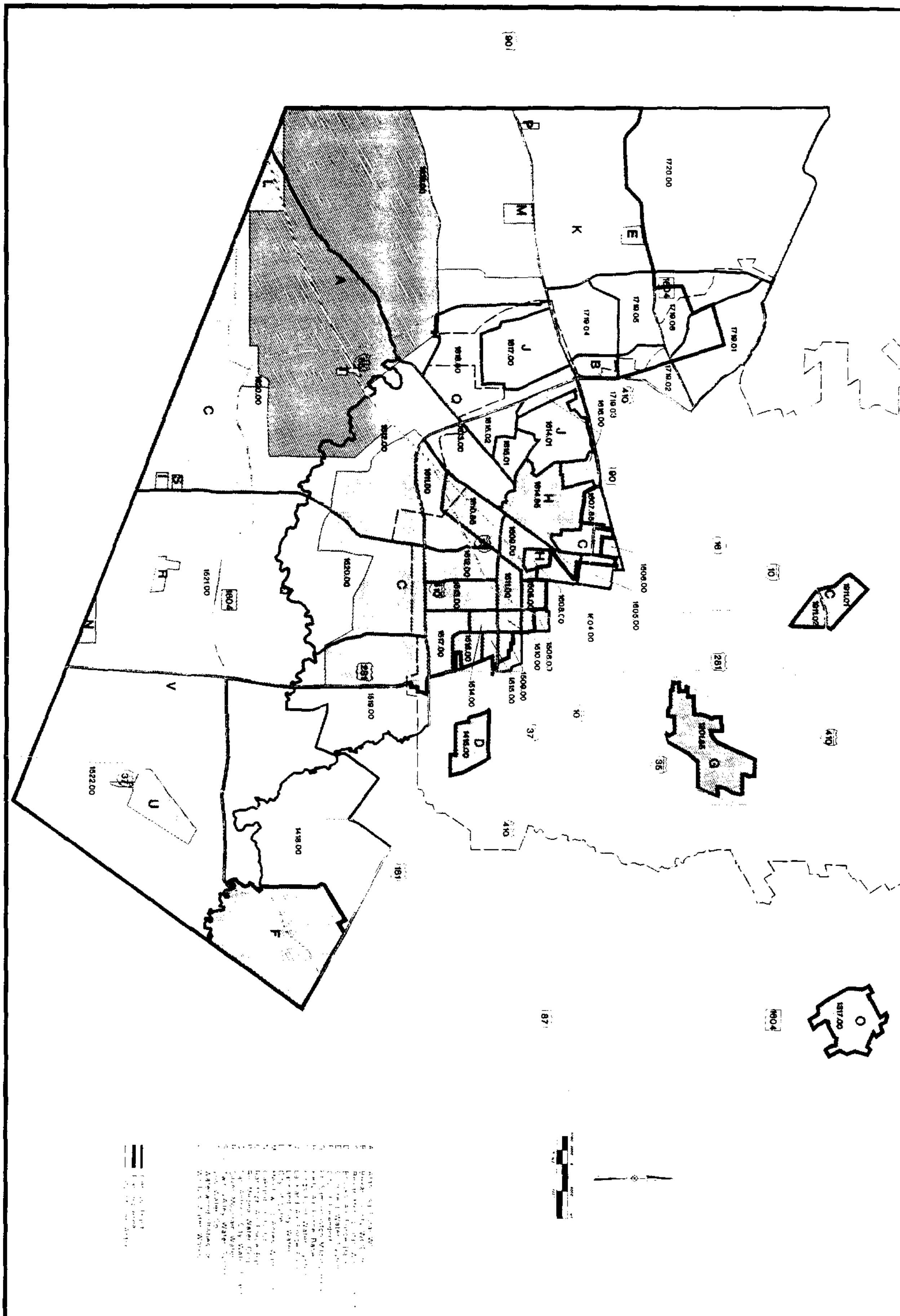
DRAWN BY: GRG



MICHAEL SULLIVAN & ASSOC., INC. Engineering & Environmental Consultants Air - Water Quality - Water Resources	**FIGURE 3-1** **REGIONAL WATER PURVEYOR MAP**	SUBMITTED TO: **Bexar Metropolitan Water District** FOR: **Southern Bexar County Medina Valley Surface Water Supply Study**	DATE: AUG 1992 DRAWN BY: GRG

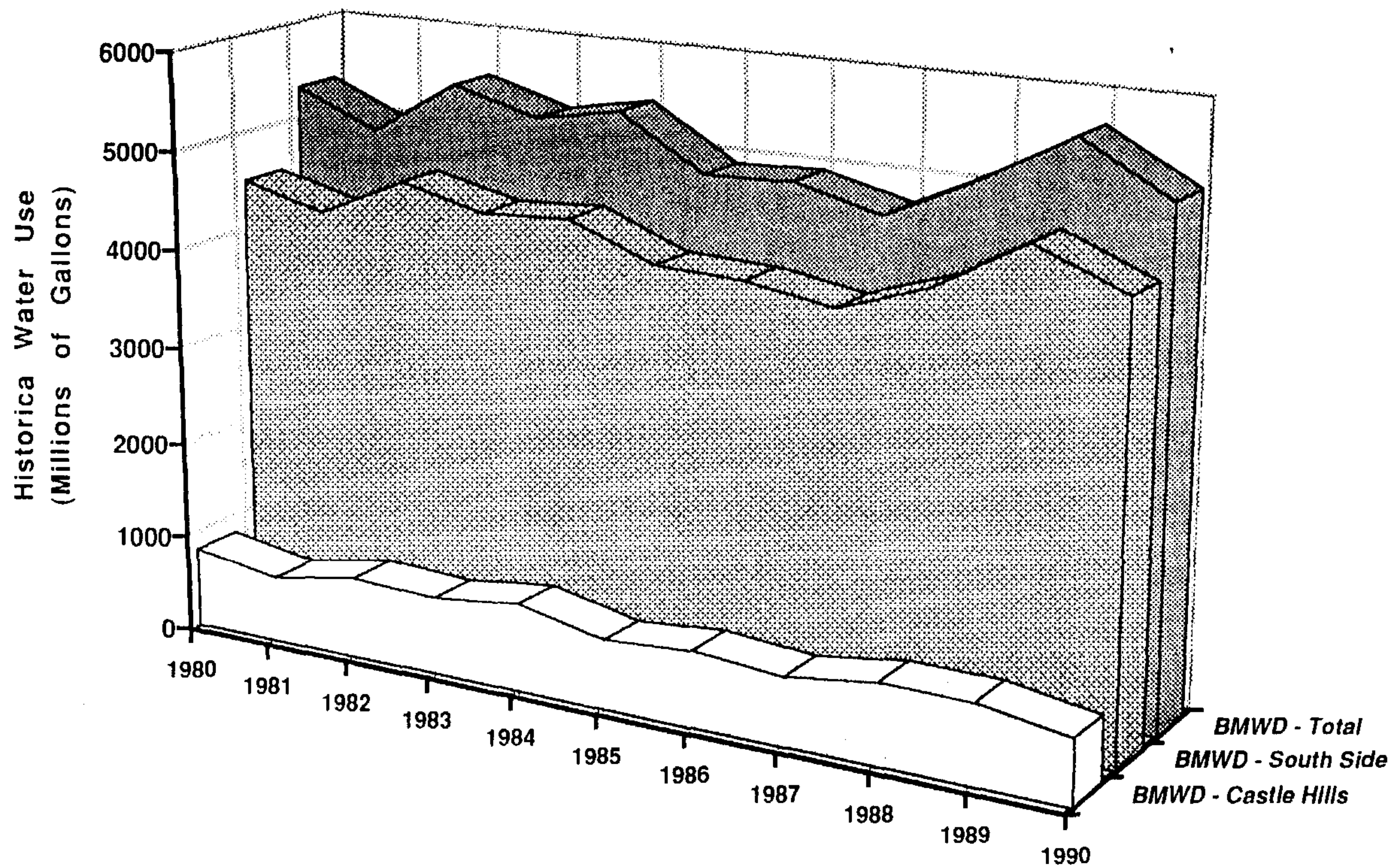


MICHAEL SULLIVAN & ASSOC., INC, Engineering & Environmental Consultants Air - Water Quality - Water Resources	**FIGURE 3-2** **PRIMARY PLANNING AREA CENSUS TRACT MAP**	SUBMITTED TO: **Bexar Metropolitan Water District** FOR: **Southern Bexar County Medina Valley Surface Water Supply Study**	DATE: AUG 1992 DRAWN BY: GRG



MICHAEL SULLIVAN & ASSOC., INC, Engineering & Environmental Consultants Air - Water Quality - Water Resources	**FIGURE 3-3** OVERLAY OF CENSUS TRACTS & WATER PURVEYORS IN PRIMARY PLANNING AREA	SUBMITTED TO: **Bexar Metropolitan Water District** FOR: **Southern Bexar County Medina Valley Surface Water Supply Study**	DATE: AUG 1992 DRAWN BY: GRG

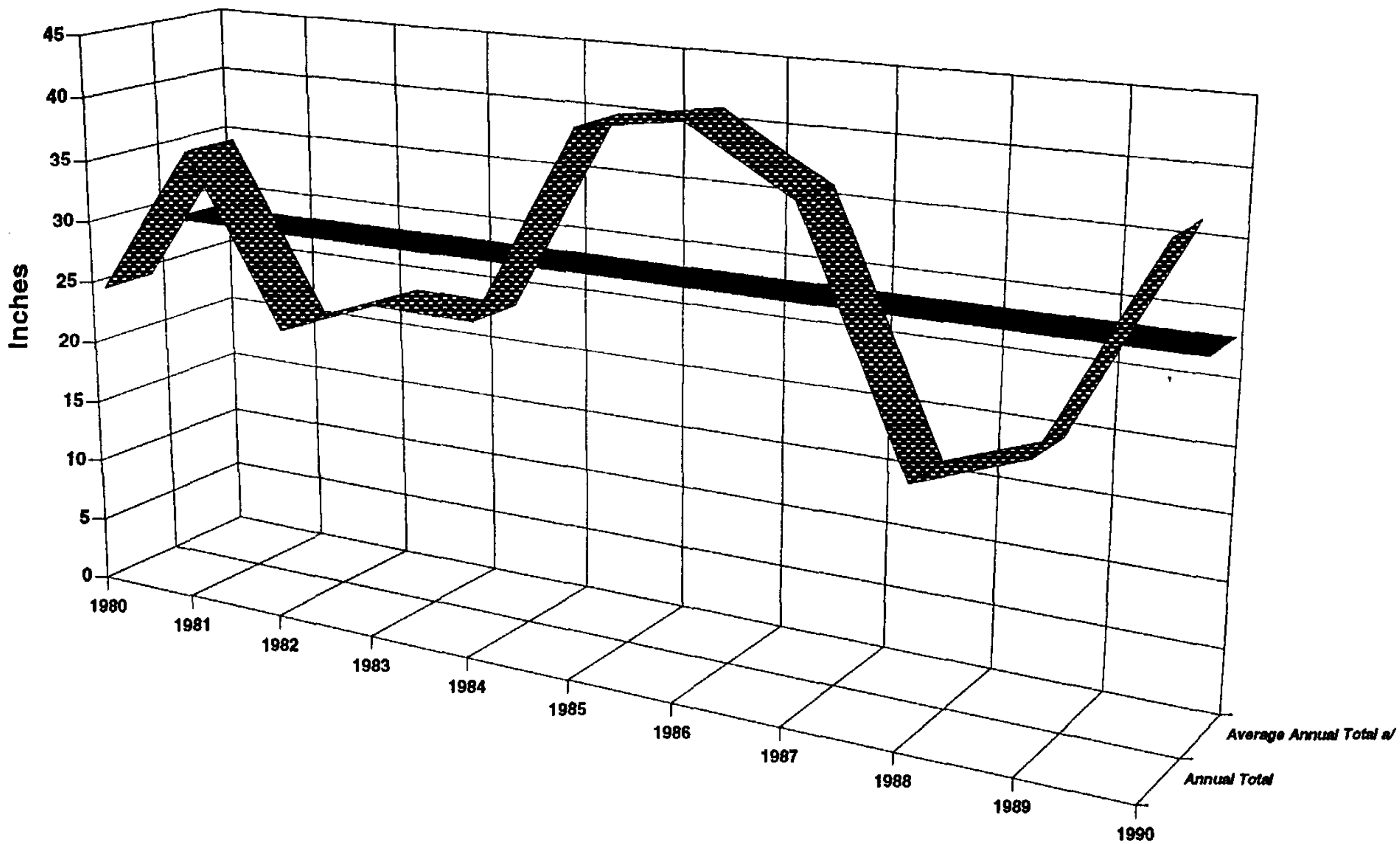
Figure 3- 4
Historical Water Use for Bexar Metropolitan Water District
(Self-Supplied Ground Water)



Source: Texas Water Development Board

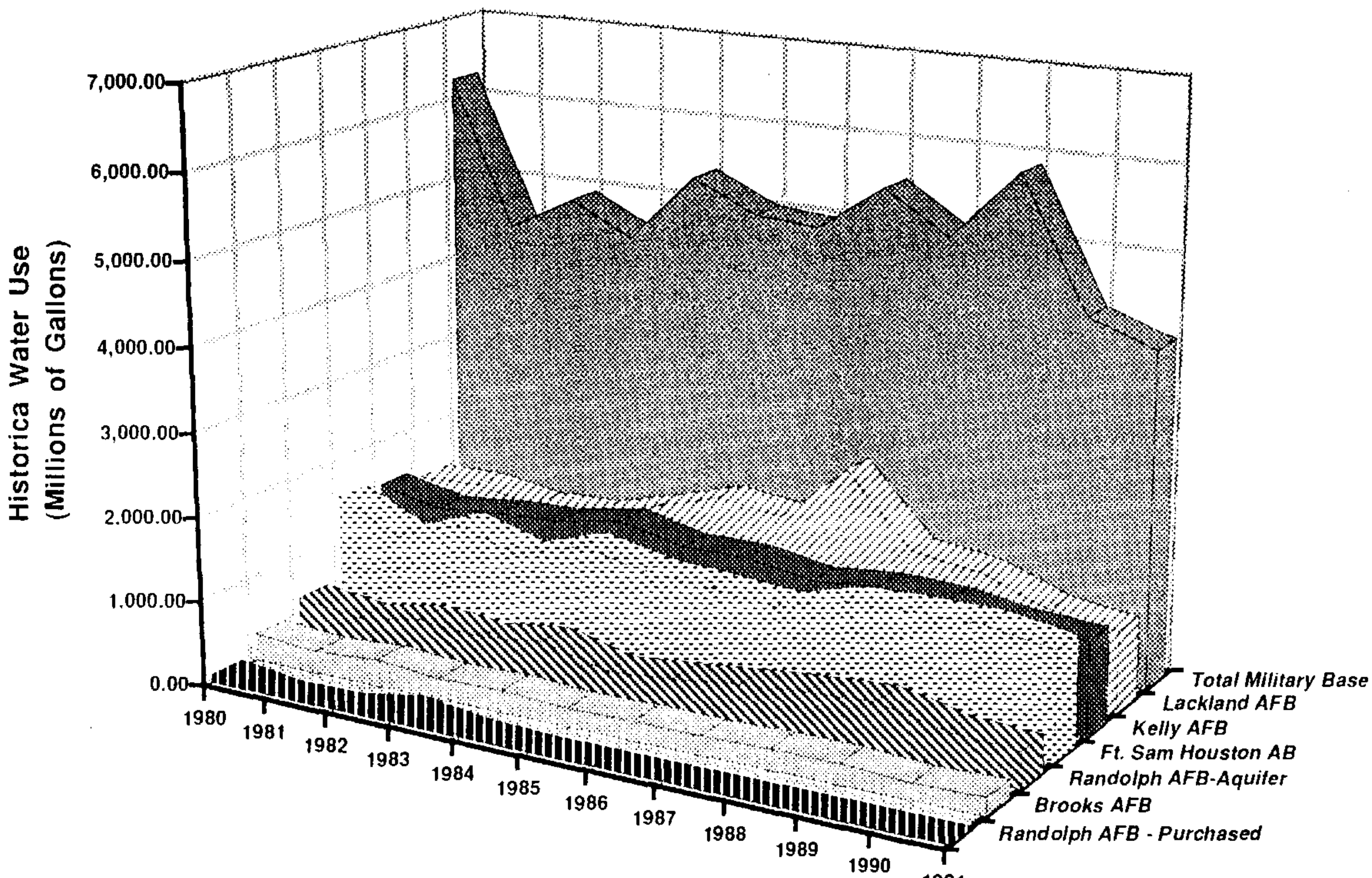
MSA

Figure 3-5
Total Annual Rainfall in Bexar County



a/ Average Annual Total Covers Year 30 Period of Record (1961-1990)
Source: National Oceanic and Atmospheric Administration

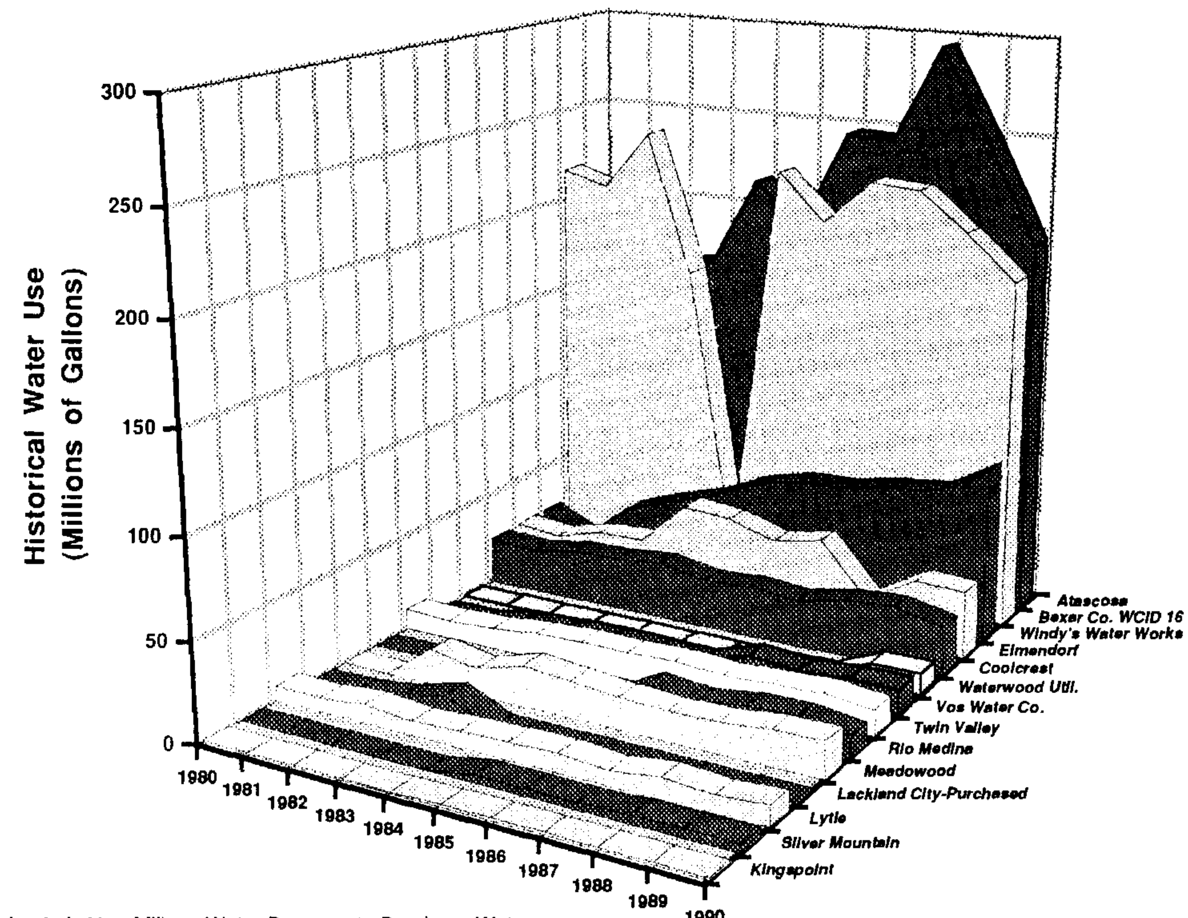
Figure 3-6
Historical Water Use for Military Bases Within Planning Area
(Self-Supplied Ground Water & Purchased Water a/)



a/ Randolph AFB is the only military base to purchase water.
Source: Texas Water Development Board

MSA

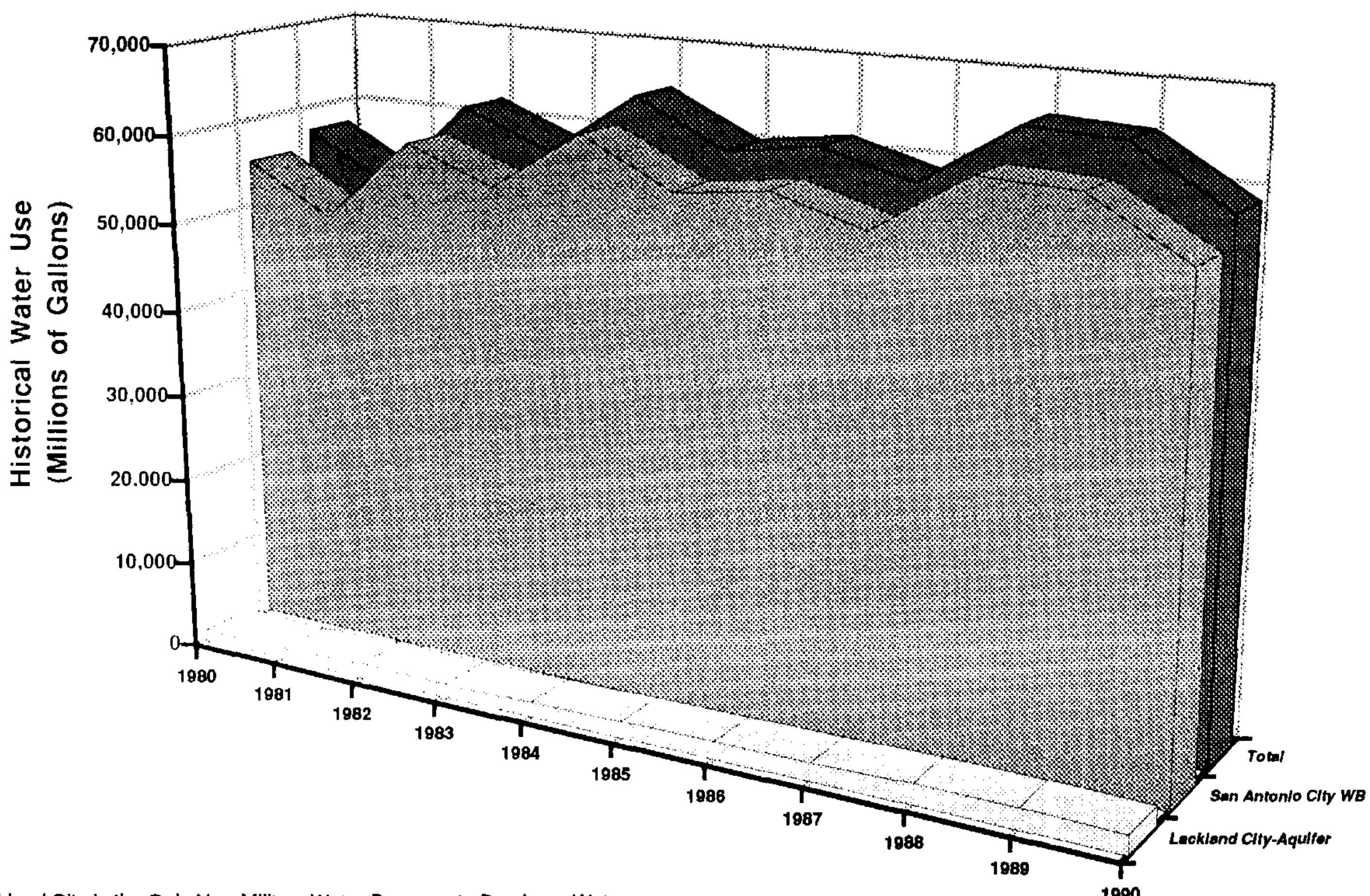
Figure 3- 7
Historical Water Use for Non-Military Water Purveyors Within Planning Area
(Self-Supplied Ground Water & Purchased Water a/)



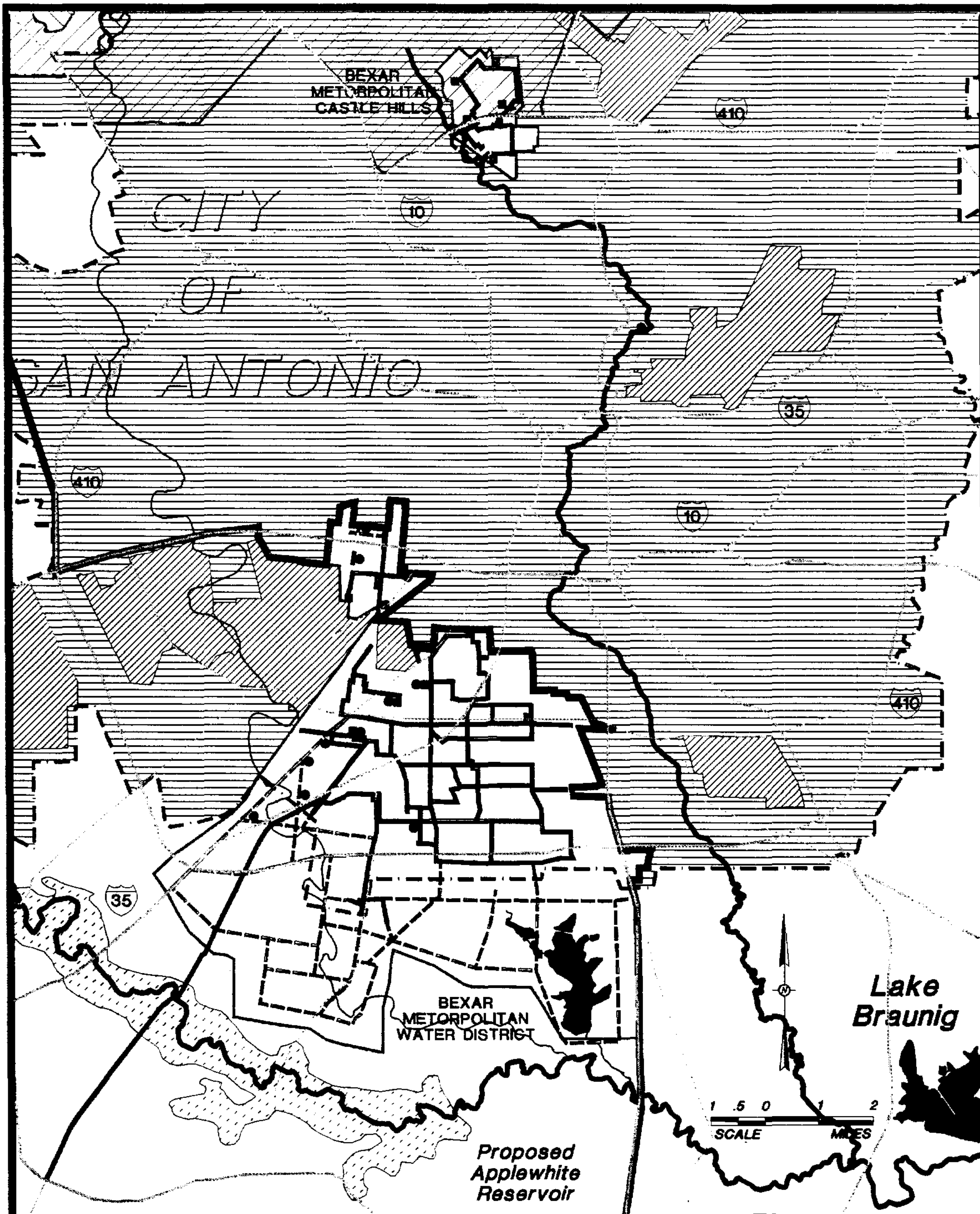
a/ Lackland City is the Only Non-Military Water Purveyor to Purchase Water
Source: Texas Water Development Board

MSA

Figure 3- 7 (Cont.)
Historical Water Use for Non-Military Water Purveyors Within Planning Area
(Self-Supplied Ground Water & Purchased Water a/)



a/ Lackland City is the Only Non-Military Water Purveyor to Purchase Water
Source: Texas Water Development Board



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Engineering & Environmental Consultants
Air - Water Quality - Water Resources

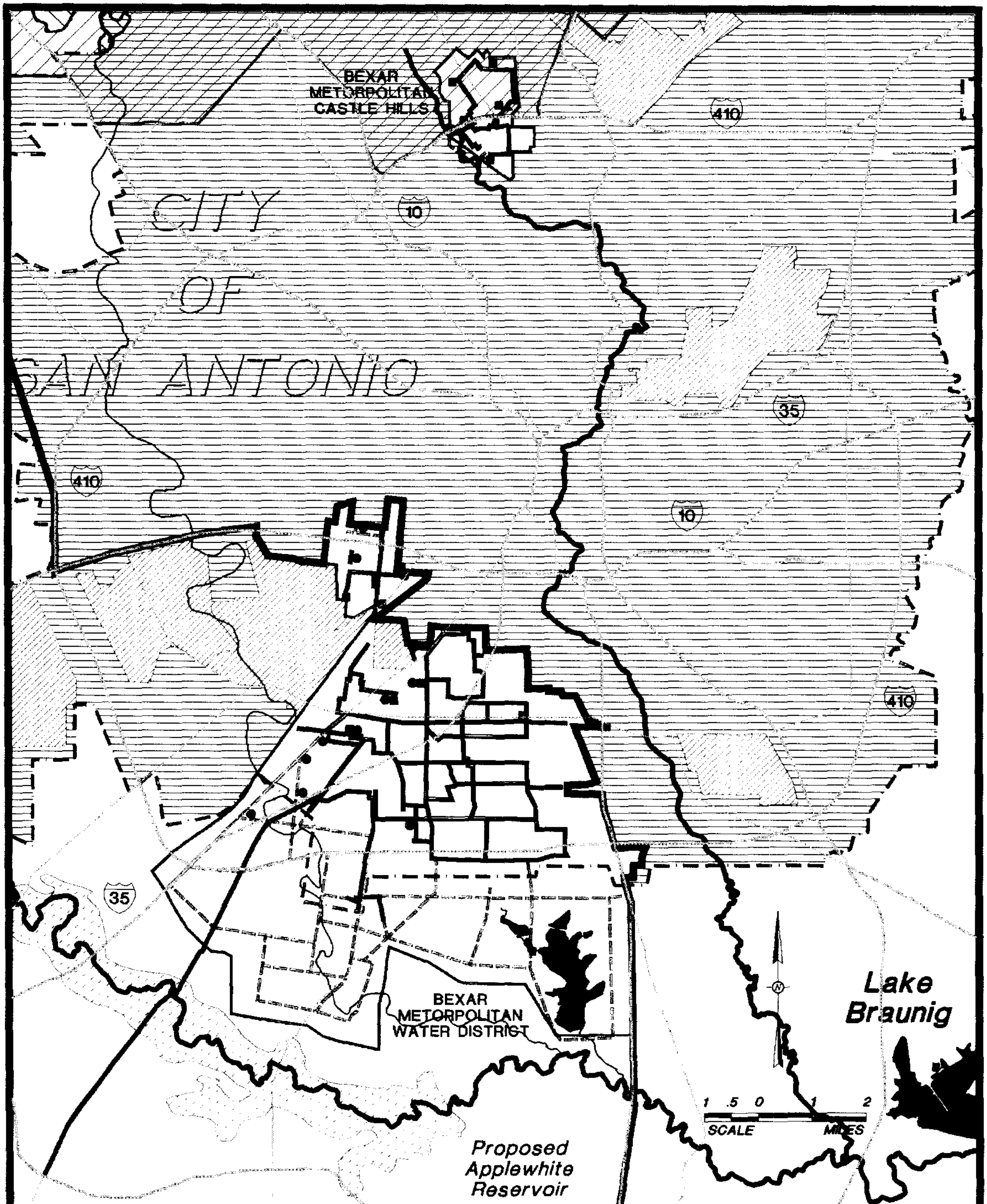
AUGUST 1992 | DRAWN BY: DWS

FIGURE 3-8

MAP OF EXISTING AND PROPOSED BMWD WELLS AND WATER LINES 12" AND LARGER

SUBMITTED TO:
Bexar Metropolitan Water District
FOR:
Southern Bexar County
Medina Valley
Surface Water Supply Study

LEGEND:
Existing Water Line
Proposed Water Line
Existing Well
Proposed Well



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Air - Water Quality - Water Resources

AUGUST 1992 | DRAWN BY: DWS

FIGURE 3-8

MAP OF EXISTING AND PROPOSED BMWD WELLS AND WATER LINES 12" AND LARGER

SUBMITTED TO:
Bexar Metropolitan Water District
FOR:
Southern Bexar County
Medina Valley
Surface Water Supply Study

LEGEND:
Existing Water Line
Proposed Water Line
Existing Well
Proposed Well

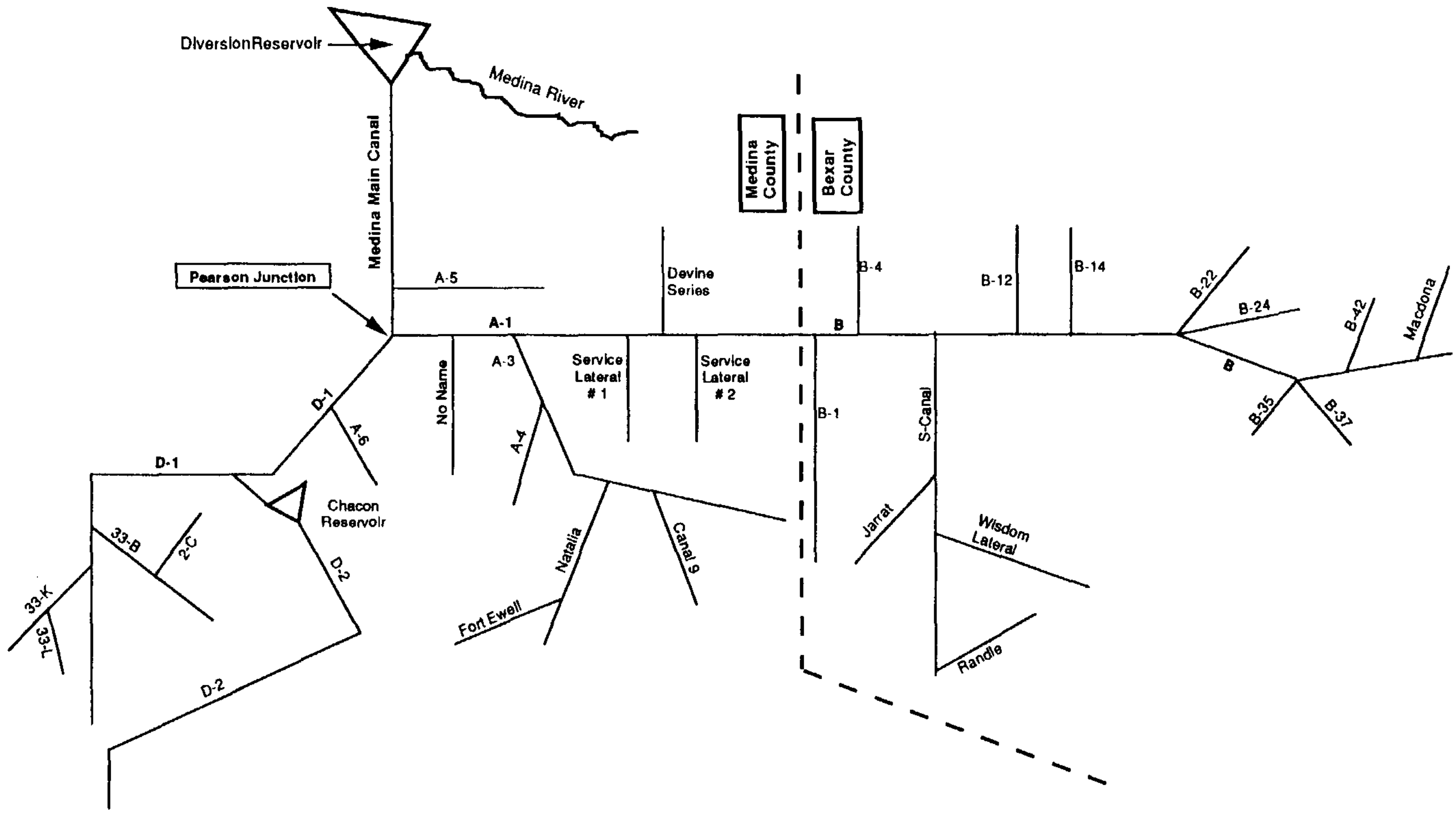


Figure 3-10 Schematic of Medina Canal System

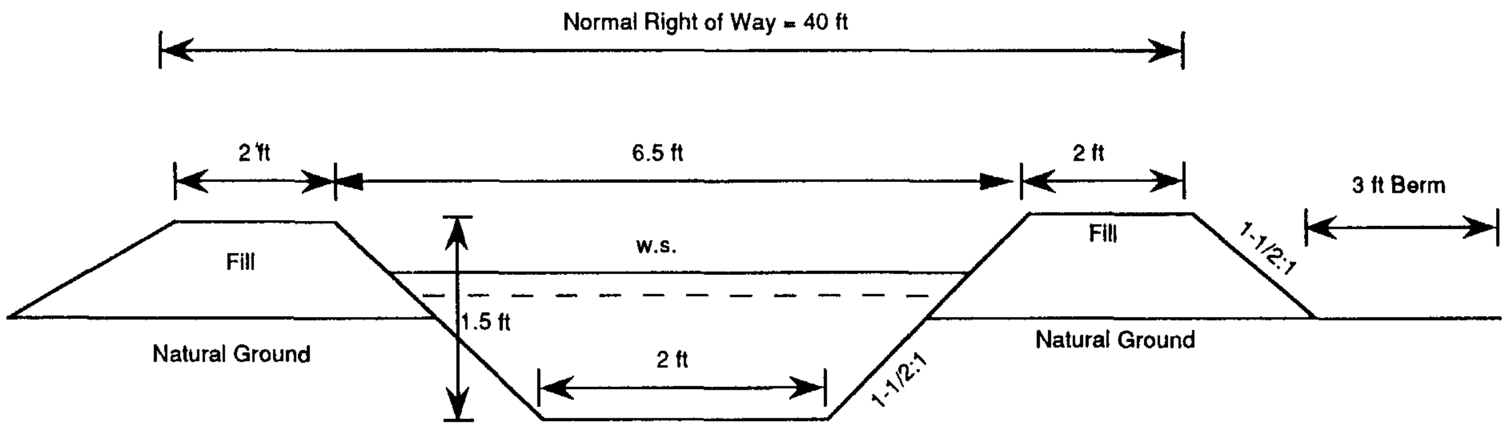


Figure 3-11 Type I - Minimum Canal
Typical Cross-Section
(not to scale)

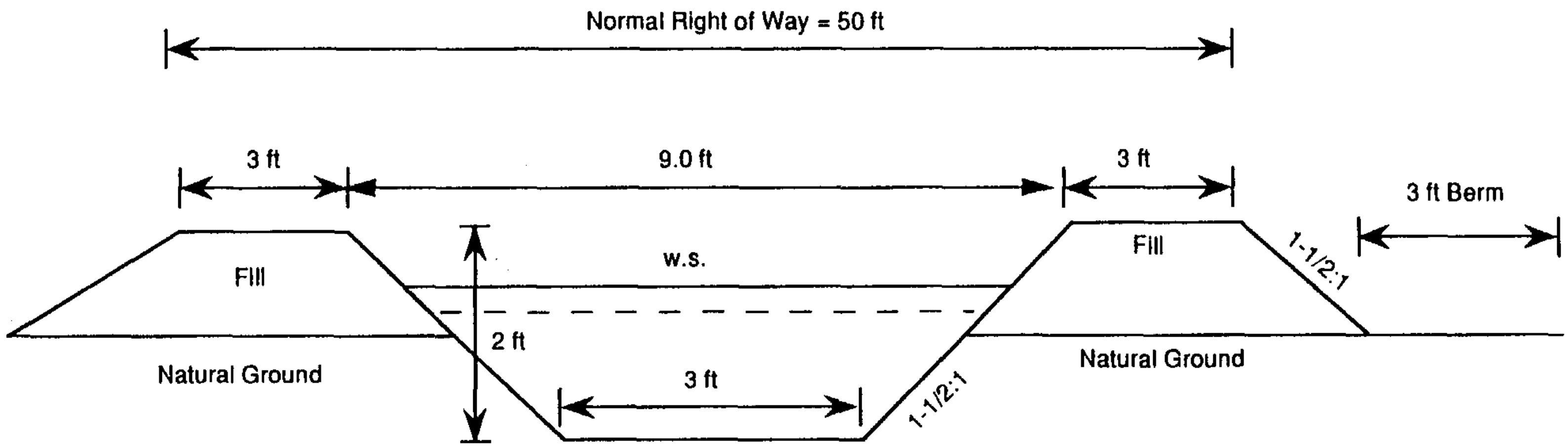


Figure 3-12 Type II Canal
Typical Cross-Section
(not to scale)

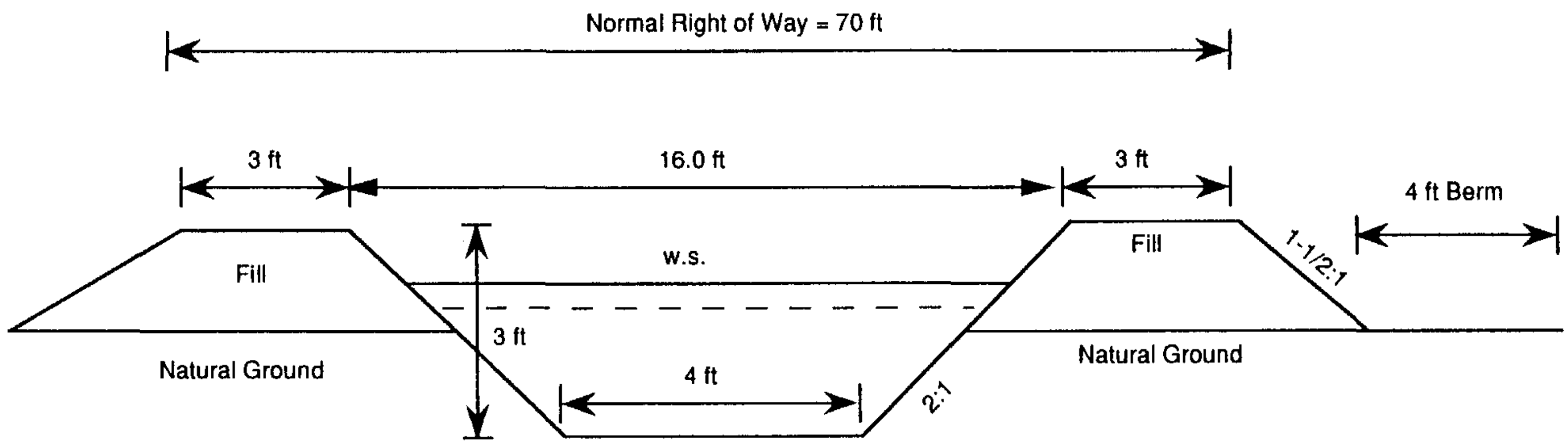


Figure 3-13 Type III Canal
Typical Cross-Section
(not to scale)

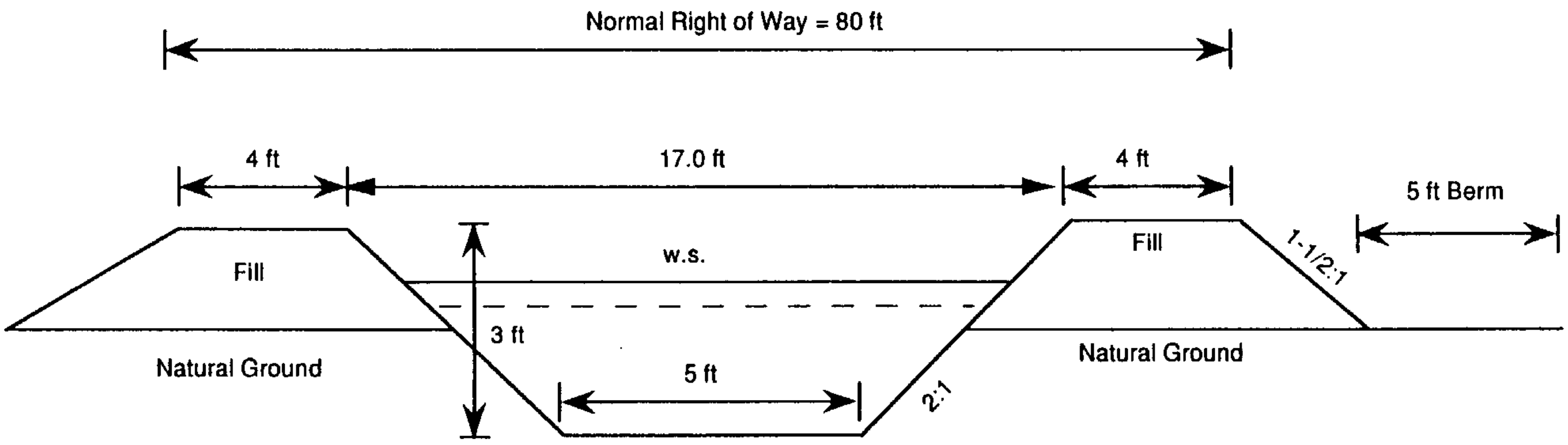


Figure 3-14 Type IV Canal
Typical Cross-Section
(not to scale)

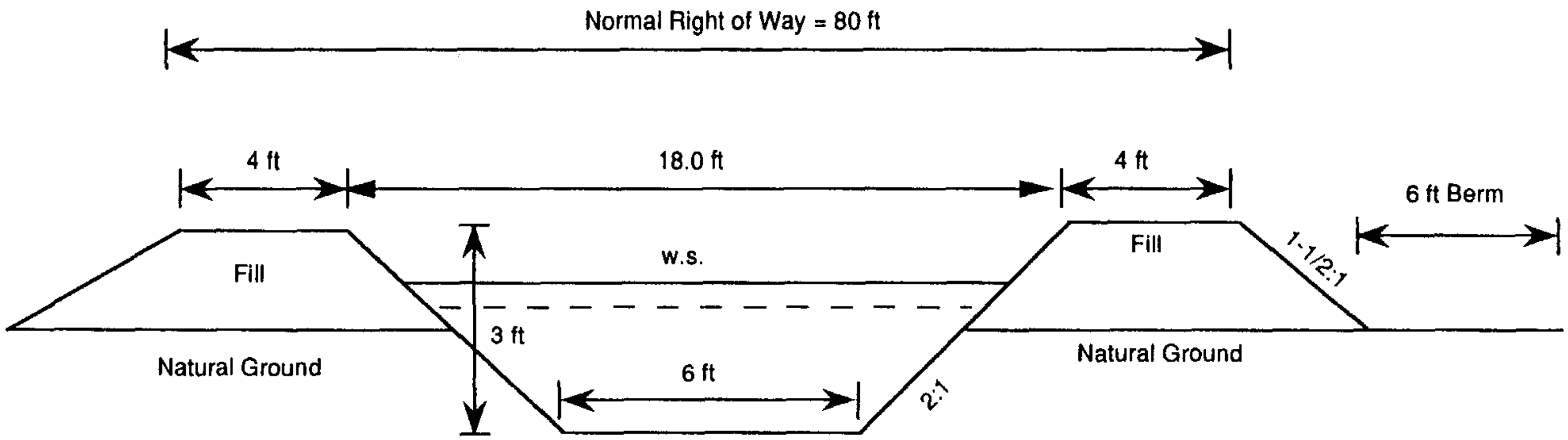


Figure 3-15 Type V Canal
Typical Cross-Section
(not to scale)

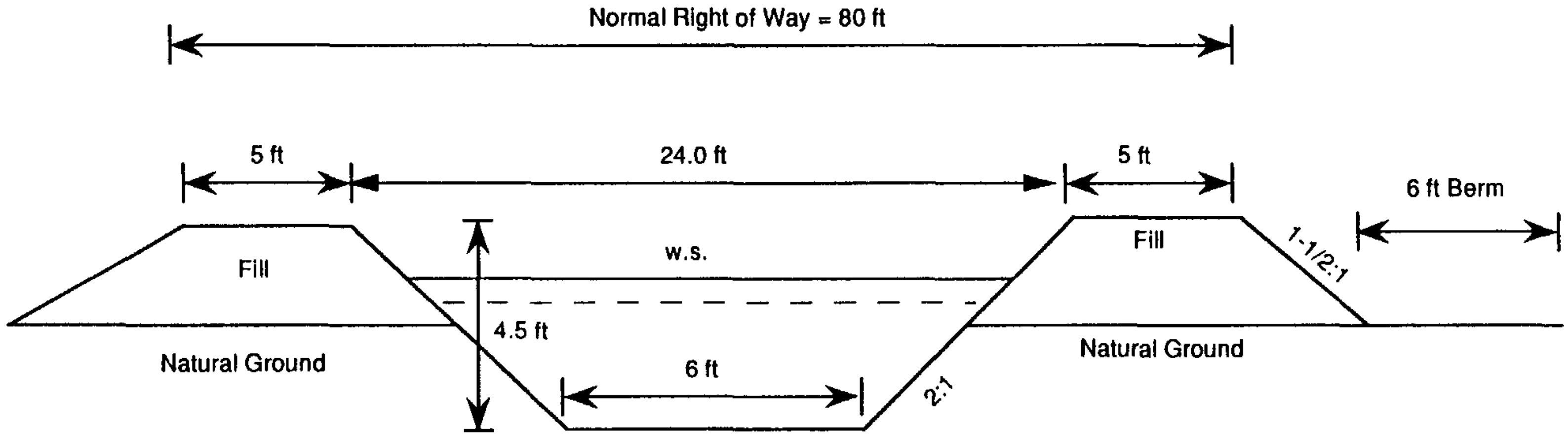


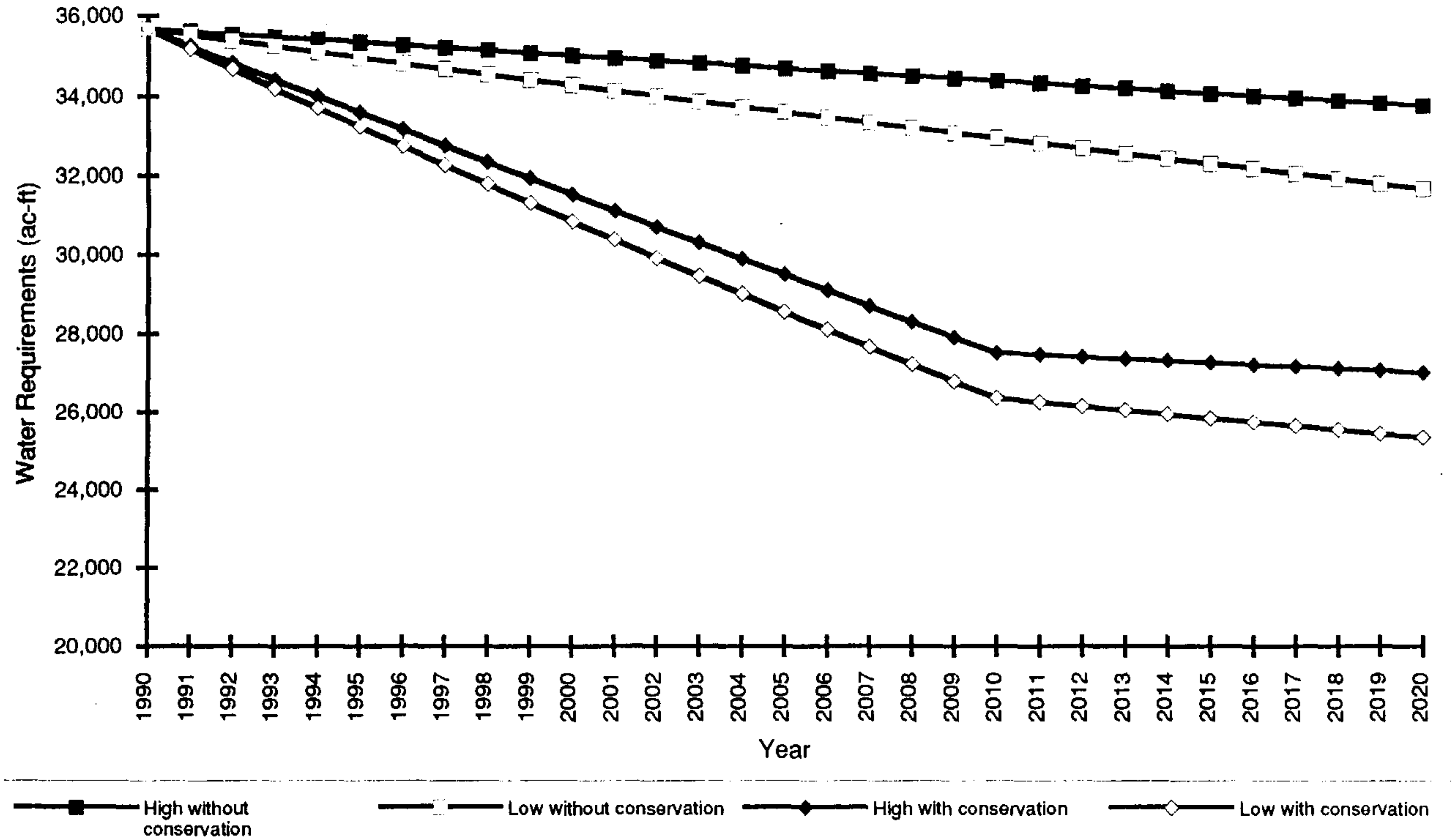
Figure 3-16 Type VI Canal
Typical Cross-Section
(not to scale)

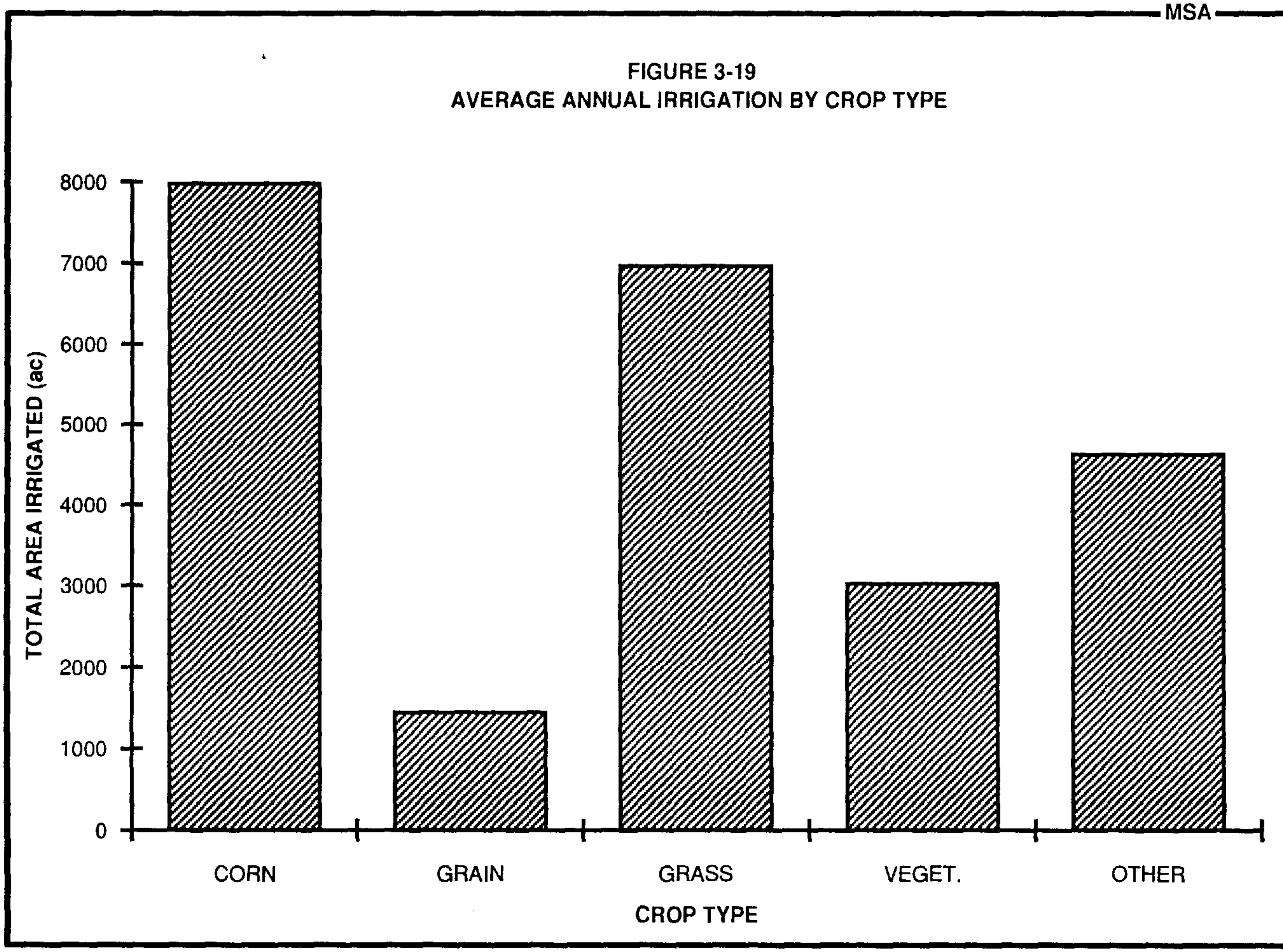
MSA

Figure 3-17
Total Projected Irrigated Acres (1958-1979) and
Total Measured Water Diverted (1958-1980) and Total Irrigated Acres (1980- 1990)

MSA

Figure 3-18
Projection of BMA Water Requirements
With and Without Conservation

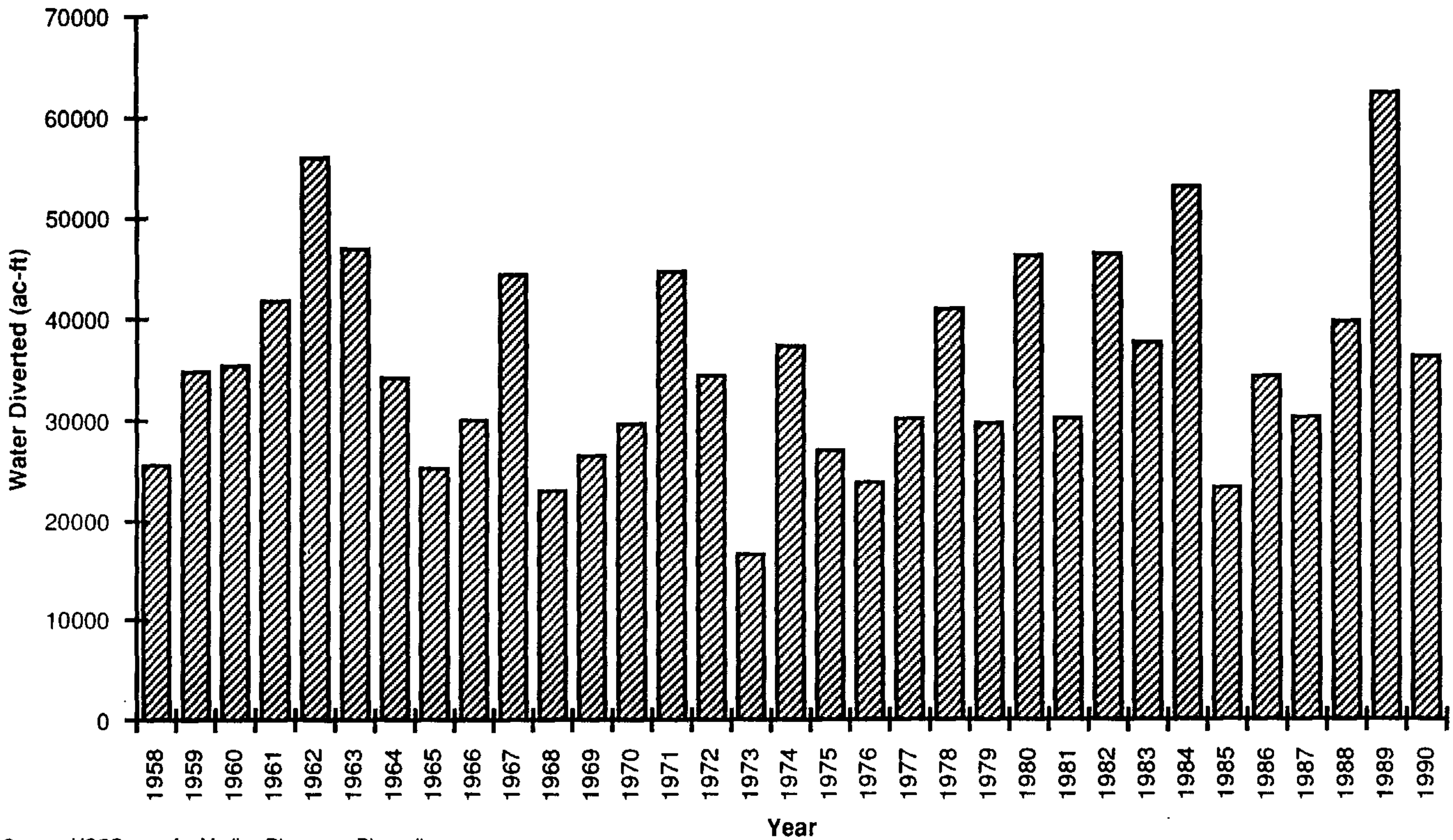




Source: BMA Records and TWC Report of Surface Water Used Data Reported from 1980 through 1986

MSA

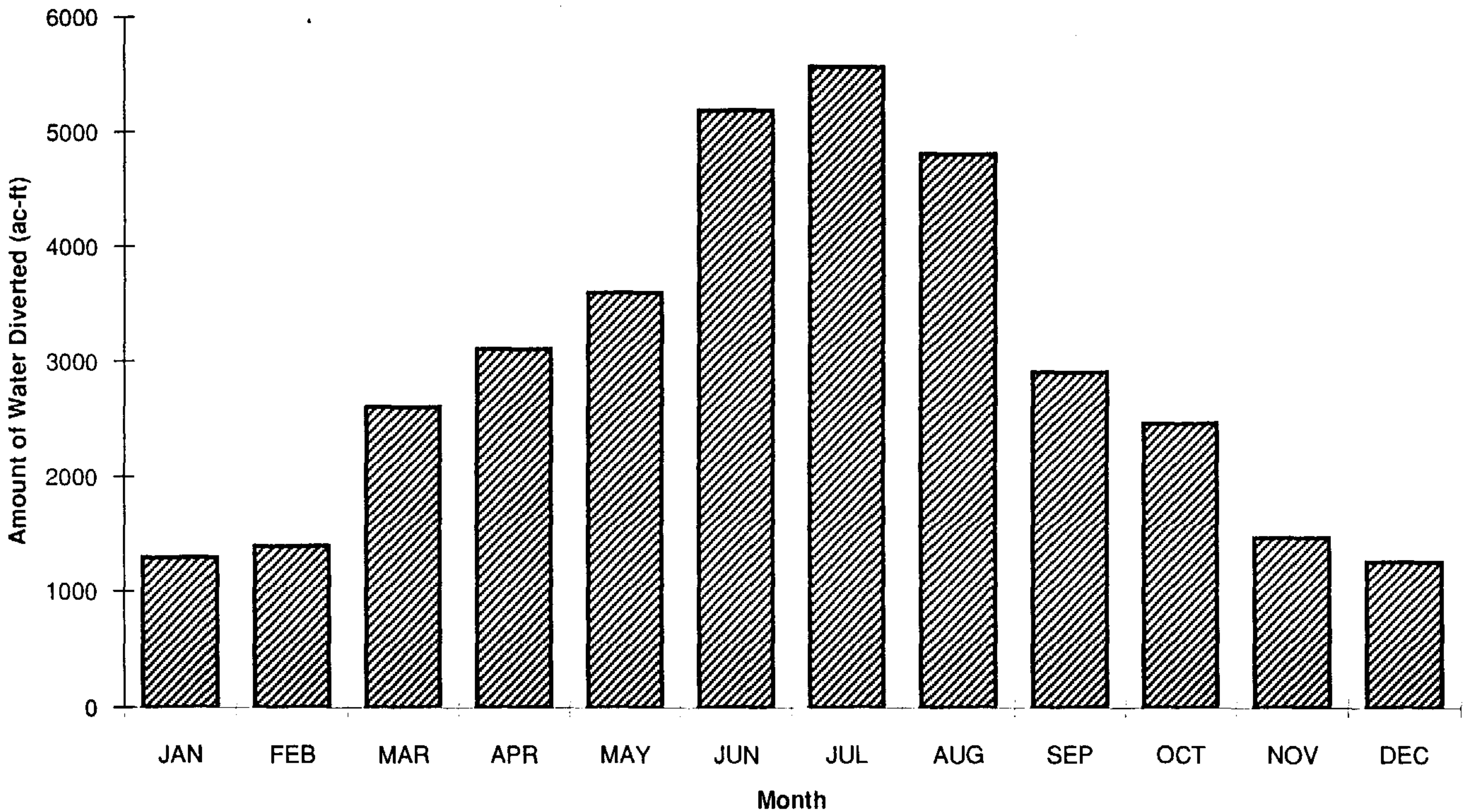
Figure 3-20
BMA Total Annual Diversion (ac-ft) to the Main Canal from Diversio Lake



Source: USGS gage for Medina River near Riomedina

MSA

Figure 3-21
BMA Historical Monthly Average Water (Acre-Feet)
Diverted from Diversion Lake to Main Canal



Source: USGS gage for Medina Canal near Riomedina Period of Record: January 1958 through September 1990

MSA

Figure 3-22
Lake Medina Recharge and Seepage Analysis From Lowery (1953)
as modified by Freese & Nichols (1971)

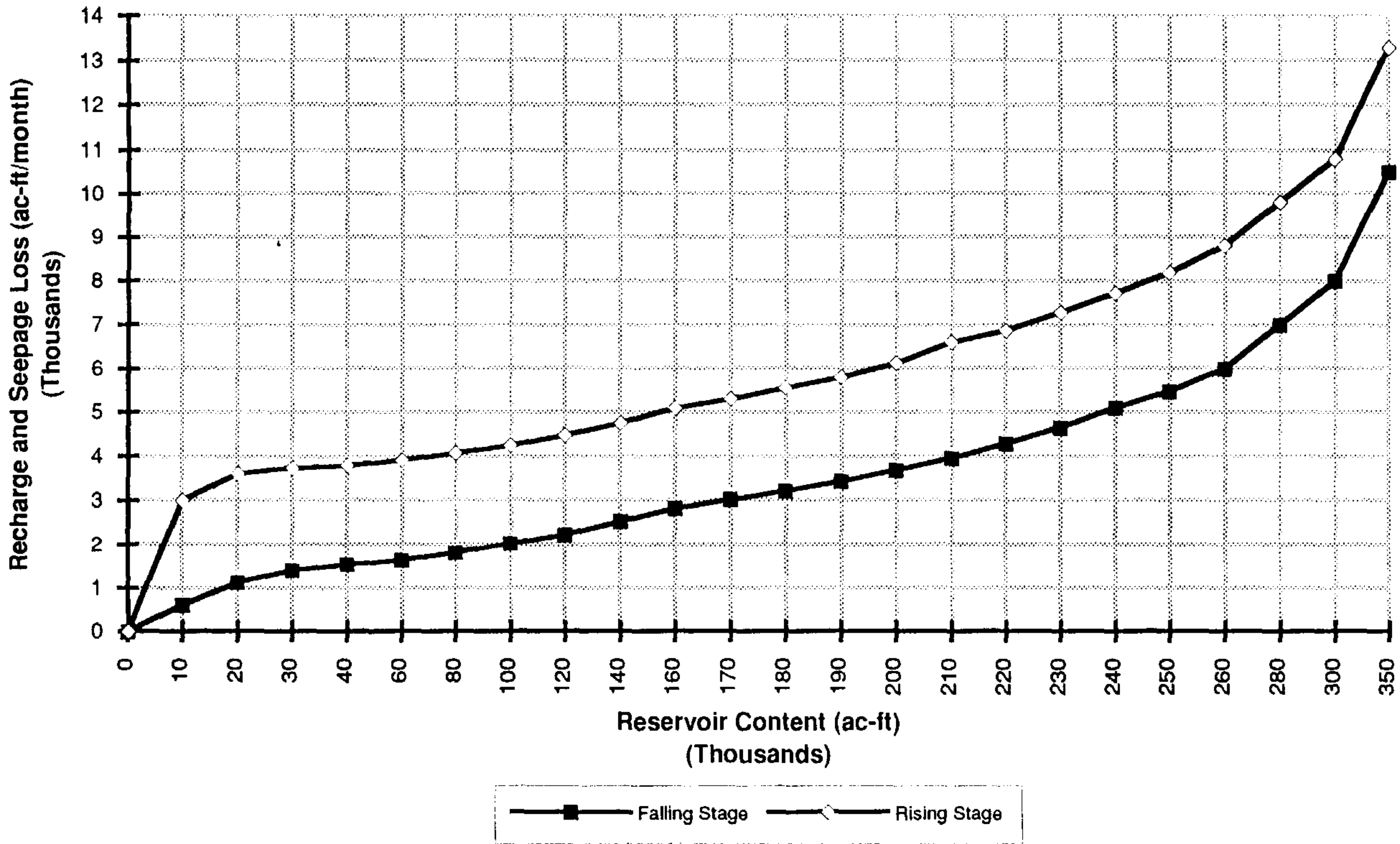
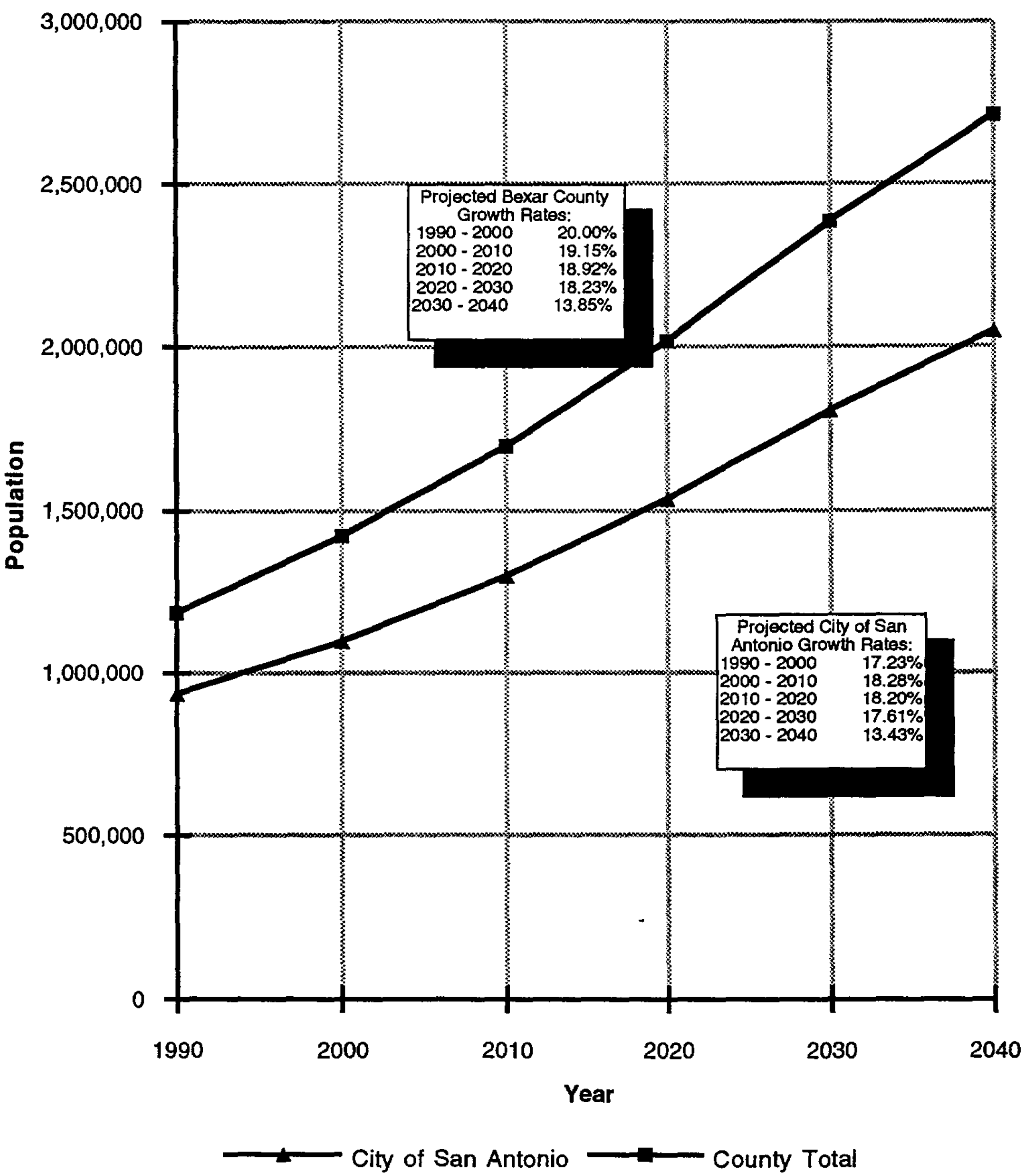
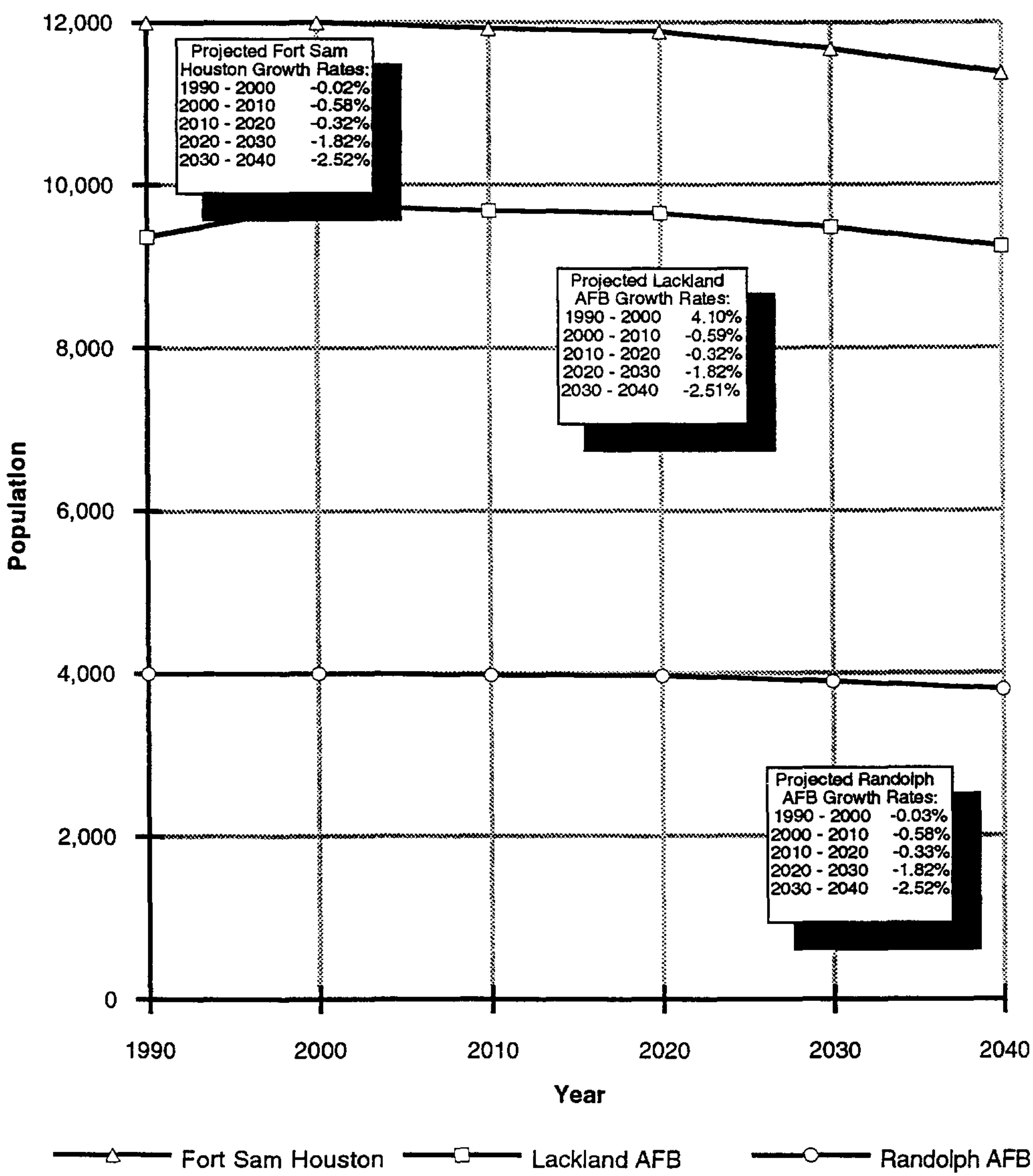


Figure 4-1
Projected Poulation for the City of San Antonio and Bexar County
Low Series



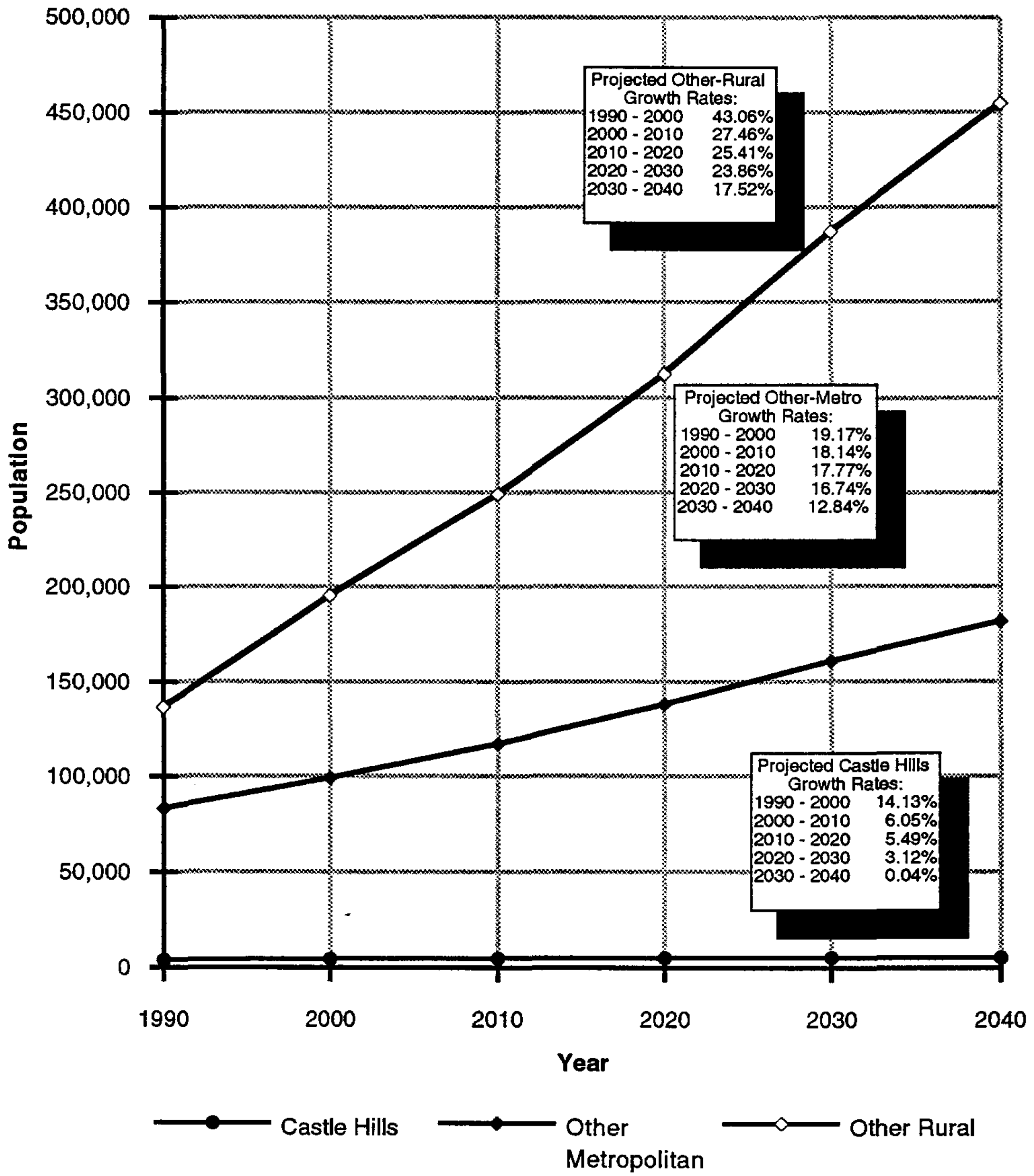
Source: Texas Water Development Board

Figure 4-1 (Cont.)
Projected Poulation for Military Bases Within Bexar County
Low Series



Source: Texas Water Development Board
a/ Brooks AFB and Kelly AFB were not included in the TWDB Population Projections

Figure 4-1 (Cont.)
Projected Poulation for the Castle Hills, Other Rural and Other Metropolitan
Low Series



Source: Texas Water Development Board

MSA

Figure 4-2
Projected Population for Primary Planning Area
Low Population Series

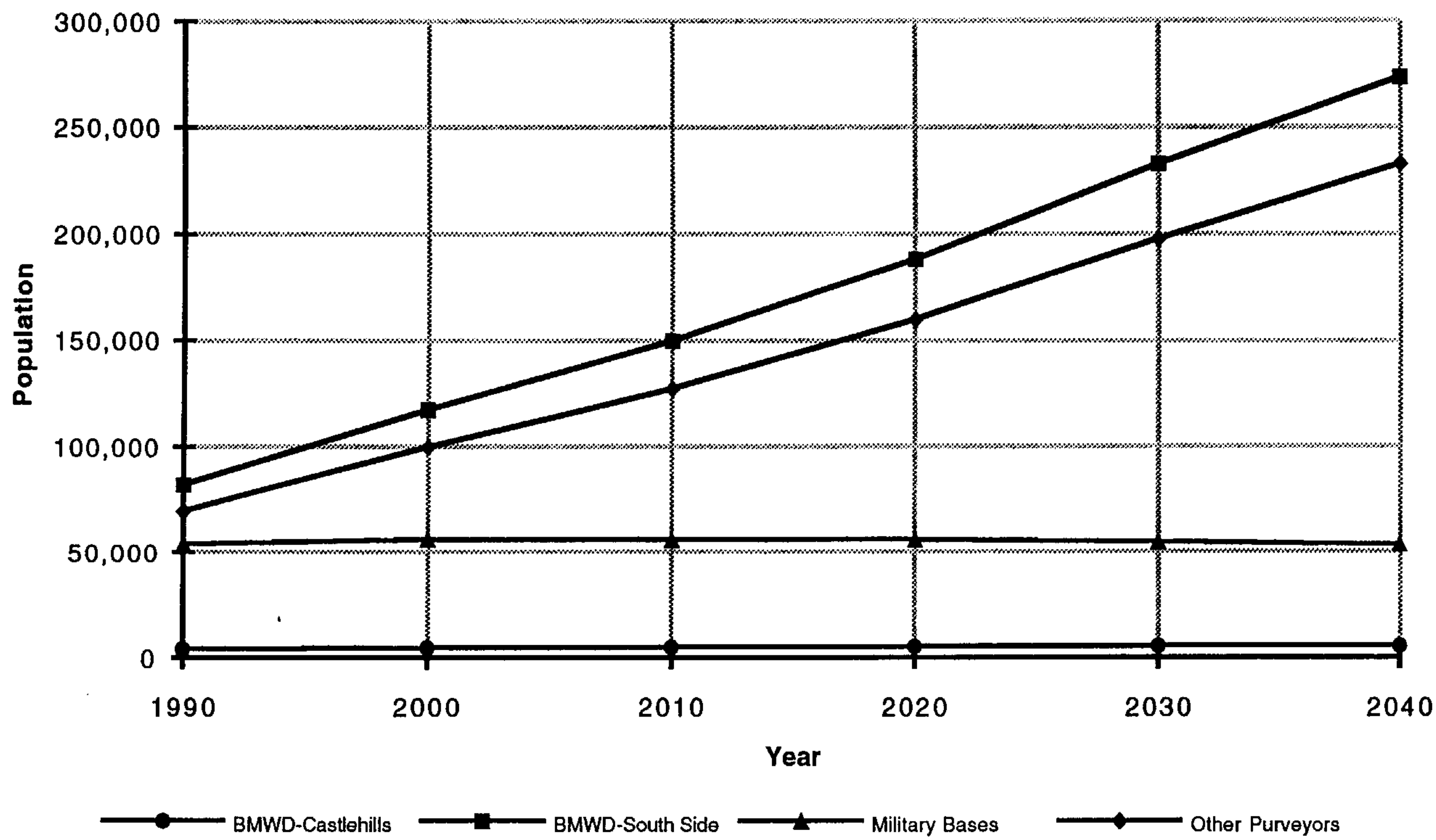
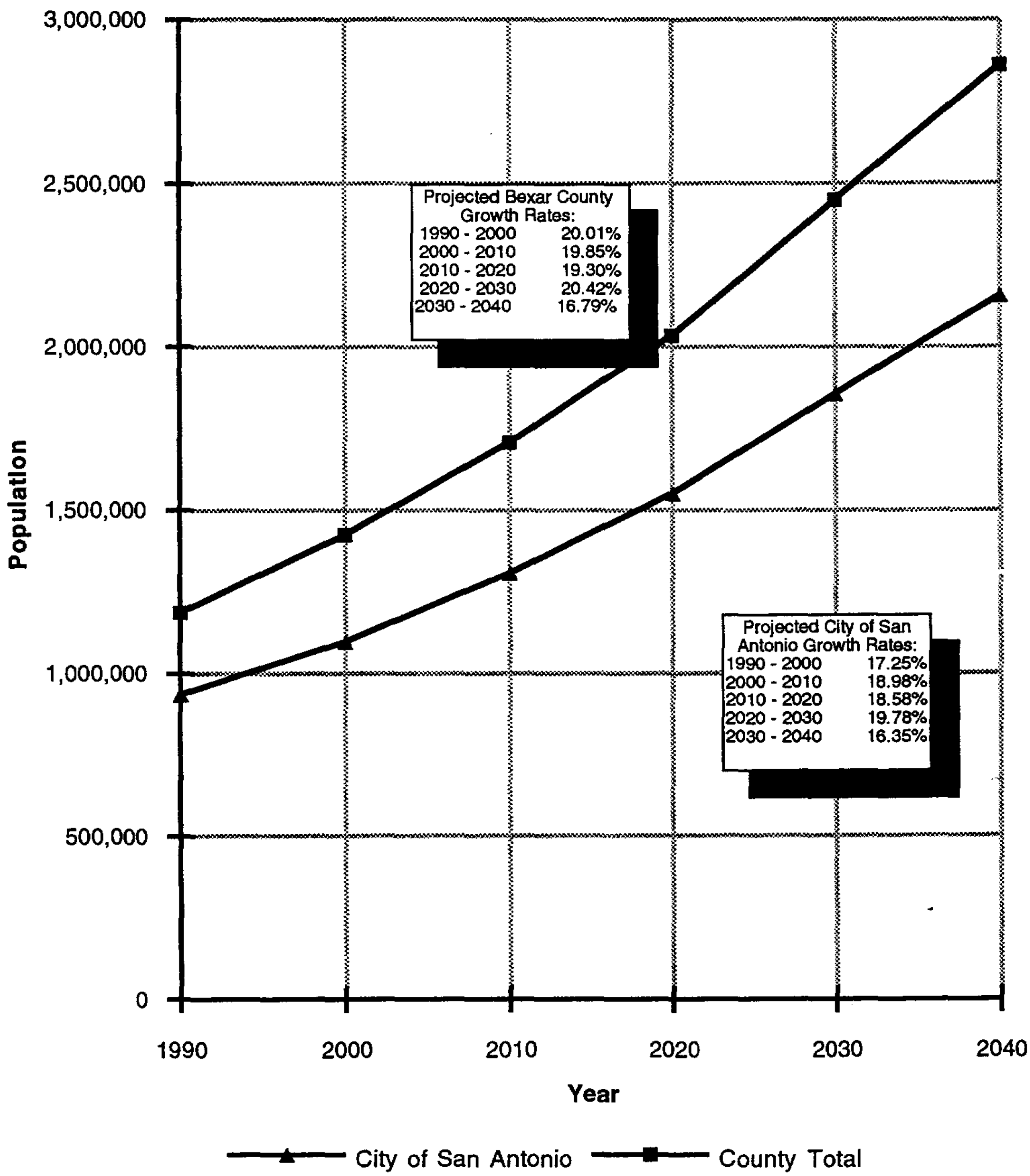
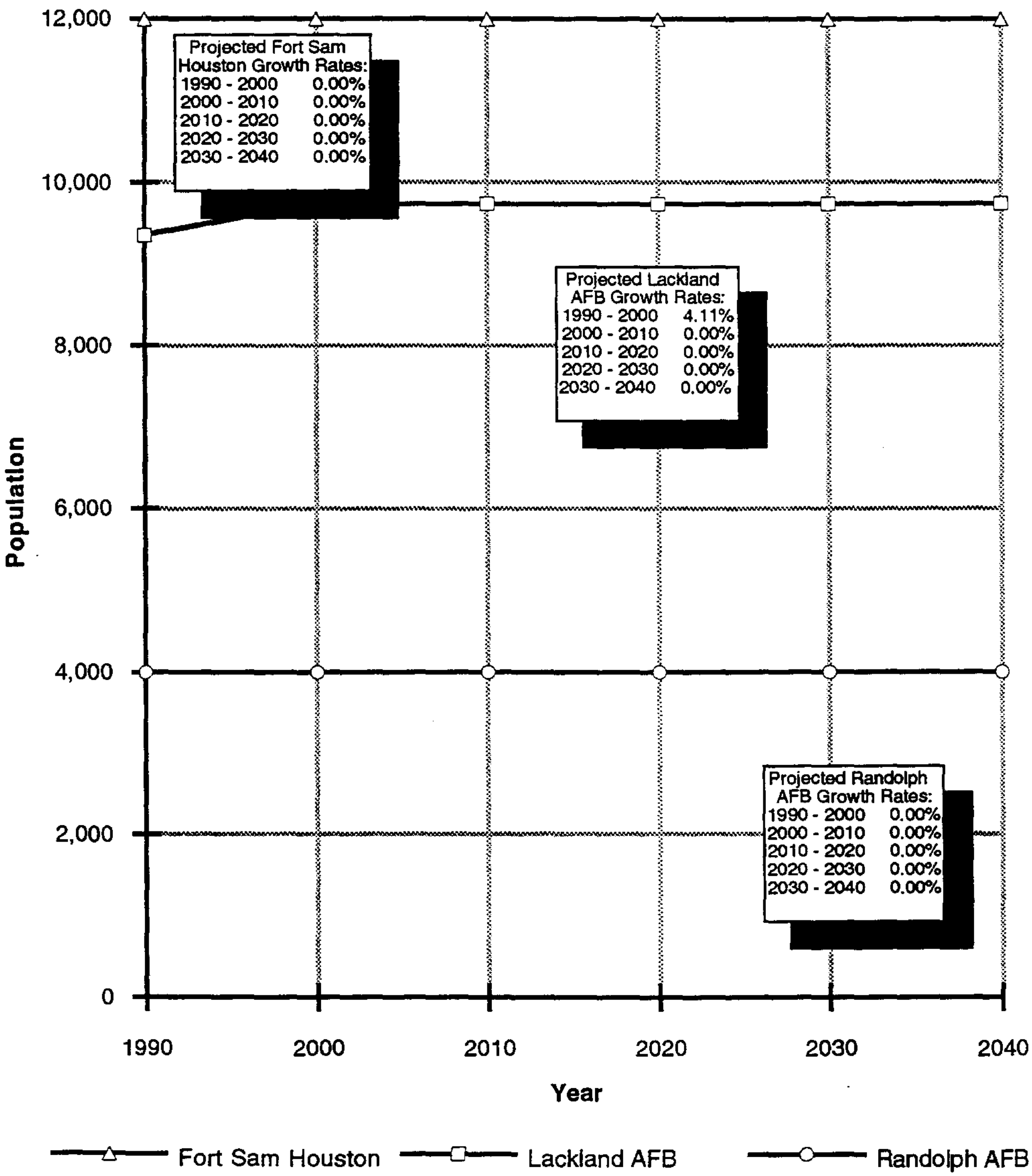


Figure 4-3
Projected Poulation for the City of San Antonio and Bexar County
High Series



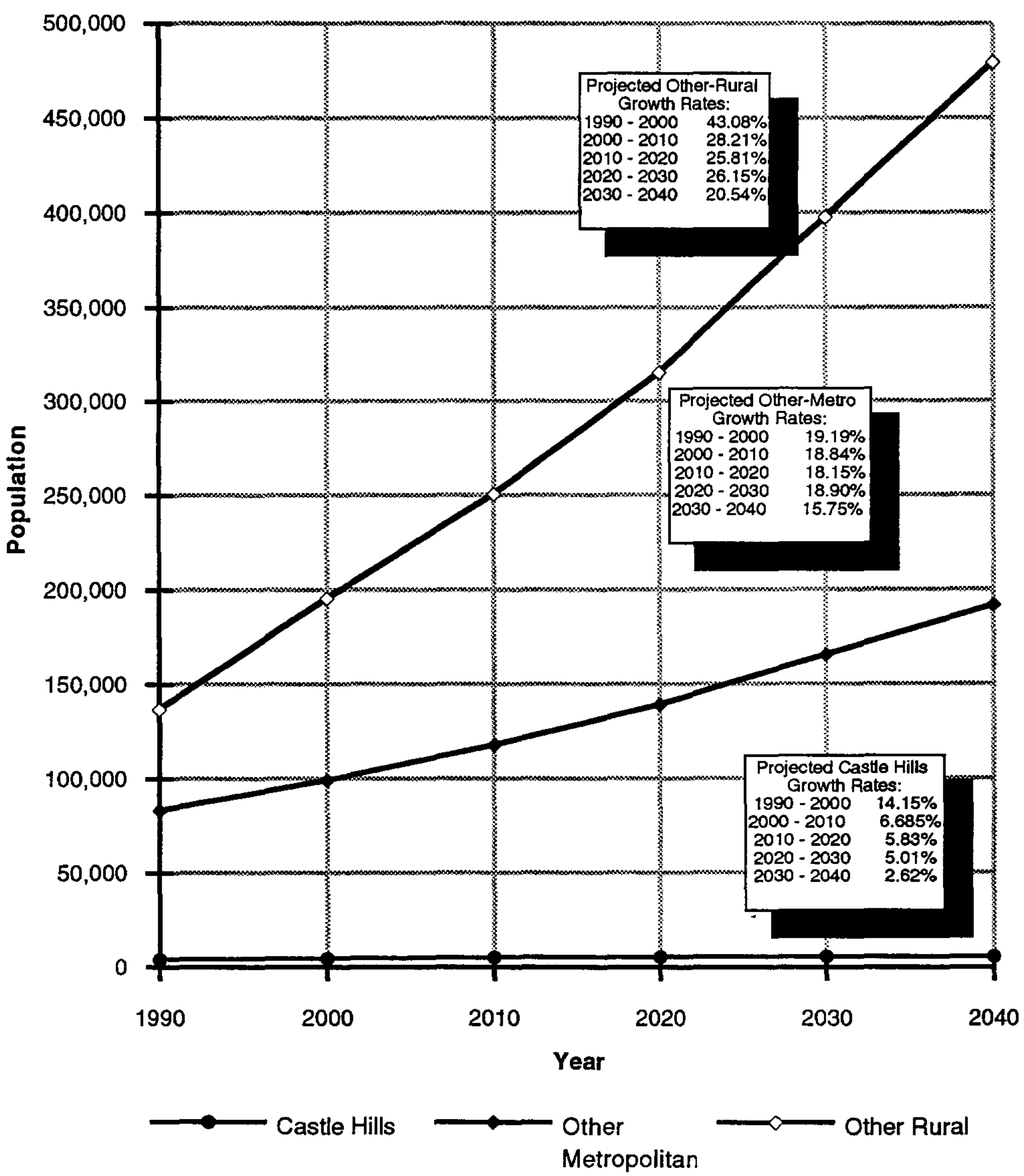
Source: Texas Water Development Board

Figure 4-3 (Cont.)
Projected Poulation for Military Bases Within Bexar County
High Series



Source: Texas Water Development Board
a/ Brooks AFB and Kelly AFB were not included in the TWDB Population Projections

Figure 4-3 (Cont.)
Projected Poulation for the Castle Hills, Other Rural and Other Metropolitan
High Series



Source: Texas Water Development Board

Figure 4-4
Projected Population for Primary Planning Area
High Population Series

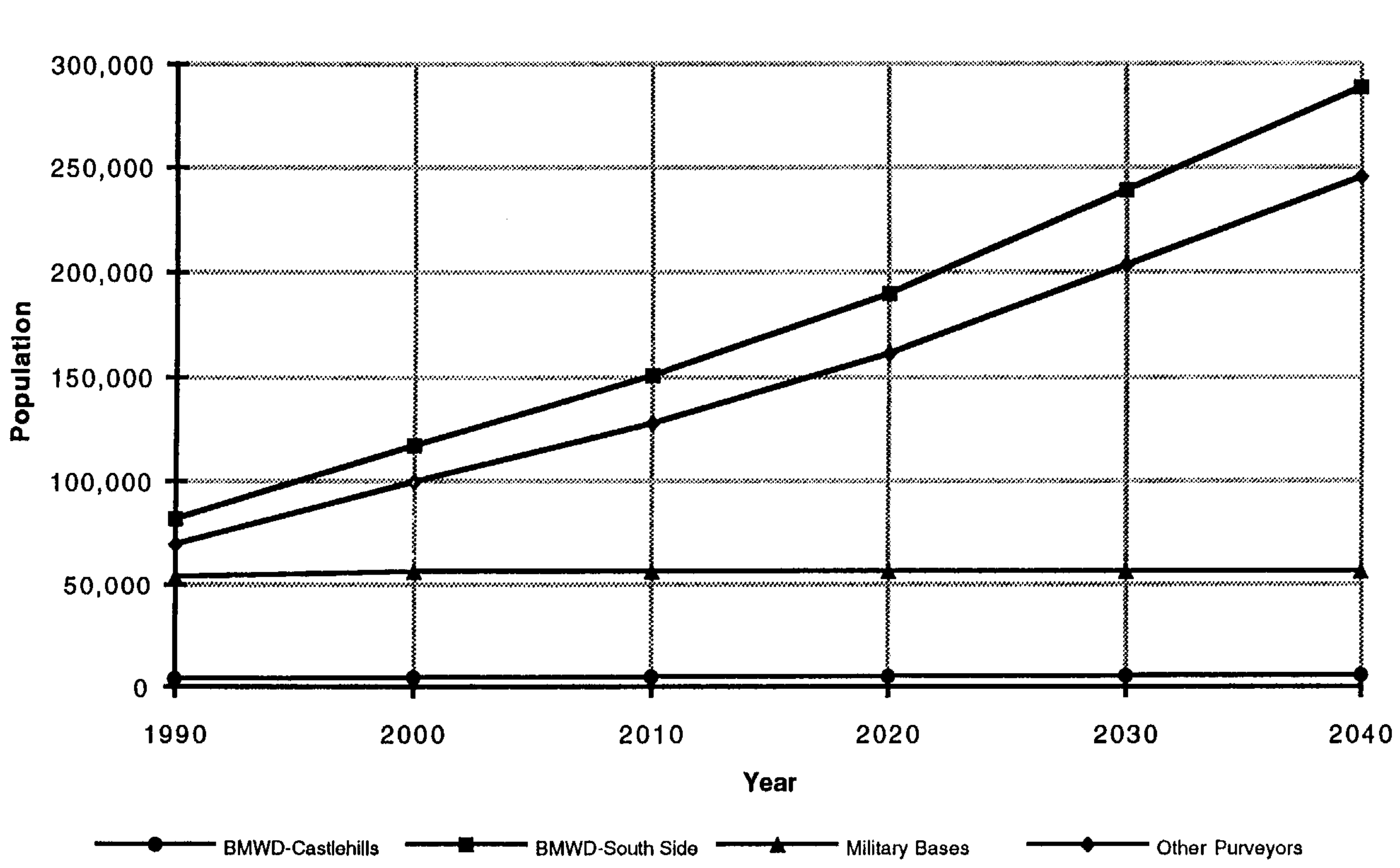
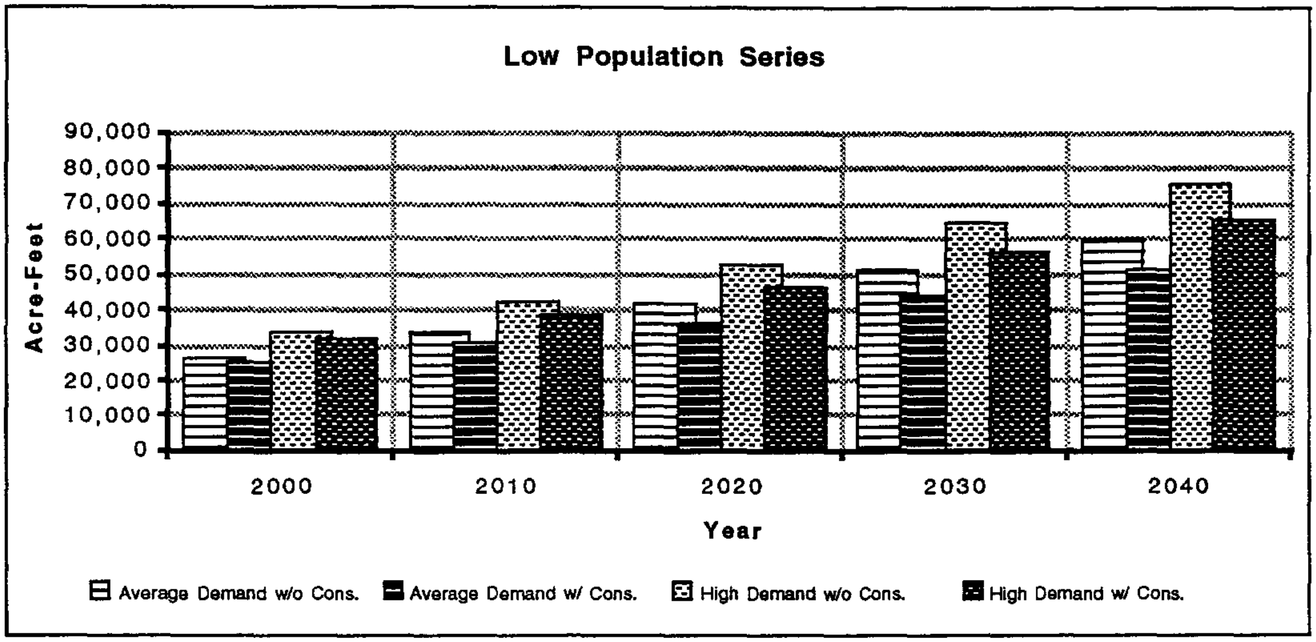


Figure 4-5
Projected Water Use for Bexar Metropolitan Water District



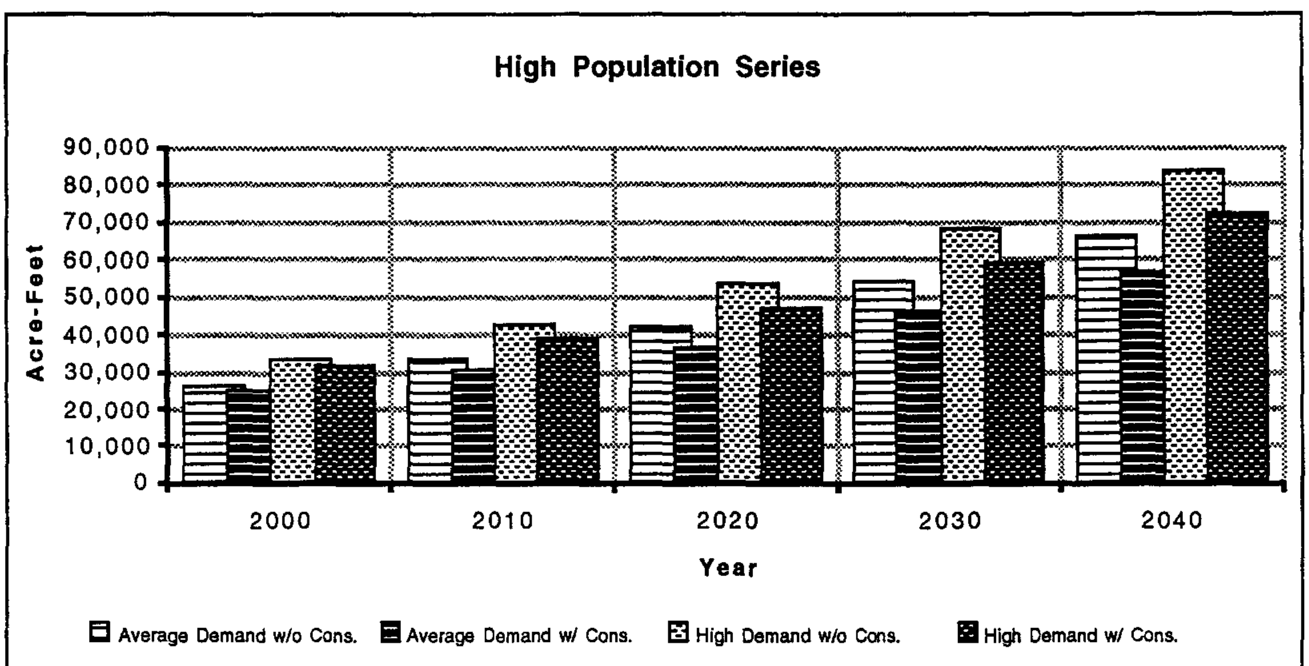
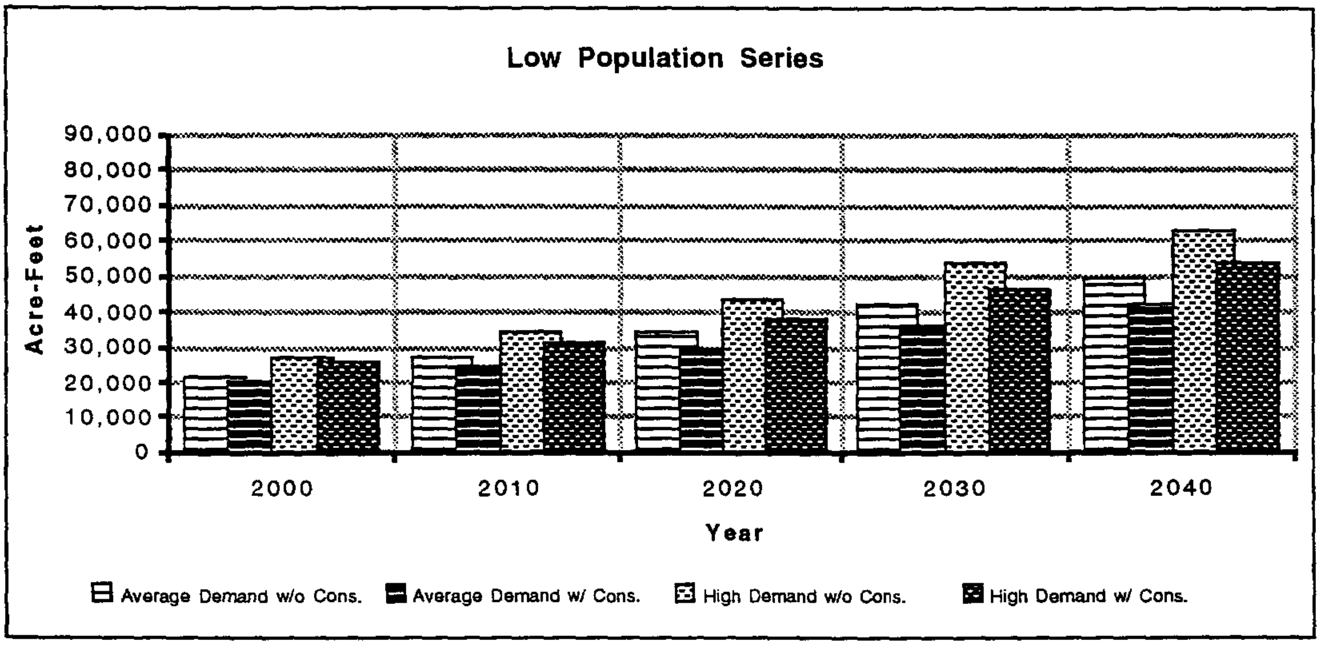


Figure 4-6
Projected Water Use for Other Non-Military Water Purveyors



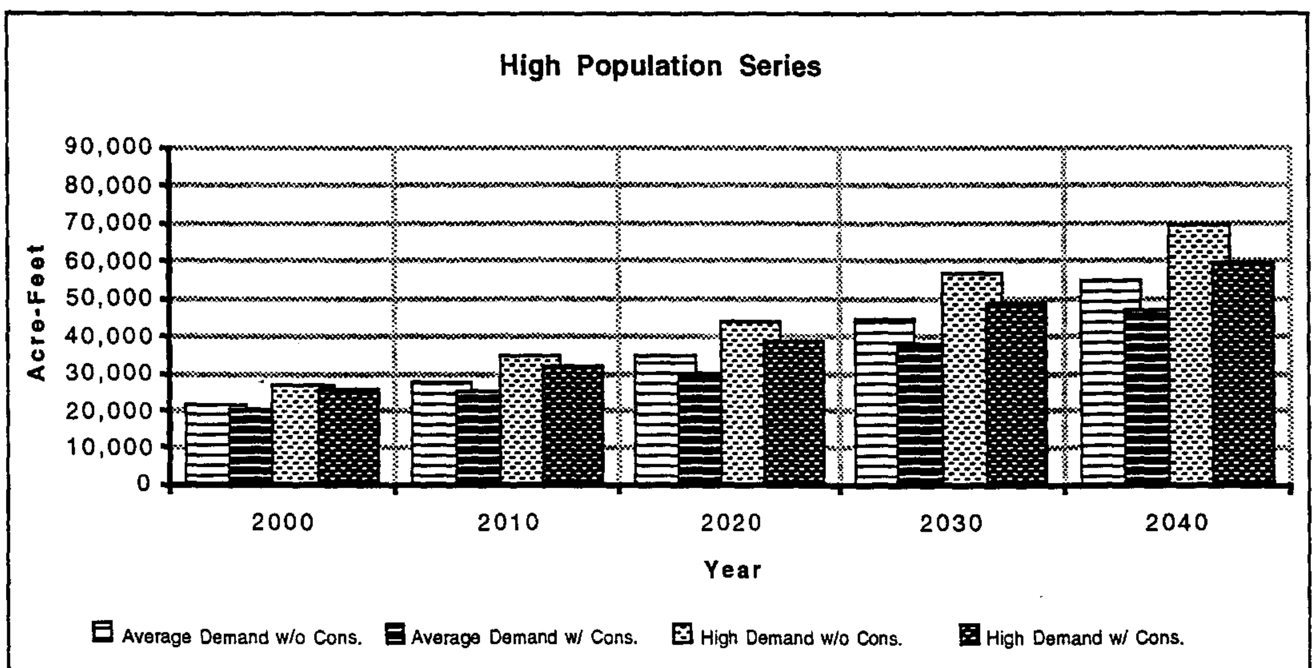
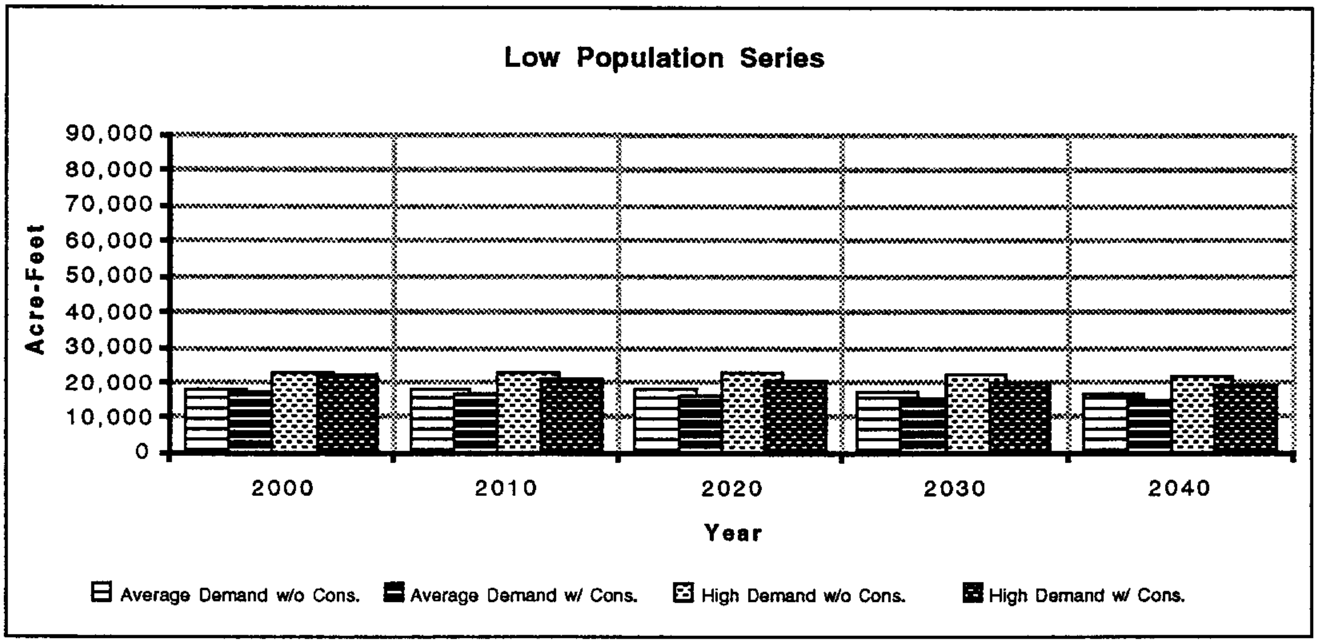
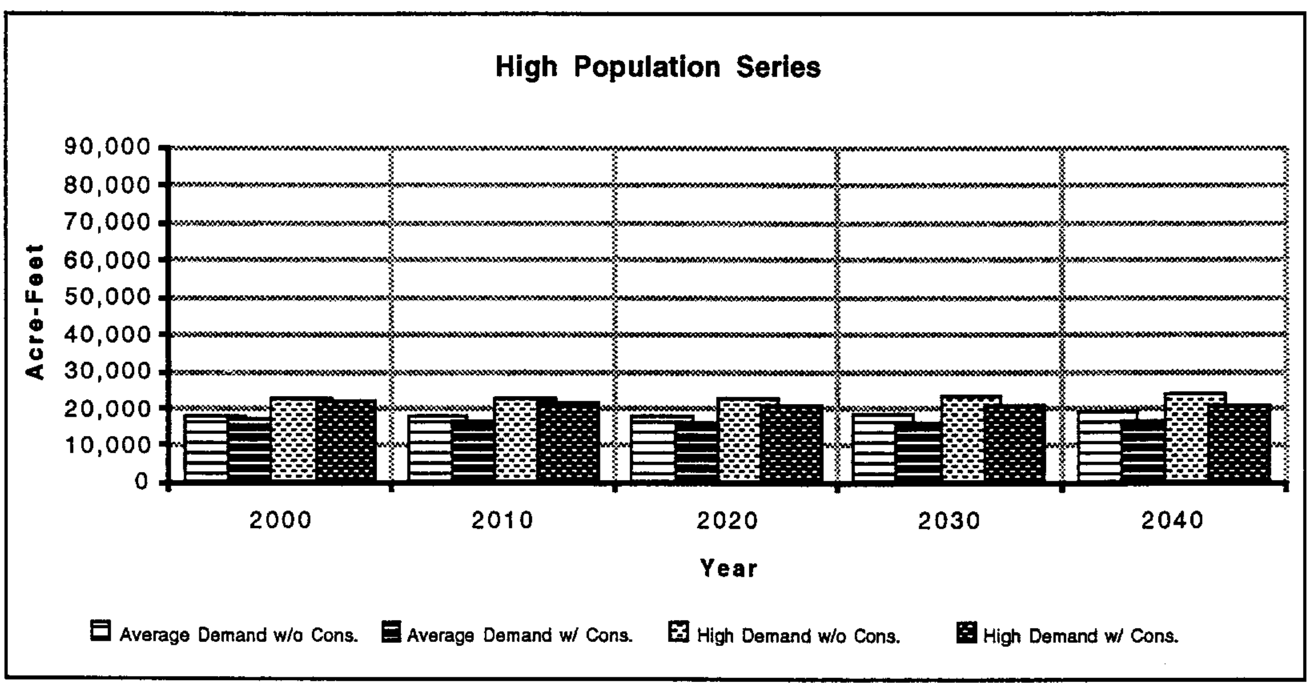


Figure 4-7
Projected Water Use for Military Bases Within Bexar County





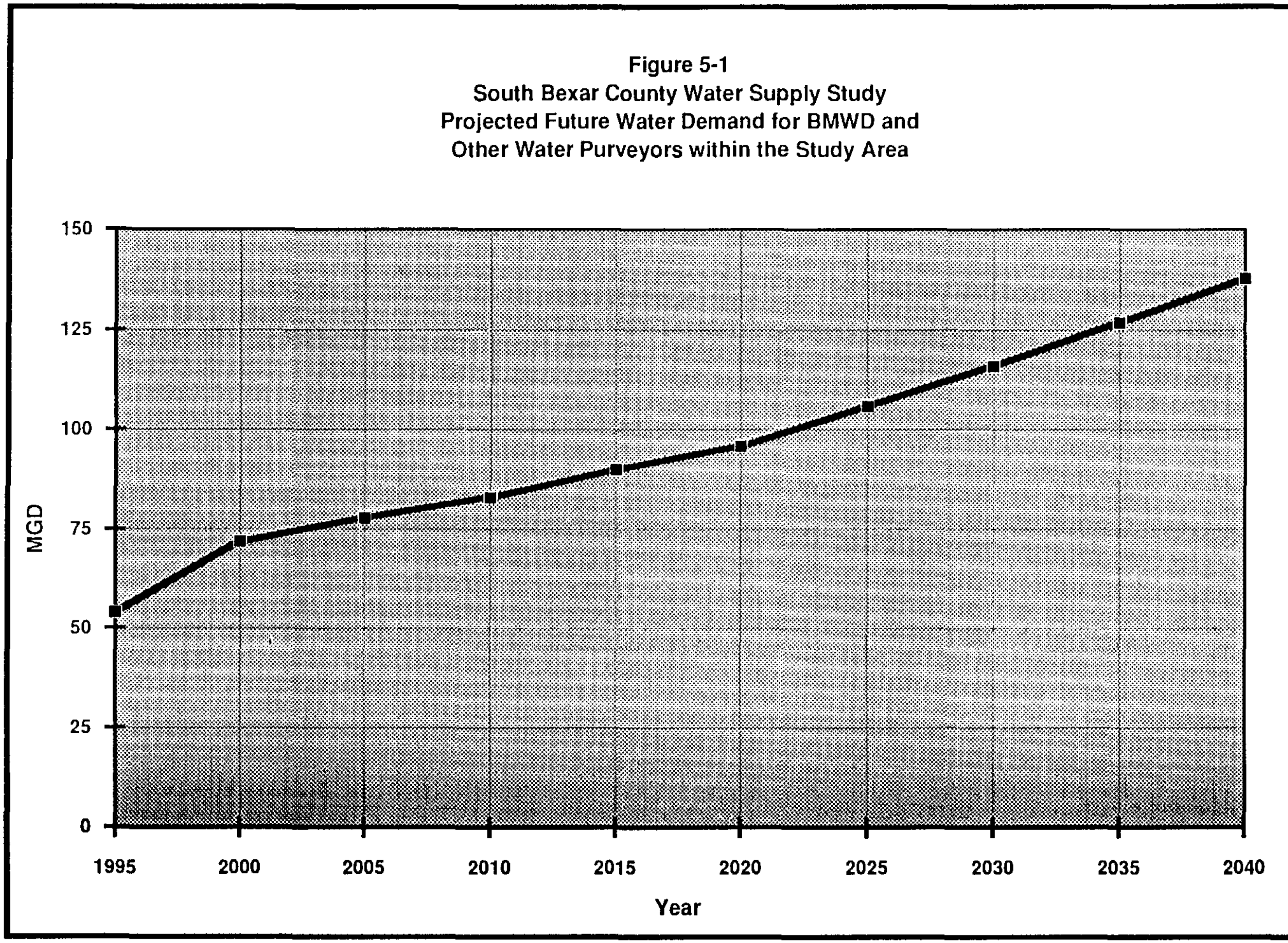
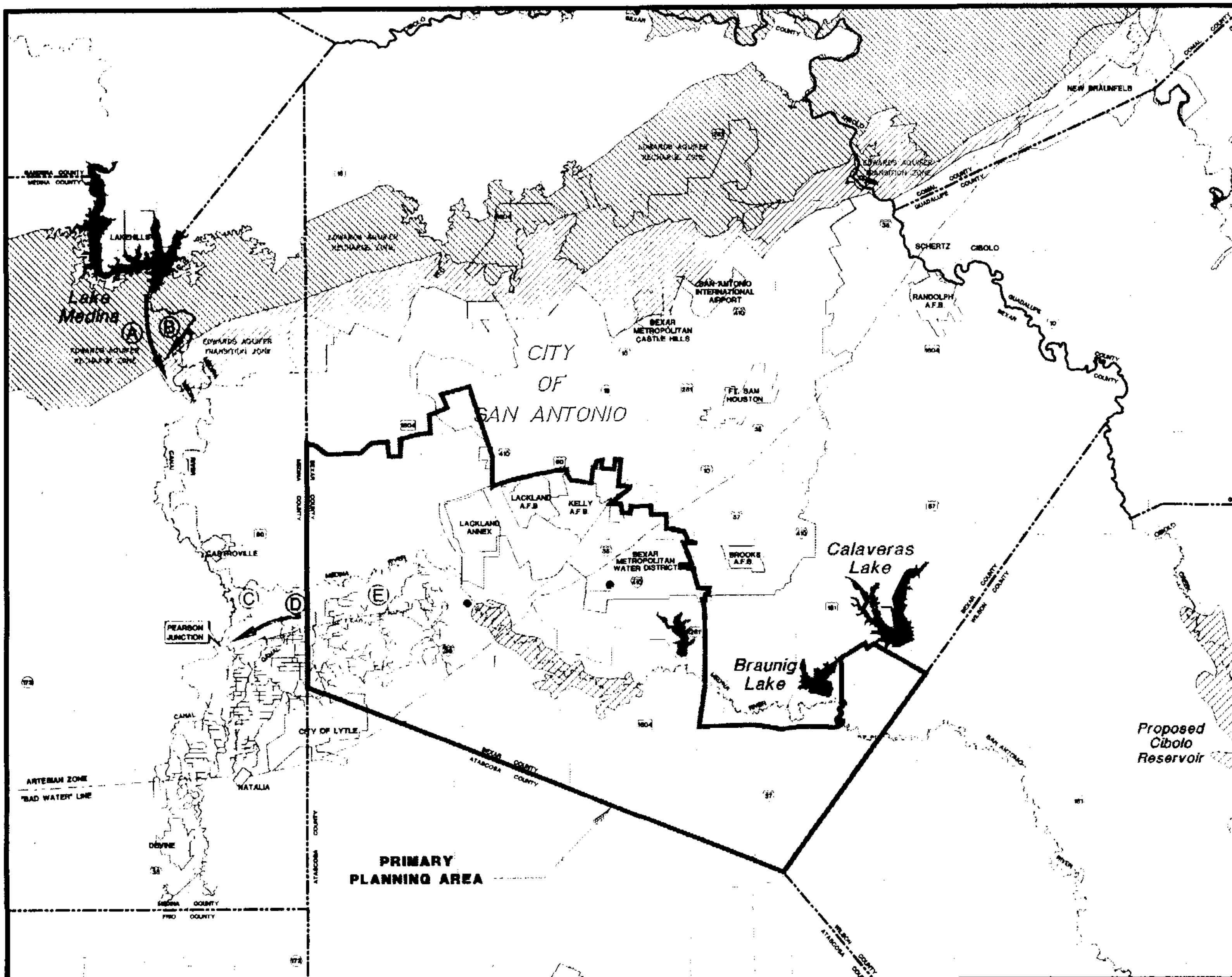


Figure 5-1
South Bexar County Water Supply Study
Projected Future Water Demand for BMWD and
Other Water Purveyors within the Study Area
150
125
100
75
50
25
0
MGD
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
Year



LEGEND:

A - BMW Medina Lake Diversions

B - BMA Diversion Lake Withdrawl

C - BMA Medina River Diversion Points

D - BMA Edwards Aquifer Wells

E - BMA Use of Living Waters Cat Fish Farm Effluent

DATE: March 1993

DRAWN BY: DWS

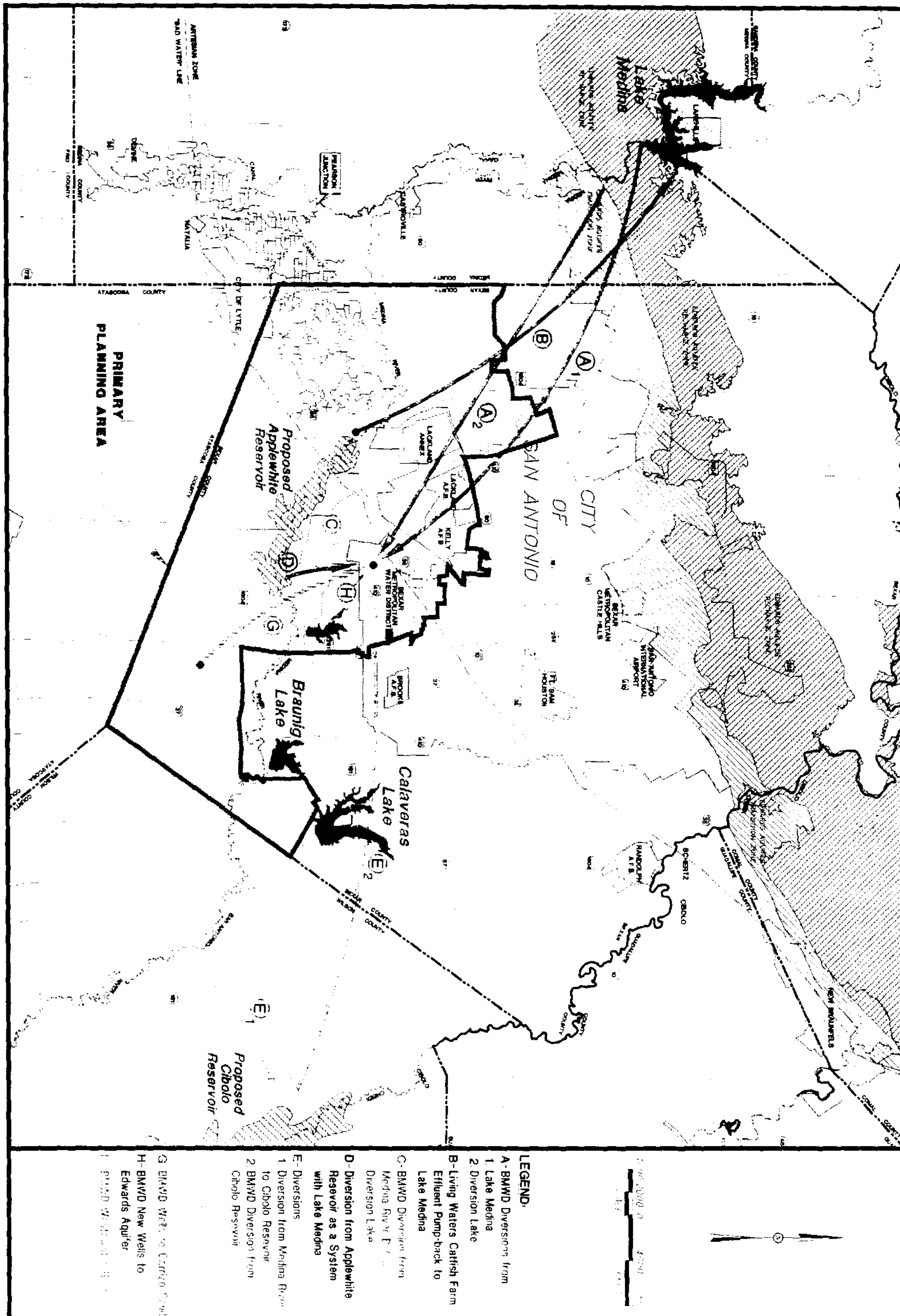
SUBMITTED TO: Bexar Metropolitan Water District

FOR: Southern Bexar County Medina Valley Surface Water Supply Study

Figure 5-2

BMA System Modification Options

MICHAEL SULLIVAN & ASSOC., INC.
Engineering & Environmental Consultants
Air - Water Quality - Water Resources



MICHAEL SULLIVAN & ASSOC., INC.
Engineering & Environmental Consultants
Air - Water Quality - Water Resources

Figure 5-3
BMWD Future Water Supply Source Options

SUBMITTED TO:
Bexar Metropolitan Water District
FOR:
Southern Bexar County
Medina Valley Surface Water Supply Study

DATE: March 1993

DRAWN BY: DWS

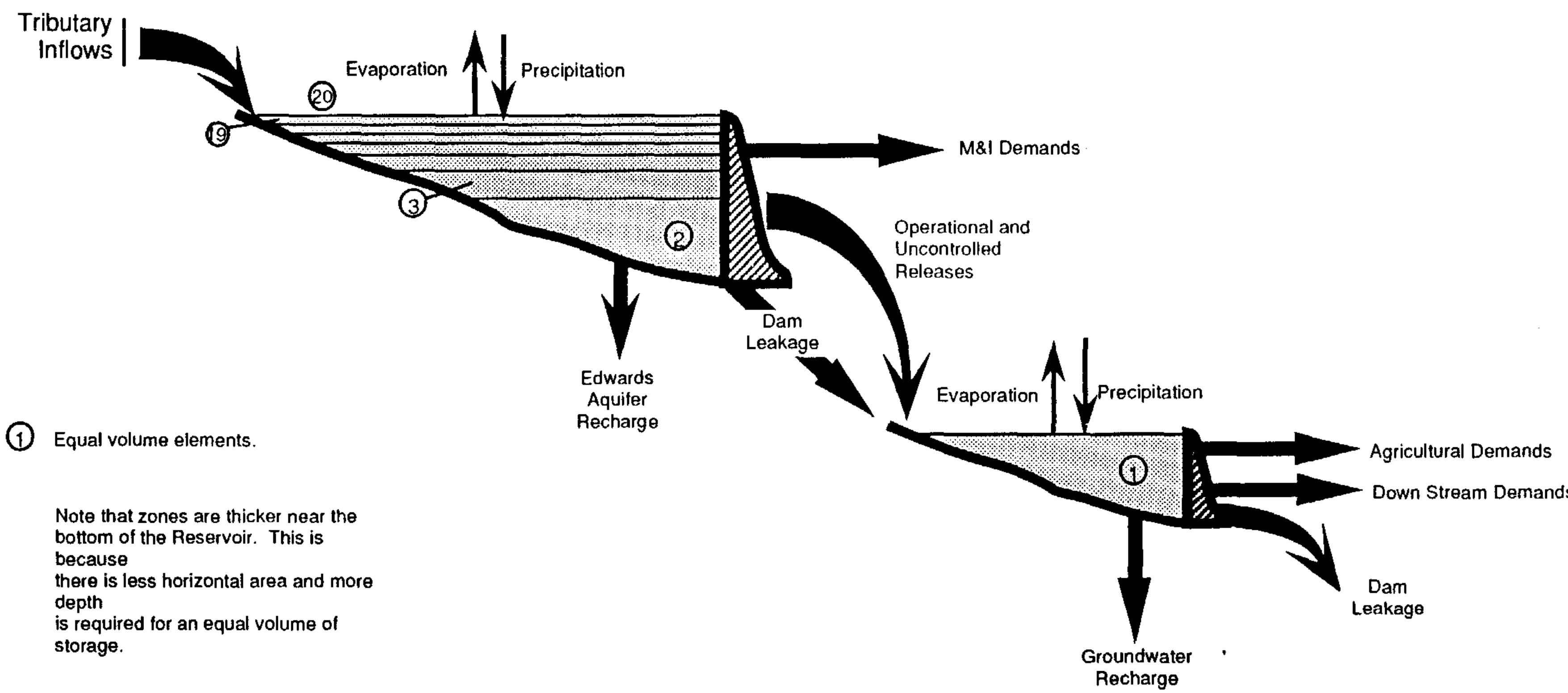
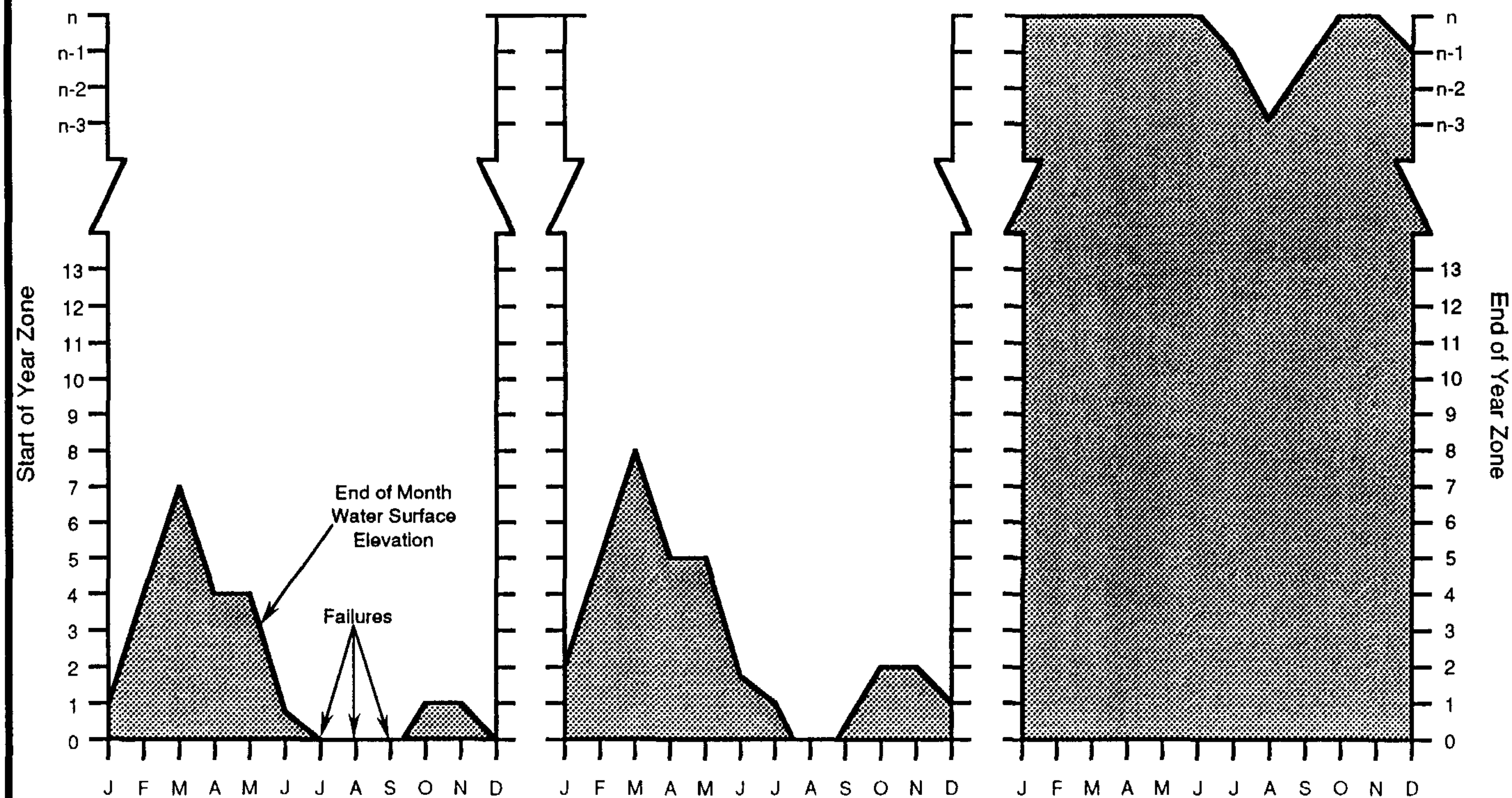


Figure 6-1
Typical Two Reservoir System



Each year of hydrodynamic data is routed through the reservoir system n-times. First assuming the year starts in Zone 1, then in Zone 2. And so-on through all n zones. For each start zone, the number of times that the water surface ends in each zone is recorded to construct the [S/E] Matrix. Failures are recorded as a function of start zone to construct the [Failure] Matrix.

End Zone

Start Zone

$$[S/E] = \begin{bmatrix} E_{1,1} & E_{1,2} & \cdots & E_{1,n} \\ E_{2,1} & E_{2,2} & \cdots & E_{2,n} \\ \cdots & \cdots & \cdots & \cdots \\ E_{n,1} & E_{n,2} & \cdots & E_{n,n} \end{bmatrix} ; \quad [Failure] = \begin{bmatrix} F_1 \\ F_2 \\ \cdots \\ F_n \end{bmatrix}$$

$E_{a,b}$ = Number of times that the water surface ended the year in Zone b when starting the year in Zone a.

F_a = Total number of failures for all month for all years starting in Zone a.

Figure 6-2
Behavioral Reservoir Routing and Start Zone/End Zone and Failure Matrix Creation

$$
[T] = \begin{bmatrix}
\frac{E_{1,1}}{\#yrs} & \frac{E_{12}}{\#yrs} & \frac{E_{13}}{\#yrs} & \frac{E_{14}}{\#yrs} & \cdots & \cdots & \frac{E_{1n-1}}{\#yrs} & \frac{E_{1n}}{\#yrs} \\
\frac{E_{2,1}}{\#yrs} & \frac{E_{23}}{\#yrs} & \frac{E_{23}}{\#yrs} & \frac{E_{24}}{\#yrs} & \cdots & \cdots & \frac{E_{2n-1}}{\#yrs} & \frac{E_{2n}}{\#yrs} \\
\frac{E_{3,1}}{\#yrs} & \frac{E_{32}}{\#yrs} & \frac{E_{33}}{\#yrs} & \frac{E_{34}}{\#yrs} & \cdots & \cdots & \frac{E_{3n-1}}{\#yrs} & \frac{E_{3n}}{\#yrs} \\
\frac{E_{4,1}}{\#yrs} & \frac{E_{42}}{\#yrs} & \frac{E_{43}}{\#yrs} & \frac{E_{44}}{\#yrs} & \cdots & \cdots & \frac{E_{4n-1}}{\#yrs} & \frac{E_{4n}}{\#yrs} \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\
\frac{E_{n-1,1}}{\#yrs} & \frac{E_{n-12}}{\#yrs} & \frac{E_{n-13}}{\#yrs} & \frac{E_{n-14}}{\#yrs} & \cdots & \cdots & \frac{E_{n-1n-1}}{\#yrs} & \frac{E_{n-1n}}{\#yrs} \\
\frac{E_{n,1}}{\#yrs} & \frac{E_{n2}}{\#yrs} & \frac{E_{n3}}{\#yrs} & \frac{E_{n4}}{\#yrs} & \cdots & \cdots & \frac{E_{nn-1}}{\#yrs} & \frac{E_{nn}}{\#yrs}
\end{bmatrix} ; \quad [S] = [T]^5 = \begin{bmatrix} S_{v,1} \\ S_{v,2} \\ S_{v,3} \\ S_{v,4} \\ \cdots \\ \cdots \\ S_{v,n-1} \\ S_{v,n} \end{bmatrix} ; \quad [\text{Failure}] = \begin{bmatrix} \frac{F_1}{\#mos} \\ \frac{F_2}{\#mos} \\ \frac{F_3}{\#mos} \\ \frac{F_4}{\#mos} \\ \cdots \\ \cdots \\ \frac{F_{n-1}}{\#mos} \\ \frac{F_n}{\#mos} \end{bmatrix}
$$

$$
[P_{\text{Failure}}] = \left[(S_a)\,(\text{Failure}_a)\right] = \begin{bmatrix} (S_{v,1}) \times (\text{Failure}_1) \\ (S_{v,2}) \times (\text{Failure}_2) \\ \cdots \\ (S_{v,n}) \times (\text{Failure}_n) \end{bmatrix}
$$

$$
P_{\text{Failure}} = \sum_{1}^{n} \left\{ \left((S_{v,n})(\text{Failure}_n) \right) \right\}
$$

[T] =	Transition Matrix
[S]	Steady-State Matrix
[Failure]	Failure Matrix
[PFailure]	Conditional Probability of Failure Matrix
[PFailure]	System Conditional Probability of Failure

Figure 6-3
Transitional and Steady-State Matrix Development
Probability of Failure Determination

Figure 6-4
Example of Conditional Probability Table
Probability of Starting Any Given Year in a Specified Zone,
Conditional Probability of Failure (†) Within Any Month For Any Year if Started in a Specified Zone,
and Total Probability of Failure

Start Zone	P-Start(1) Probability of Starting Any Year in Specified Zone (1)	Conditional Probability of Failure Within Any Month For Any Year If Started in Specified Zone (2)	P-Fail(1) Product of Probabilities (1) X (2)	Cumulative Product of Probabilities Σ [(1) X (2)]
1	P-Start(1)	Fail(1)	P-Fail(1)	P-Fial(1)
2	P-Start(2)	Fail(2)	P-Fail(2)	P-Fail(1-2)
3	P-Start(3)	Fail(3)	P-Fail(3)	P-Fail(1-3)
4	P-Start(4)	Fail(4)	P-Fail(4)	P-Fail(1-4)
5	P-Start(5)	Fail(5)	P-Fail(5)	P-Fail(1-5)
6	P-Start(6)	Fail(6)	P-Fail(6)	P-Fail(1-6)
7	P-Start(7)	Fail(7)	P-Fail(7)	P-Fail(1-7)
8	P-Start(8)	Fail(8)	P-Fail(8)	P-Fail(1-8)
9	P-Start(9)	Fail(9)	P-Fail(9)	P-Fail(1-9)
10	P-Start(10)	Fail(10)	P-Fail(10)	P-Fail(1-10)
11	P-Start(11)	Fail(11)	P-Fail(11)	P-Fail(1-11)
12	P-Start(12)	Fail(12)	P-Fail(12)	P-Fail(1-12)
13	P-Start(13)	Fail(13)	P-Fail(13)	P-Fail(1-13)
14	P-Start(14)	Fail(14)	P-Fail(14)	P-Fail(1-14)
15	P-Start(15)	Fail(15)	P-Fail(15)	P-Fail(1-15)
16	P-Start(16)	Fail(16)	P-Fail(16)	P-Fail(1-16)
17	P-Start(17)	Fail(17)	P-Fail(17)	P-Fail(1-17)
18	P-Start(18)	Fail(18)	P-Fail(18)	P-Fail(1-18)
19	P-Start(19)	Fail(19)	P-Fail(19)	P-Fail(1-19)
20	P-Start(20)	Fail(20)	P-Fail(20)	P-Fail(1-20)
21	P-Start(21)	Fail(21)	P-Fail(21)	P-Fail(1-21)
22	P-Start(22)	Fail(22)	P-Fail(22)	P-Fail(1-22)
23	P-Start(23)	Fail(23)	P-Fail(23)	P-Fail(1-23)
24	P-Start(24)	Fail(24)	P-Fail(24)	P-Fail(1-24)
25	P-Start(25)	Fail(25)	P-Fail(25)	P-Fail(1-25)
26	P-Start(26)	Fail(26)	P-Fail(26)	P-Fail(1-26)
27	P-Start(27)	Fail(27)	P-Fail(27)	P-Fail(1-27)
28	P-Start(28)	Fail(28)	P-Fail(28)	P-Fail(1-28)
29	P-Start(29)	Fail(29)	P-Fail(29)	P-Fail(1-29)
30	P-Start(30)	Fail(30)	P-Fail(30)	P-Fail(1-30)
31	P-Start(31)	Fail(31)	P-Fail(31)	P-Fail(1-31)
32	P-Start(32)	Fail(32)	P-Fail(32)	P-Fail(1-32)
33	P-Start(33)	Fail(33)	P-Fail(33)	P-Fail(1-33)

† Failure = Inability to deliver both the full municipal demand and full irrigation requirement

Figure 6-5
Probability of Starting Any Year At or Above a Specified Capacity
Example

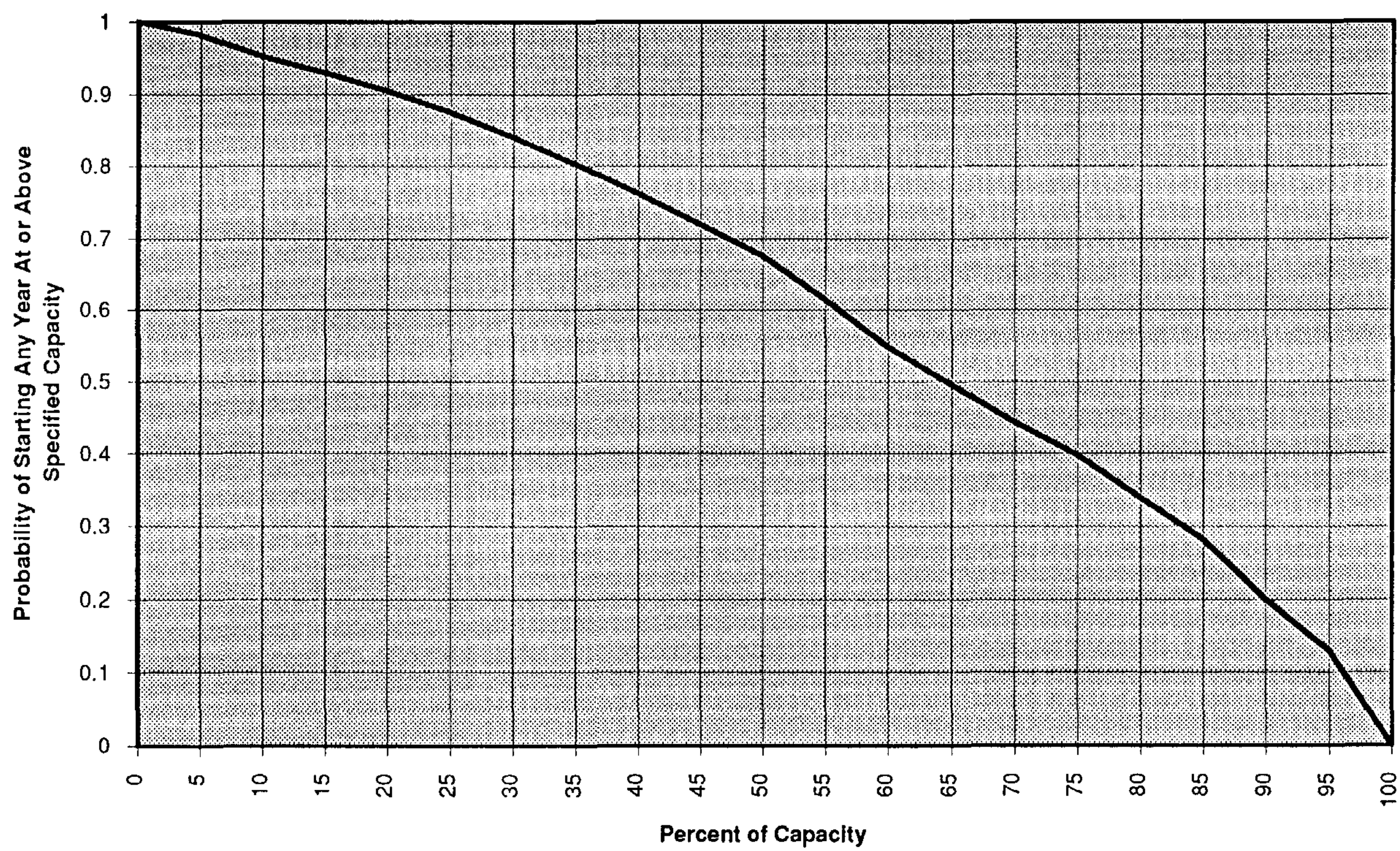
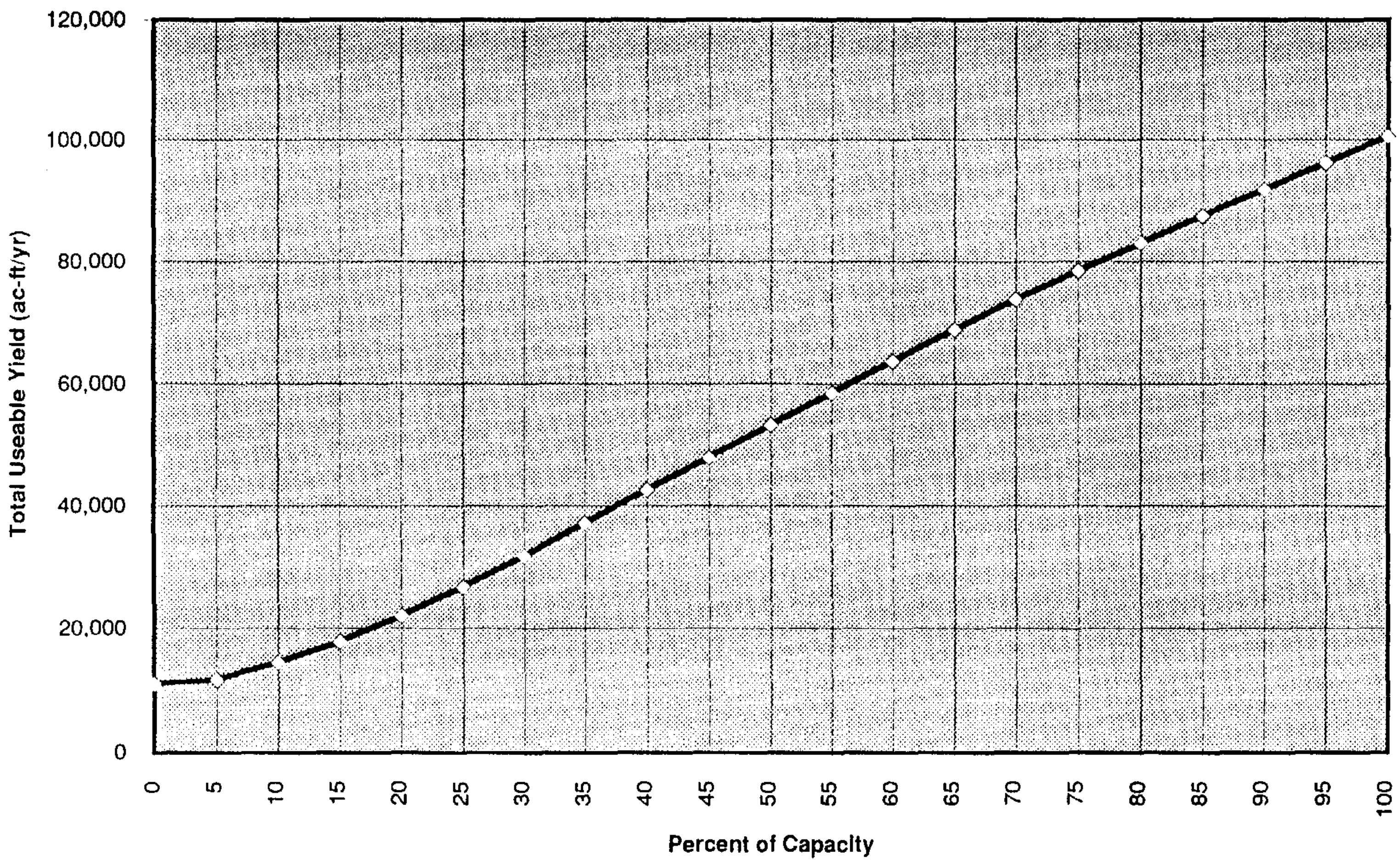


Figure 6-6
Total Useable Yield as a Function of Start of Year Capacity
Example



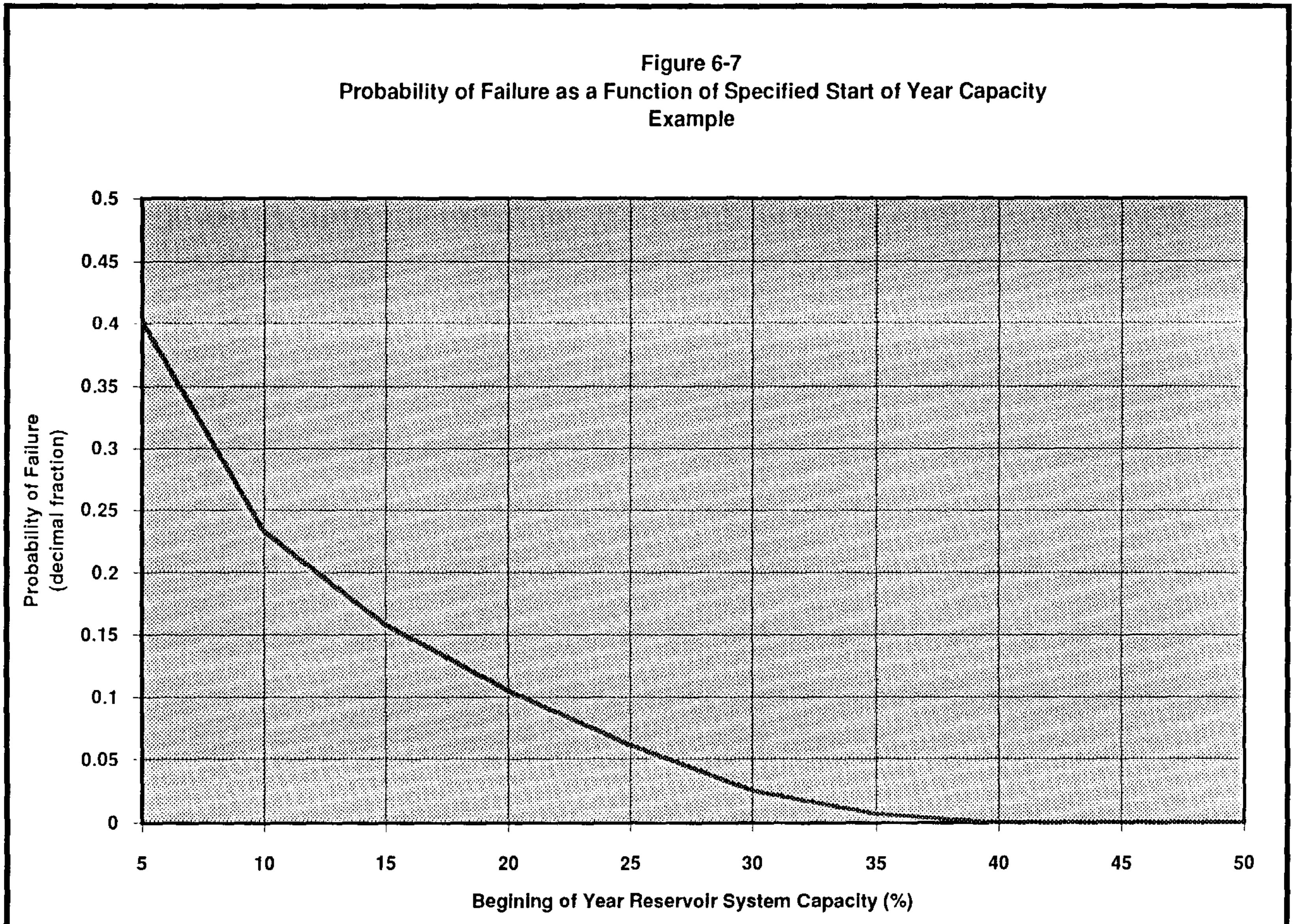


Figure 6-7
Probability of Failure as a Function of Specified Start of Year Capacity
Example
Probability of Failure
(decimal fraction)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
5
10
15
20
25
30
35
40
45
50
Begining of Year Reservoir System Capacity (%)

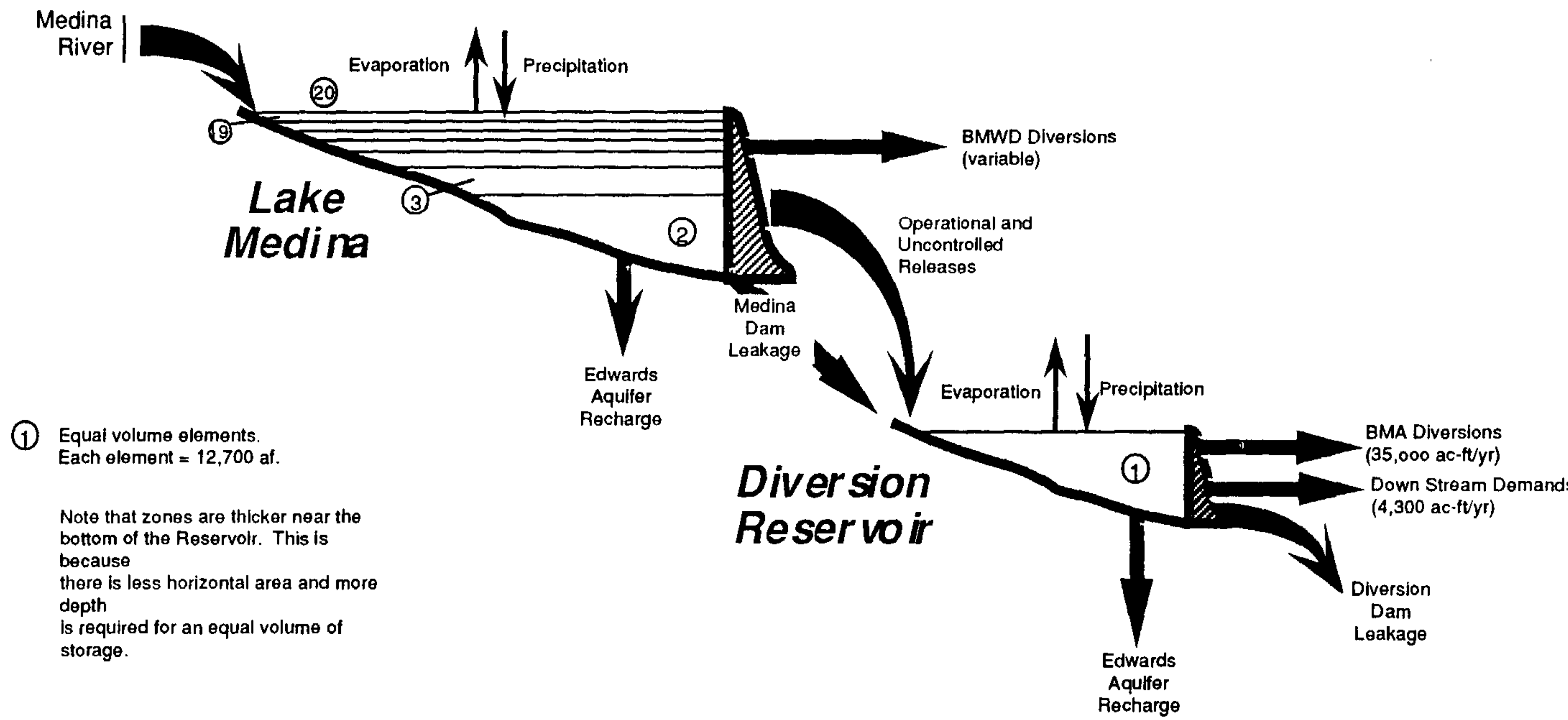


Figure 6-8
Schematic of Lake Medina and Diversion Reservoir System Simulation Case I

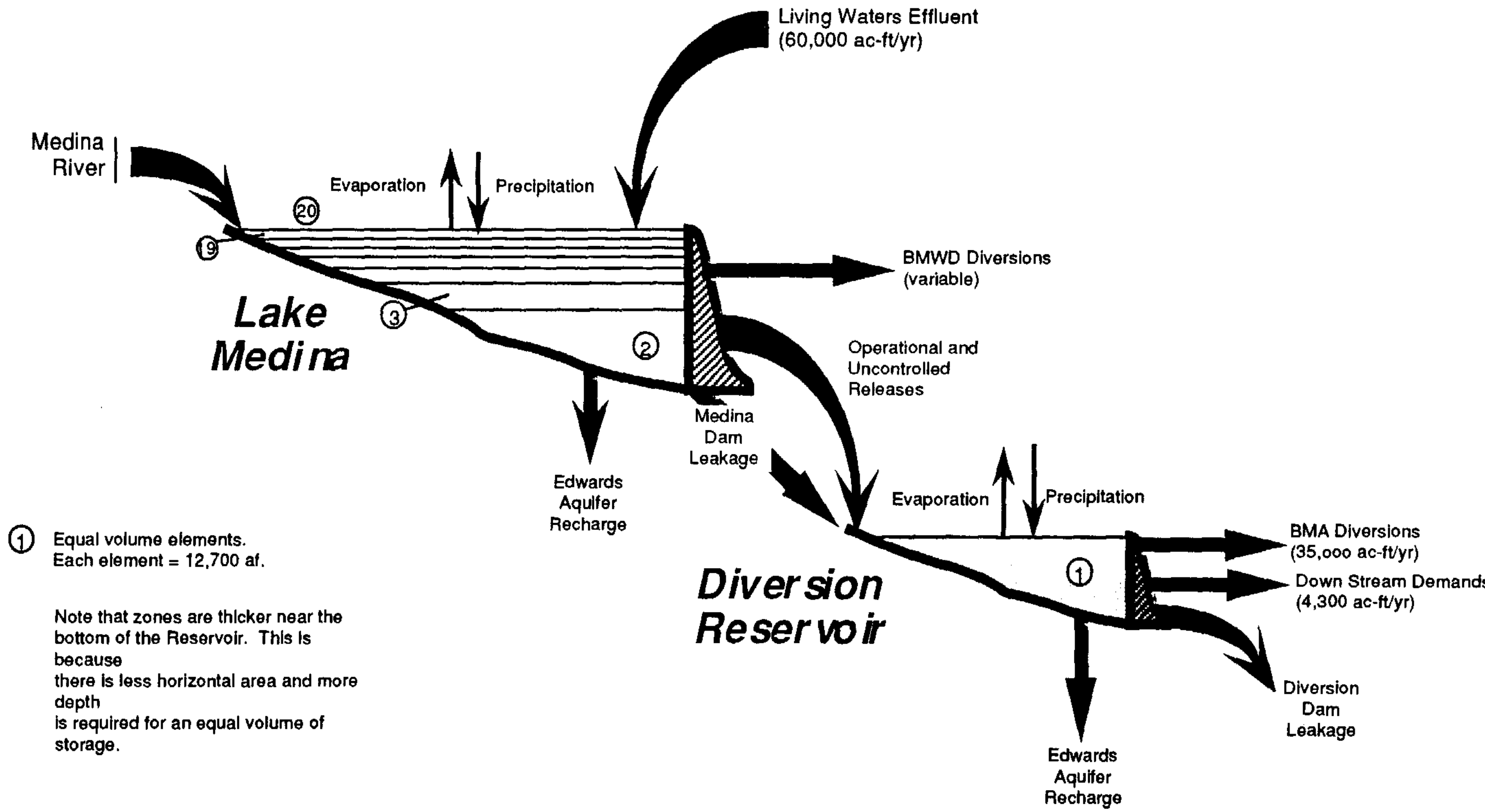


Figure 6-9
Schematic of Lake Medina and
Diversion Reservoir System
Simulation Case II

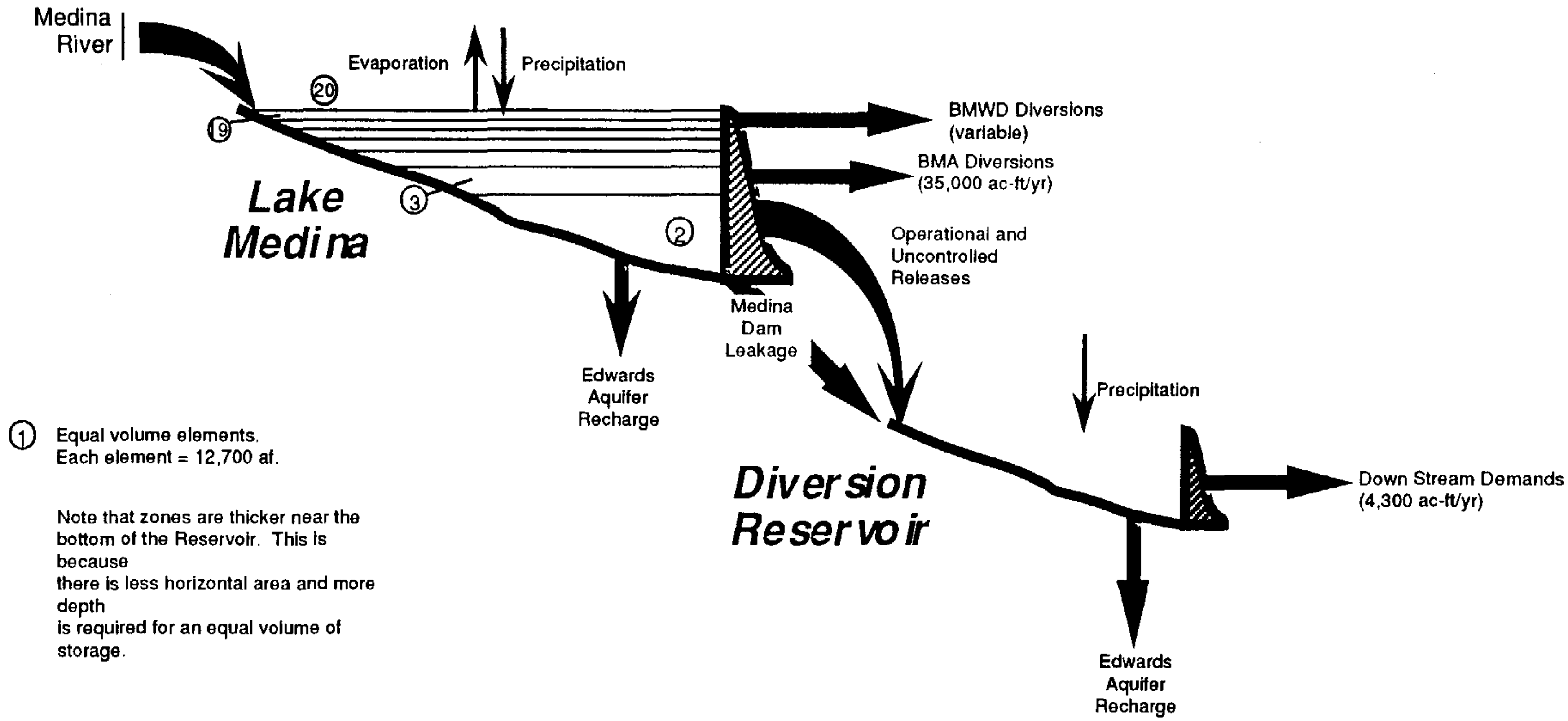


Figure 6-10
Schematic of Lake Medina and Diversion Reservoir System Simulation Case III

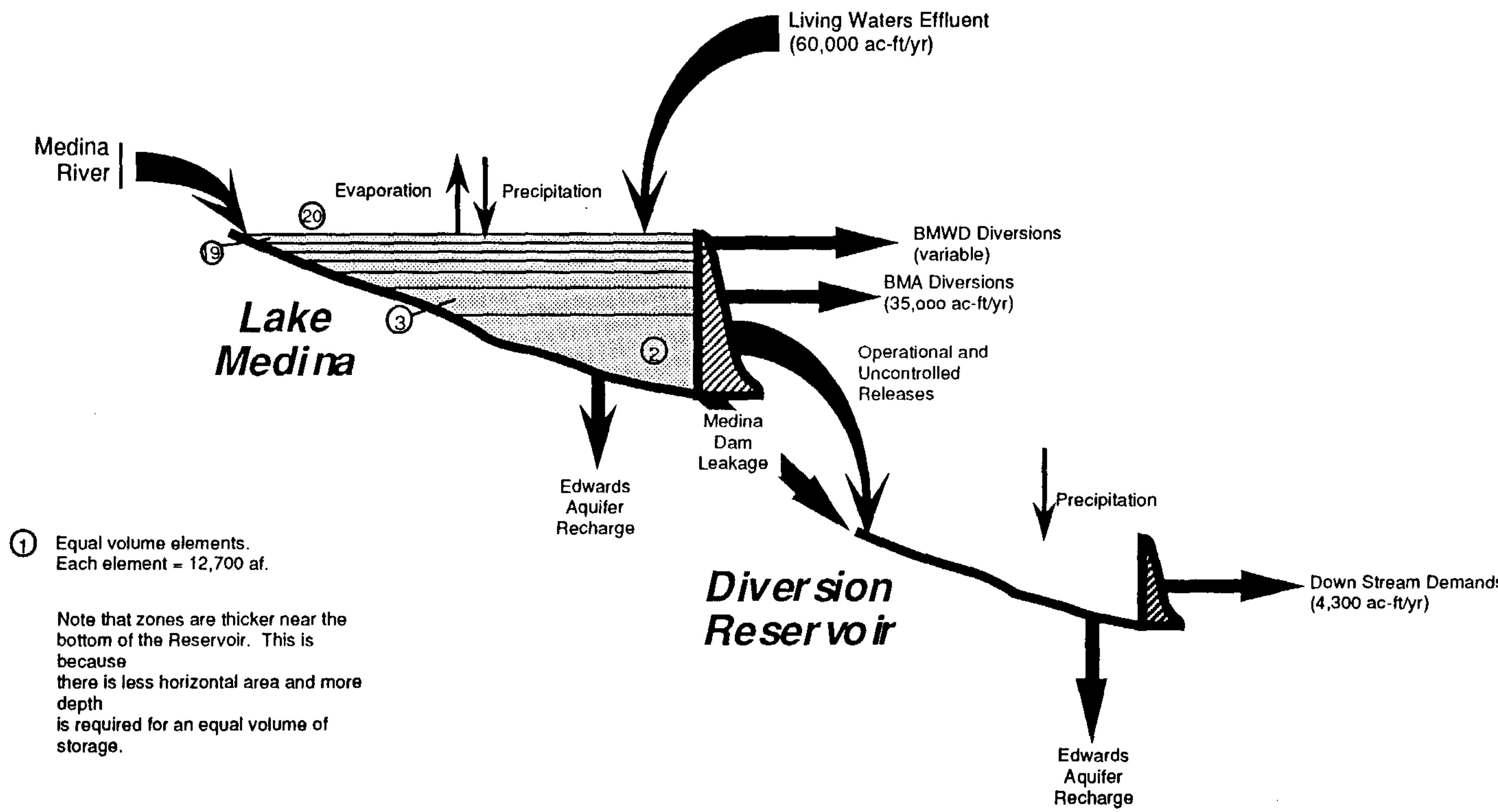
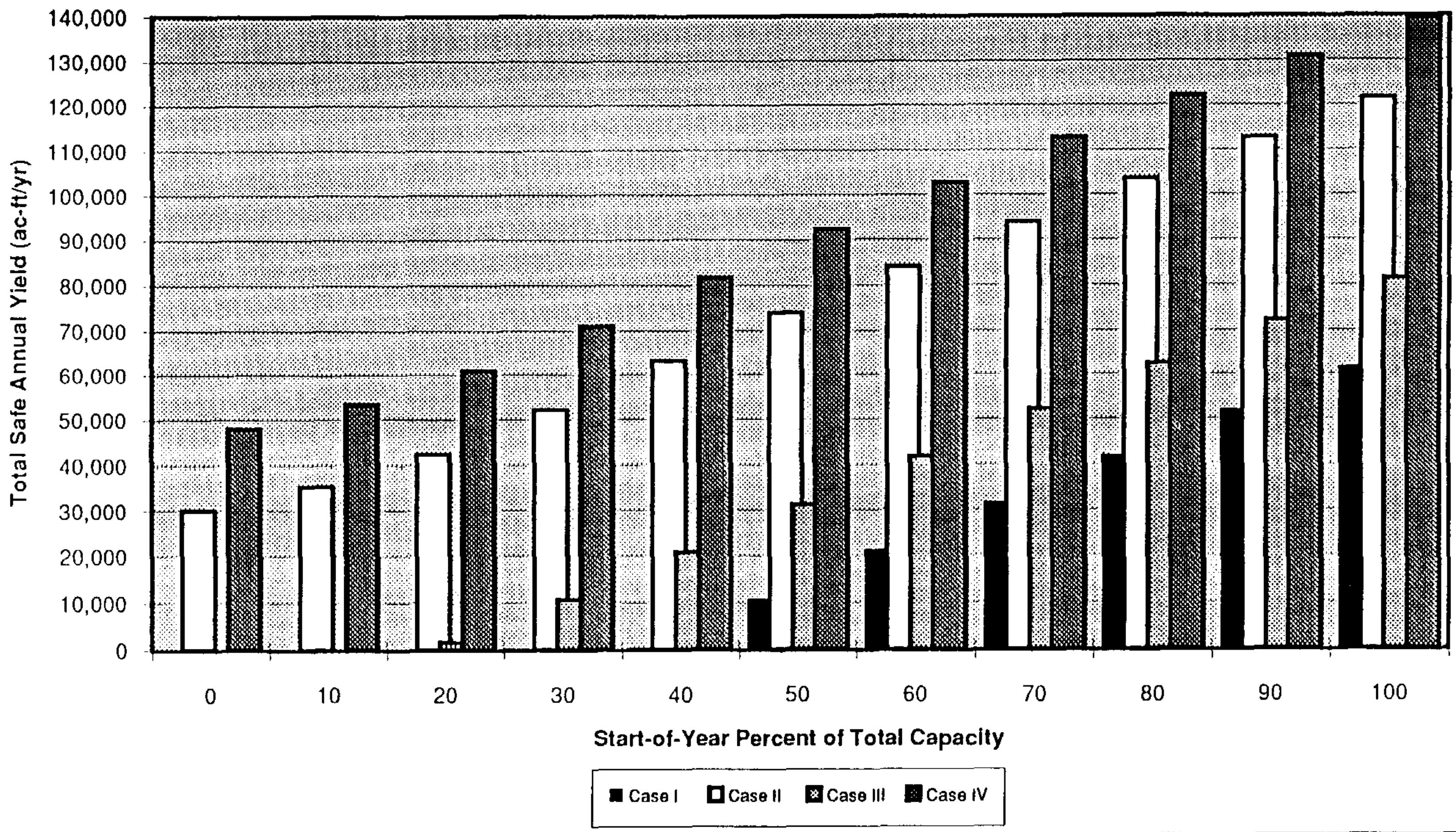


Figure 6-11
Schematic of Lake Medina and Diversion Reservoir System Simulation Case IV

Figure 6-12
Total Safe Yield From the Lake Medina/Diversion Resevoir System
as a Function of Start-of-Year Capacity
Simulation Cases I - IV



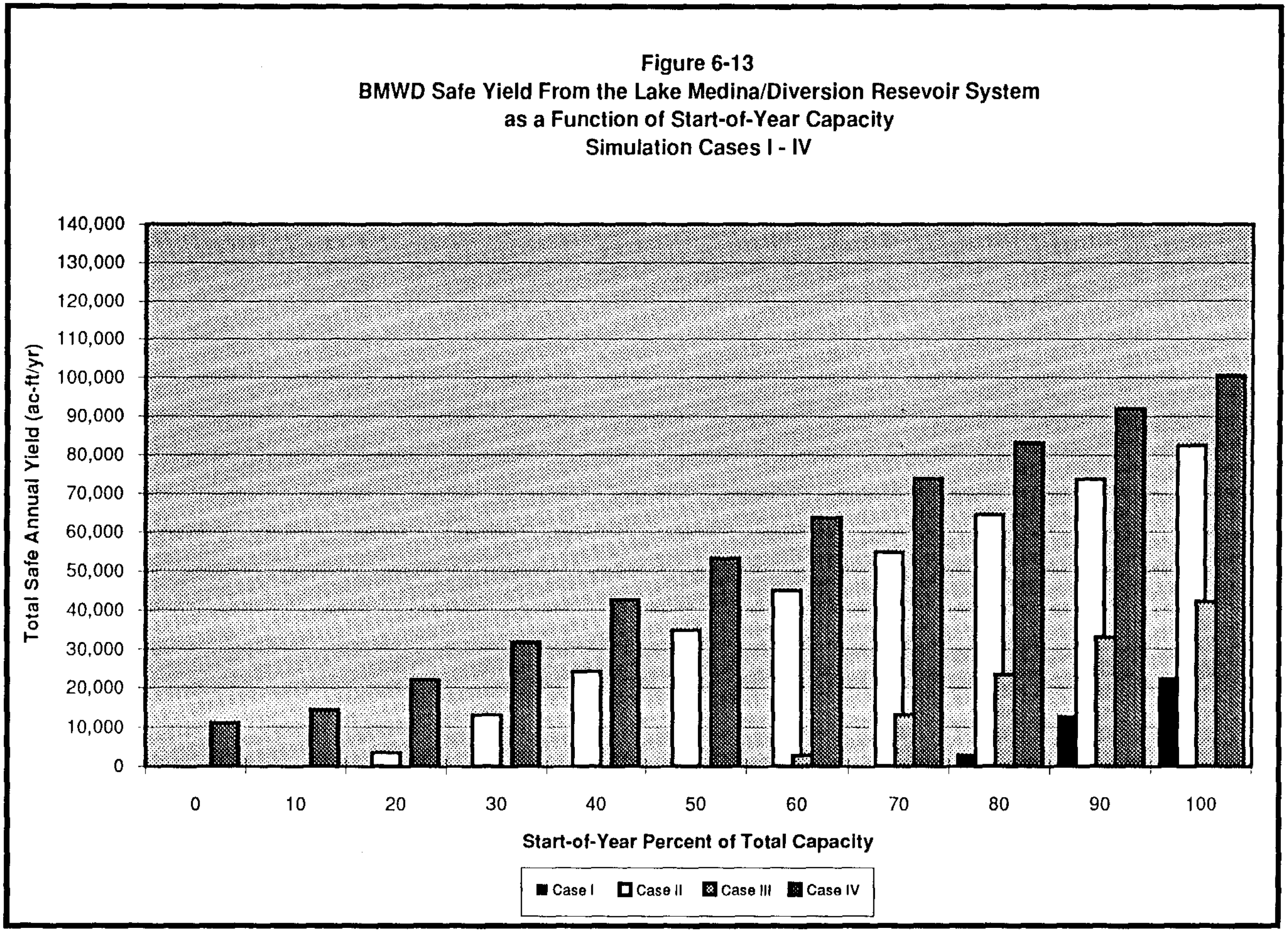


Figure 6-13
BMWD Safe Yield From the Lake Medina/Diversion Resevoir System
as a Function of Start-of-Year Capacity
Simulation Cases I - IV
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Total Safe Annual Yield (ac-ft/yr)
0
10
20
30
40
50
60
70
80
90
100
Start-of-Year Percent of Total Capacity
Case I
Case II
Case III
Case IV

Figure 6-14
Probability of Starting Any Year At or Above a Specified Capacity and Total and BMWD Useable Annual Yields of That Capacity Simulation Case I

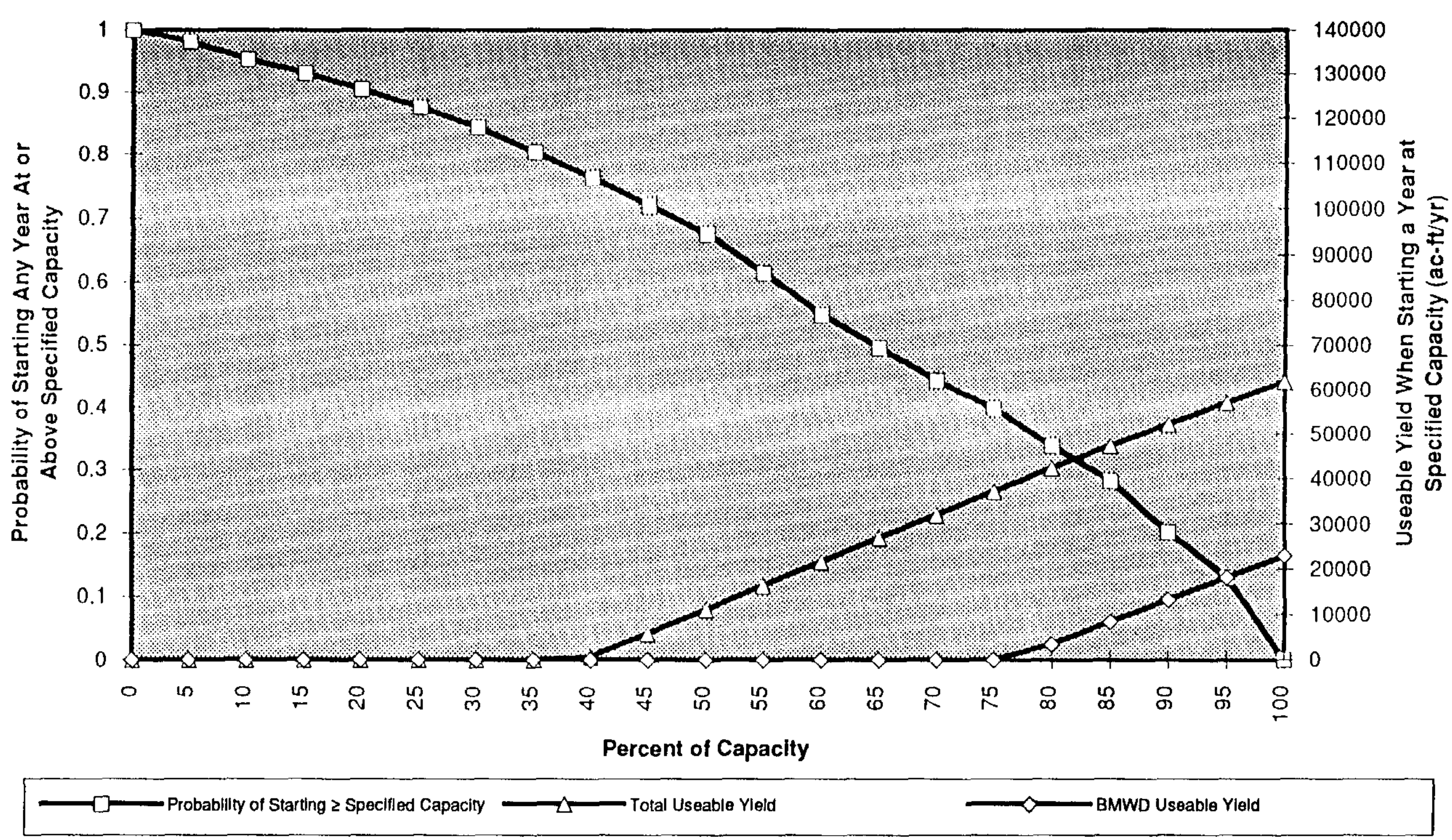
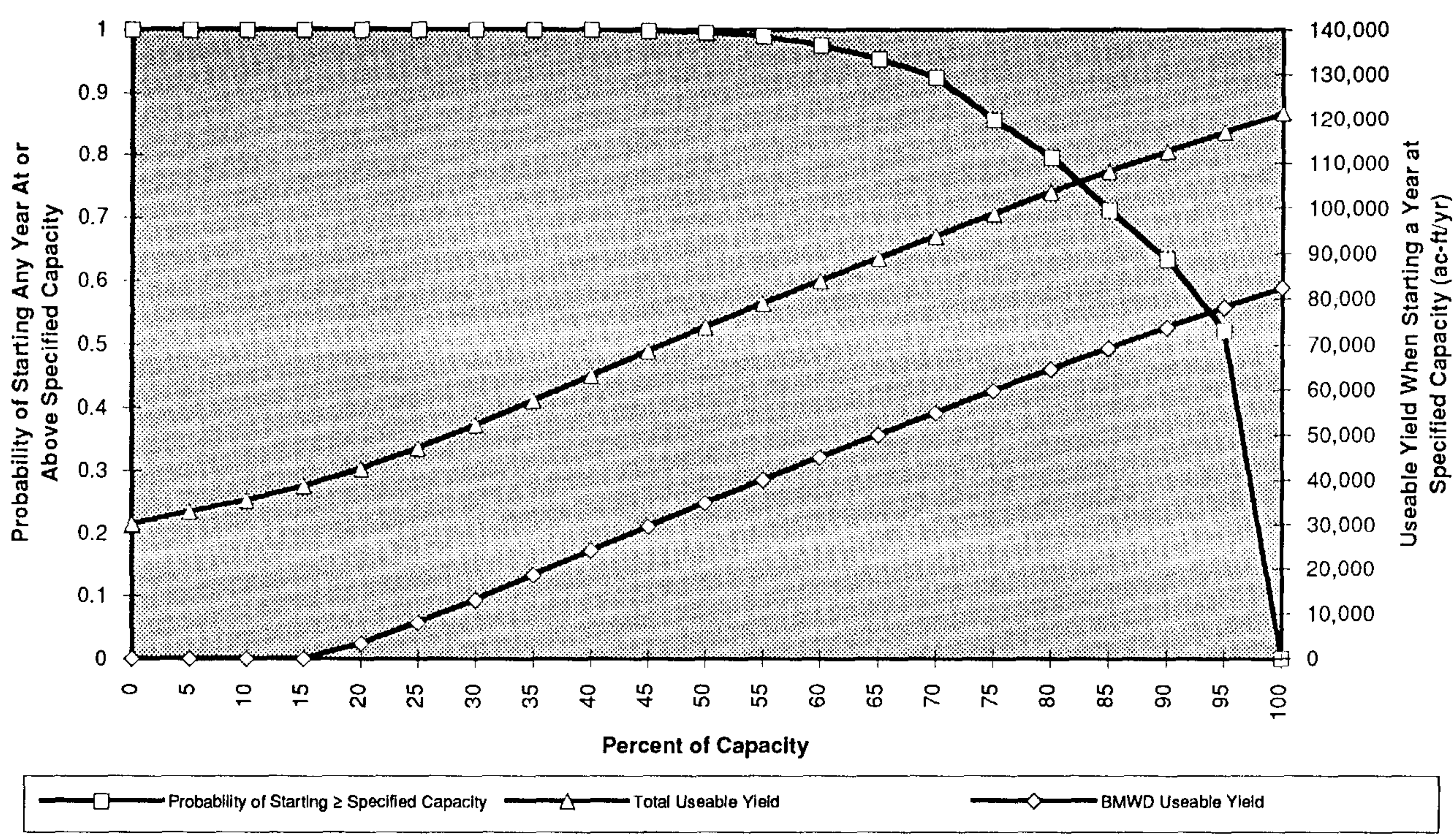


Figure 6-15
Probability of Starting Any Year At or Above a Specified Capacity and Total and BMWD Useable Annual Yields of That Capacity Simulation Case II



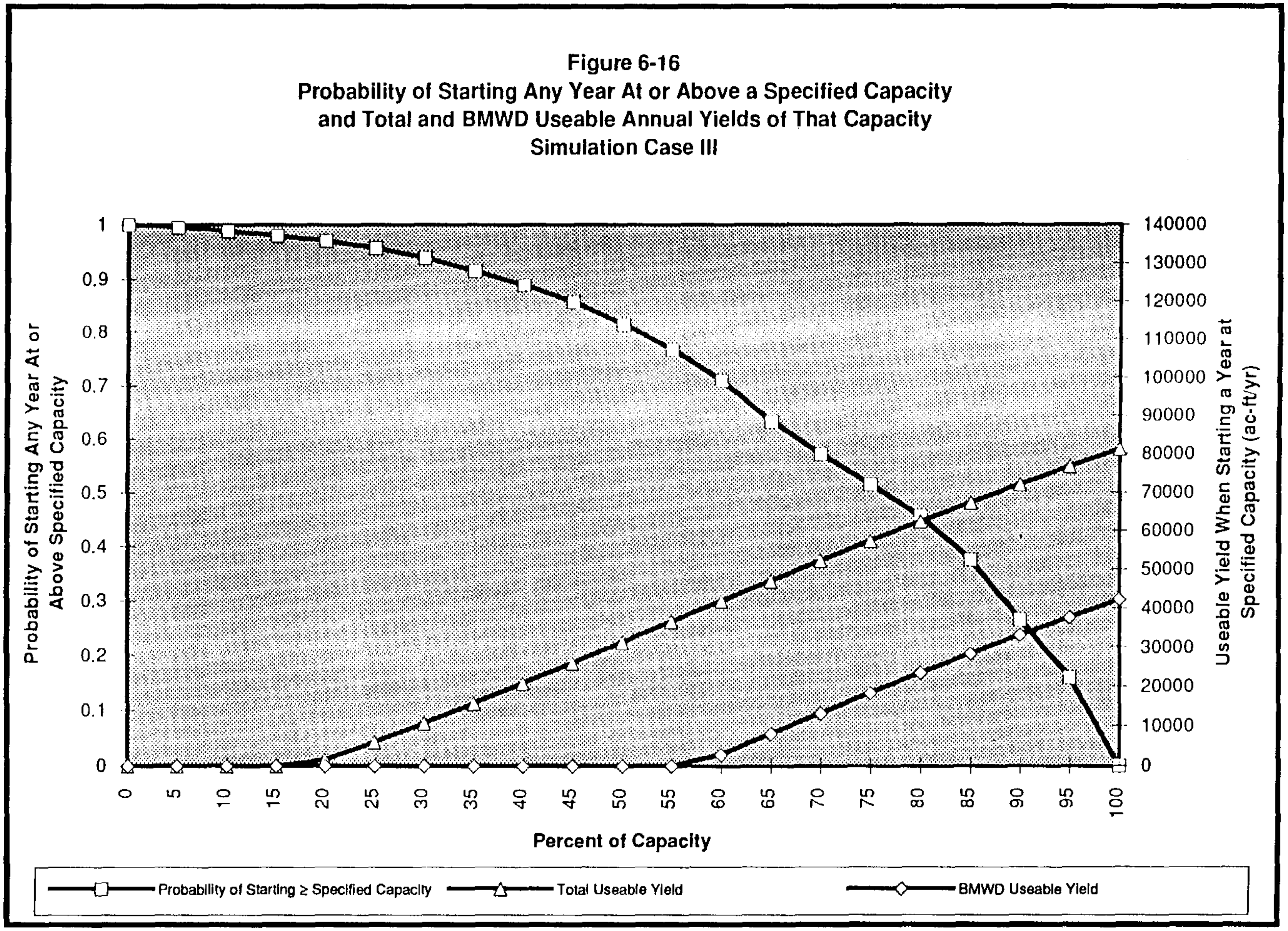


Figure 6-16
Probability of Starting Any Year At or Above a Specified Capacity
and Total and BMWD Useable Annual Yields of That Capacity
Simulation Case III
Probability of Starting Any Year At or Above Specified Capacity
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Useable Yield When Starting a Year at Specified Capacity (ac-ft/yr)
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
110000
120000
130000
140000
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Percent of Capacity
Probability of Starting ≥ Specified Capacity
Total Useable Yield
BMWD Useable Yield

Figure 6-17
Probability of Starting Any Year At or Above a Specified Capacity and Total and BMWD Useable Annual Yields of That Capacity
Simulation Case IV

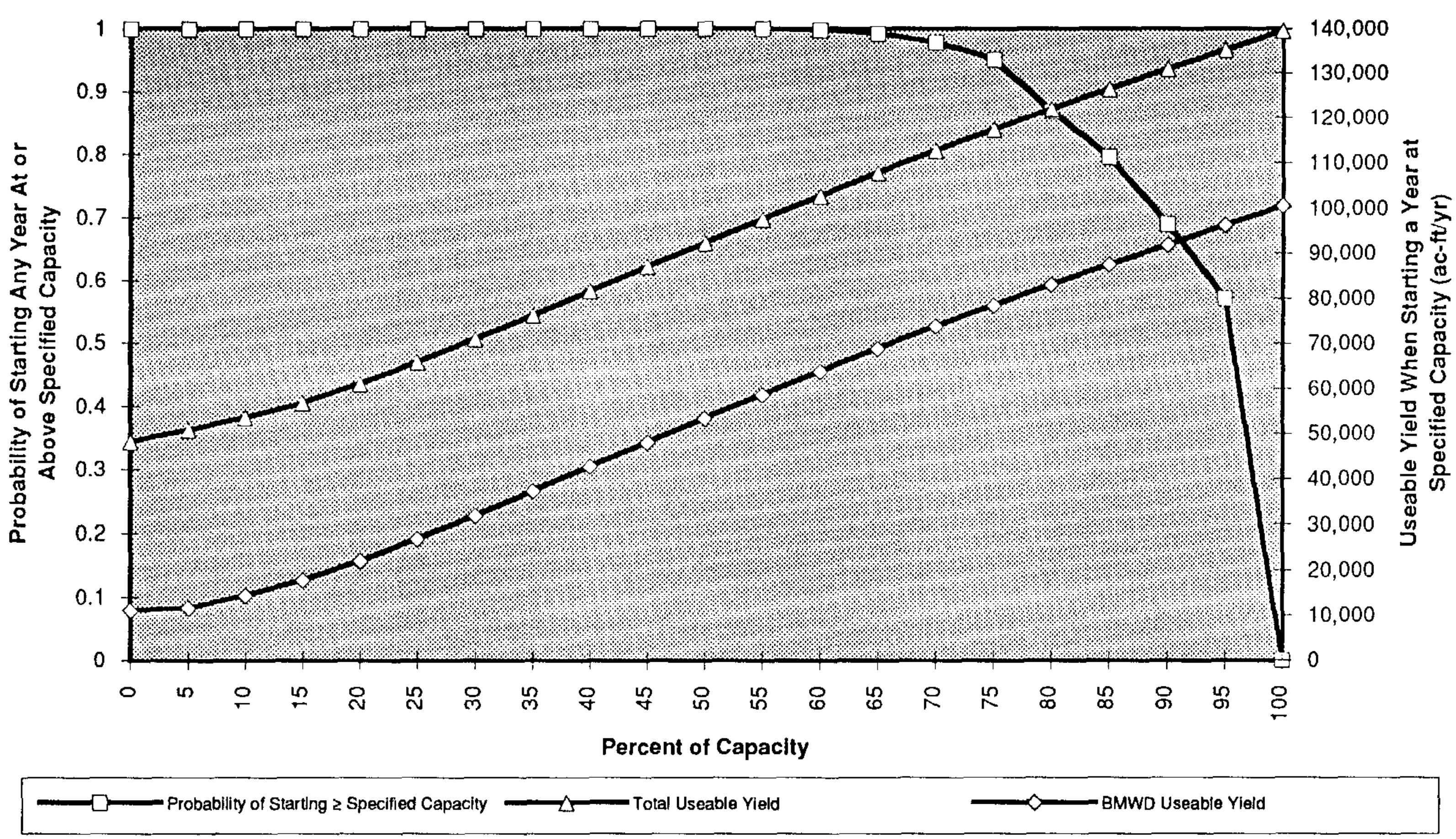
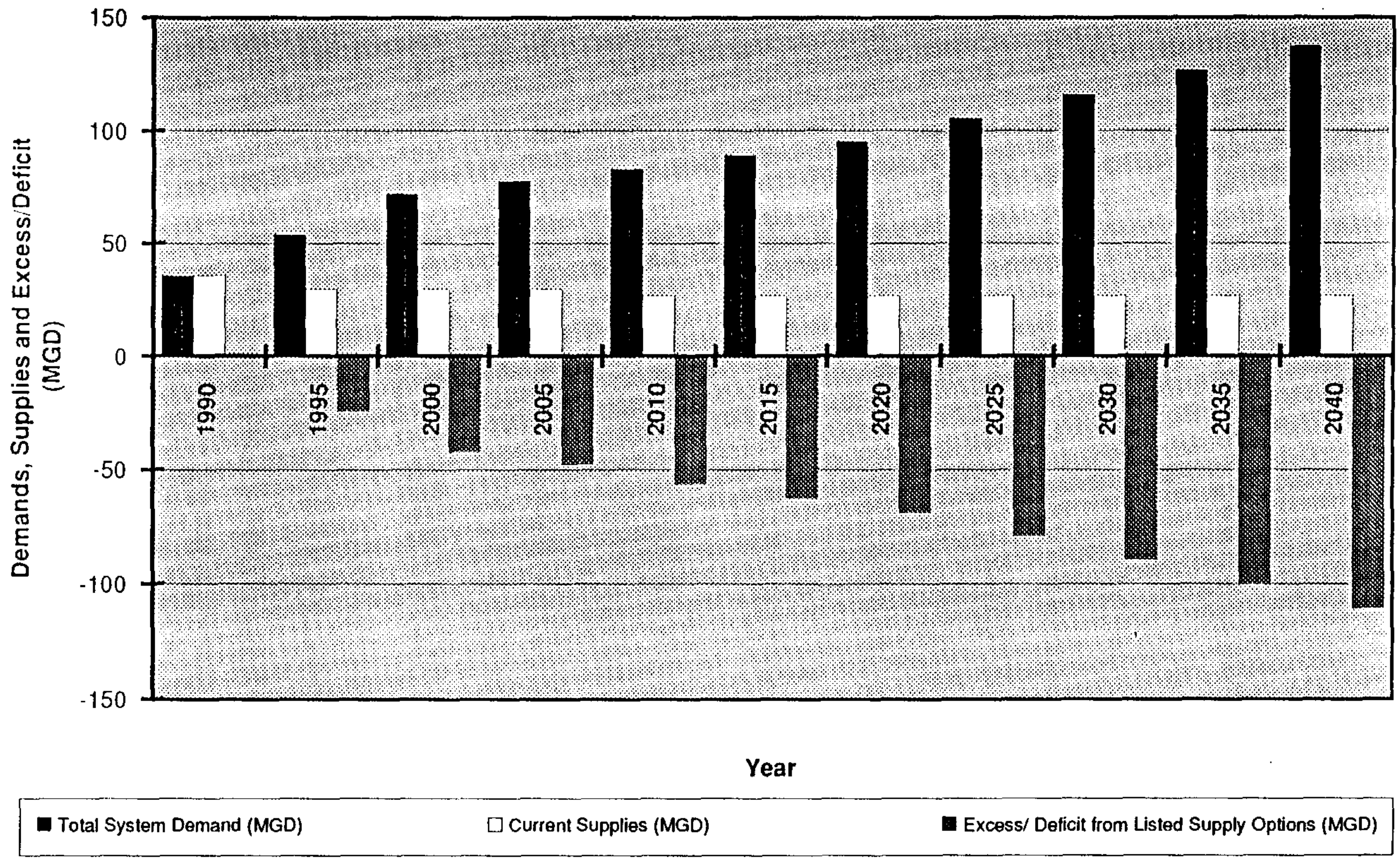


Figure 6-18
BMWD Services Area Demands, Current Supplies and Excess/Deficit



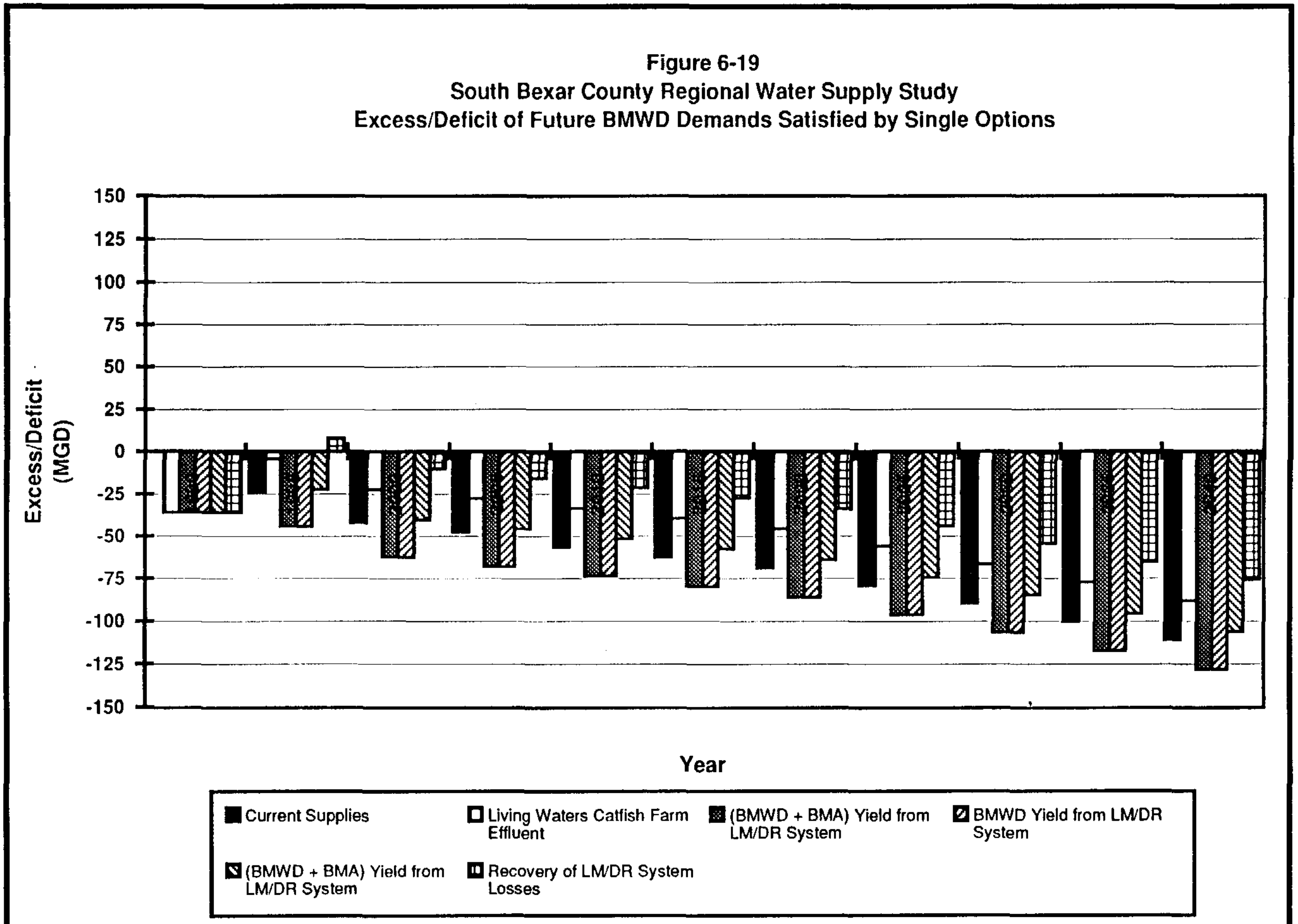


Figure 6-19
South Bexar County Regional Water Supply Study
Excess/Deficit of Future BMWD Demands Satisfied by Single Options
Excess/Deficit (MGD)
150
125
100
75
50
25
0
-25
-50
-75
-100
-125
-150
Year
Current Supplies
Living Waters Catfish Farm Effluent
(BMWD + BMA) Yield from LM/DR System
BMWD Yield from LM/DR System
(BMWD + BMA) Yield from LM/DR System
Recovery of LM/DR System Losses

Figure 6-20
South Bexar County Regional Water Supply Study
Excess/Deficit of Future BMWD Demands Satisfied by Current Supplies
Plus One Other Option

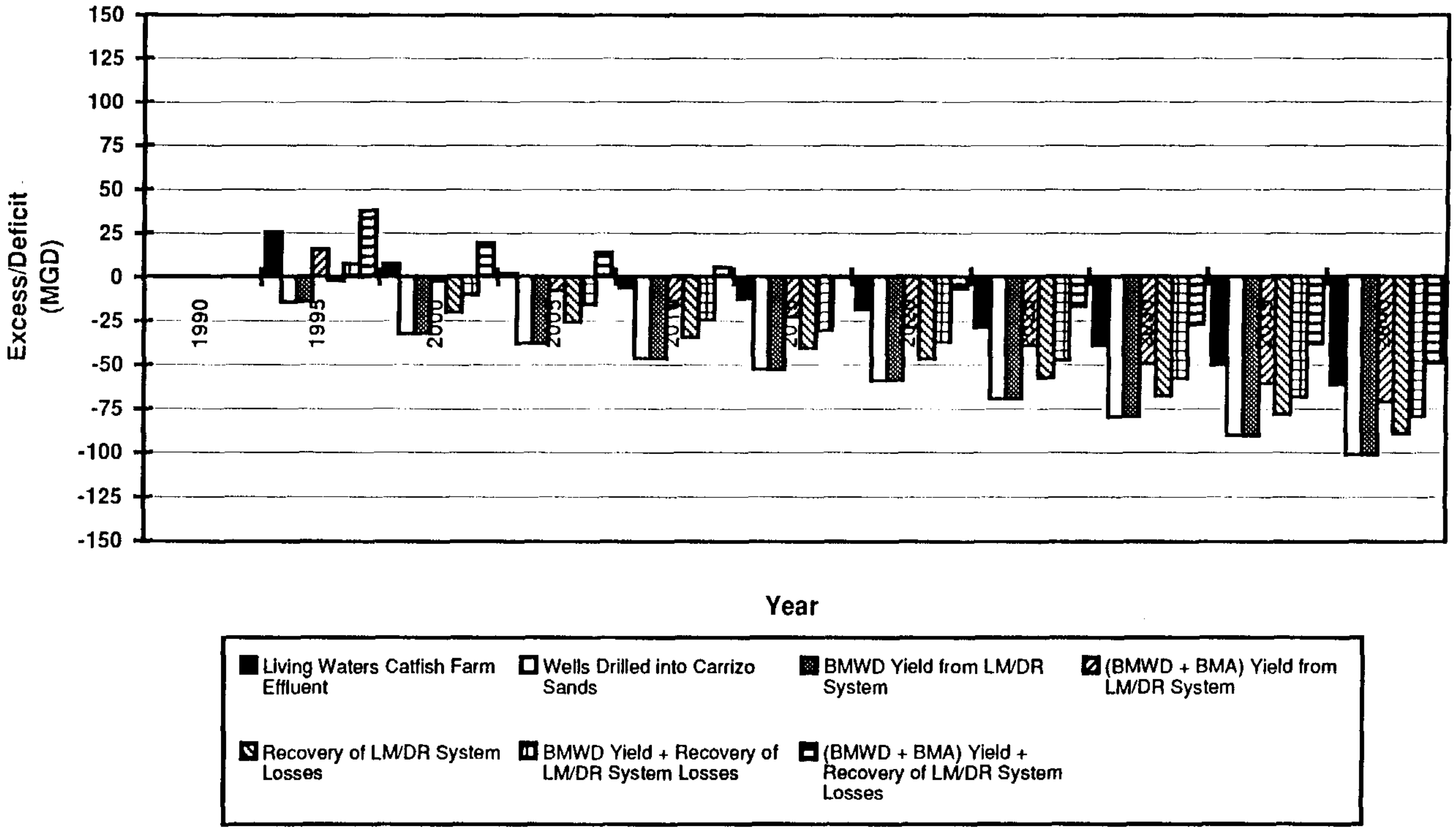


Figure 6-21
South Bexar County Regional Water Supply Study
Excess/Deficit of Future BMWD Demands Satisfied by Current Supplies,
Wells Drilled into the Carrizo Sands Plus One Other Option
(Assume All Options Developed Simultaneously)

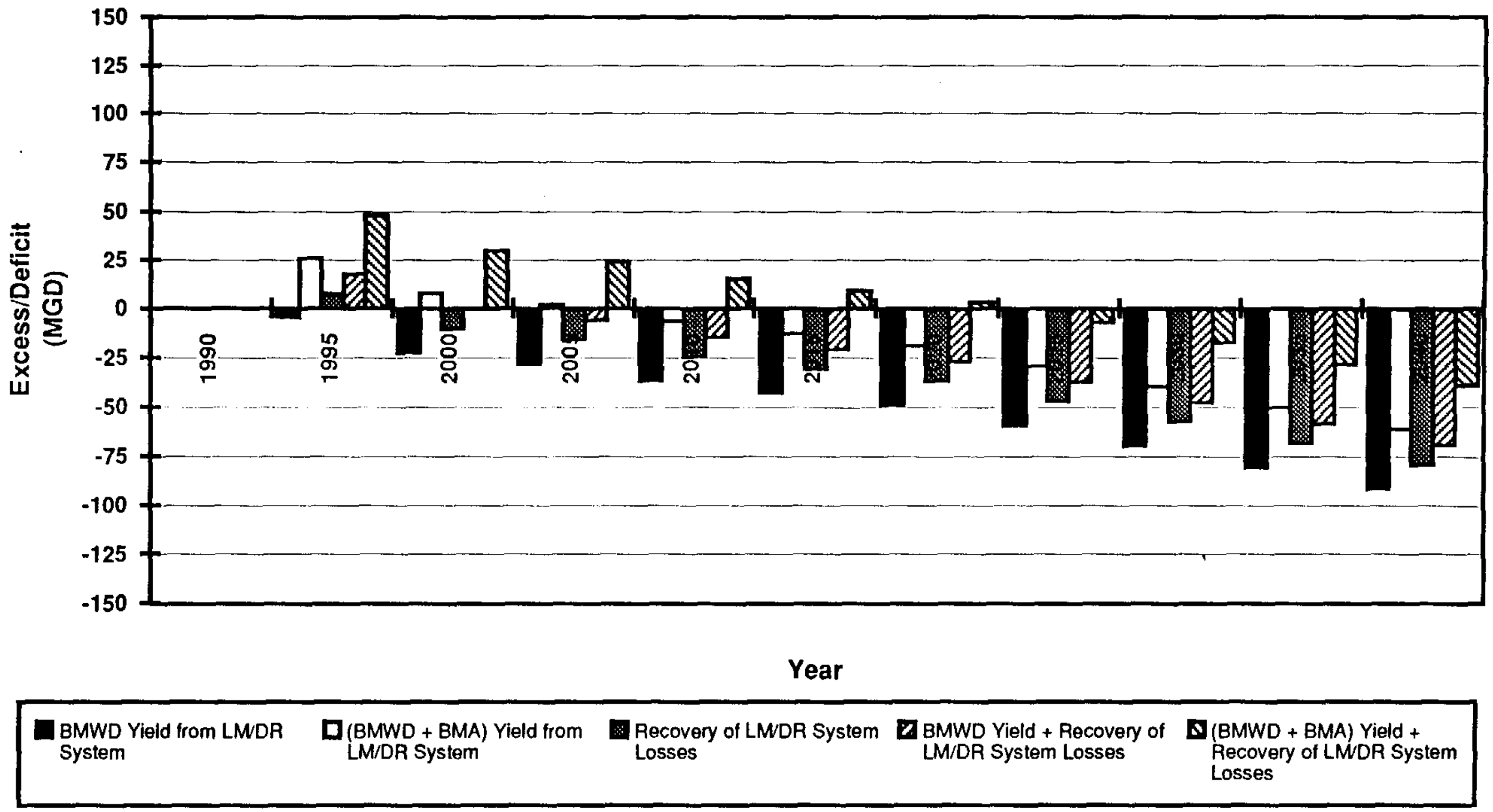


Figure 6-22
South Bexar County Regional Water Supply Study
Excess/Deficit of Future BMWD Demands Satisfied by Current Supplies, Living Waters Catfish Farm Effluent Plus One Other Option
(Assume All Options Developed Simultaneously)

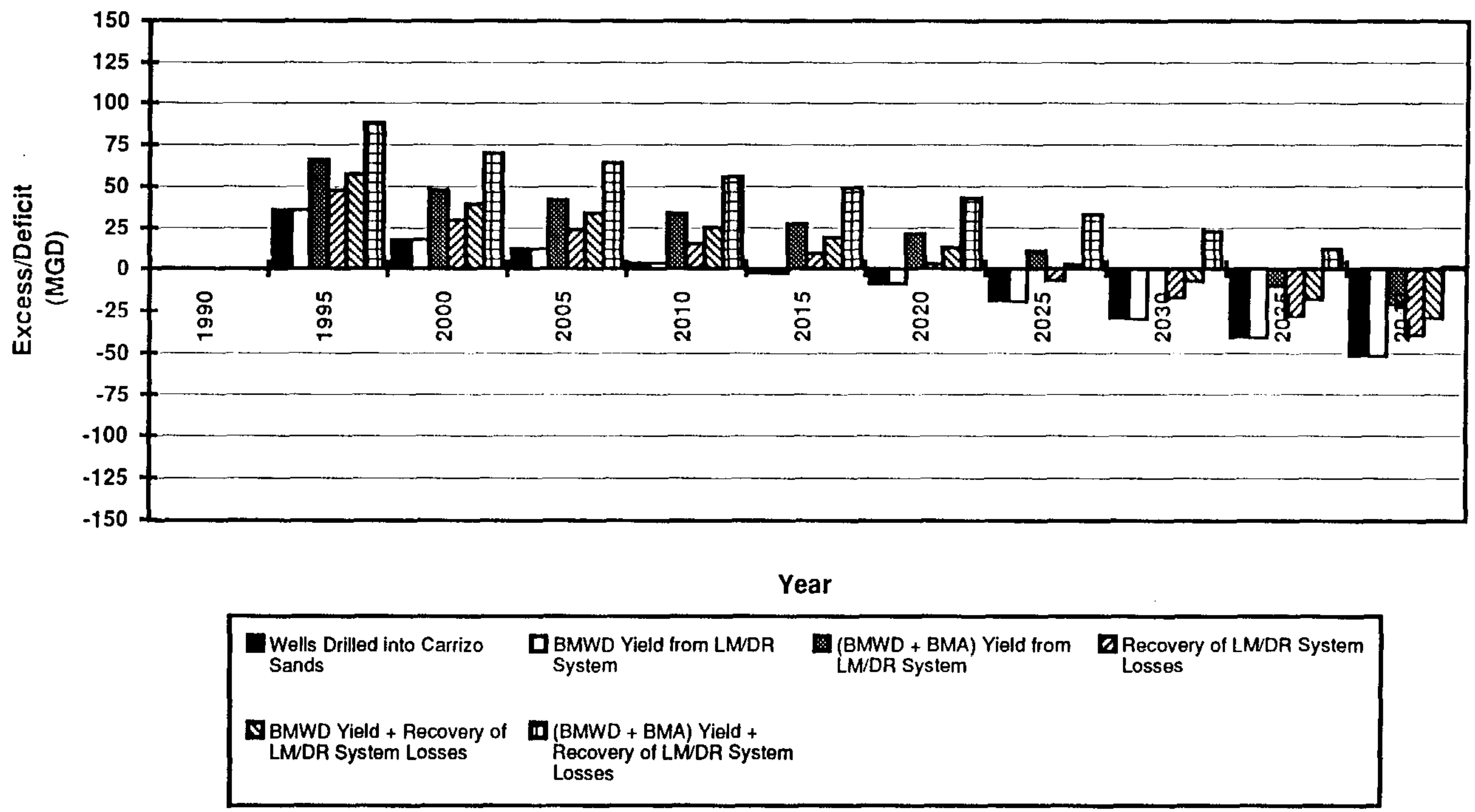


Figure 6-23
South Bexar County Regional Water Supply Study
Future BMWD Development Scenario Combinations
Plus Year Option Combination Supplies are Sufficent to Meet Projected Demand

Future Development Scenario	Year Option Combination Supplies Sufficient to Meet Projected Demand	Current Supplies	Living Waters Catfish Farm Effluent	Wells Drilled into Carizo Sands	(BMWD + BMA) Yield + Recovery of LM/DR System Losses	BMWD Yield from LM/DR System	(BMWD + BMA) Yield from LM/DR System	Recovery of LM/DR System Losses	BMWD Yield + Recovery of LM/DR System Losses
1	1990	X							
2	1990		X						
3	1990			X					
4	1990				X				
5	1990					X			
6	1990						X		
7	1990							X	
8	1990								X
10	2010	X	X						
11	1995	X		X					
12	1990	X			X				
13	1995	X				X			
14	2000	X					X		
15	2000	X						X	
16	2015	X							X
17	2020	X	X	X					
18	2010	X	X		X				
19	2030	X	X			X			
20	2020	X	X				X		
21	2025	X	X					X	
22	2040	X	X						X
23	1995	X		X	X				
24	2010	X		X		X			
25	2000	X		X			X		
26	2005	X		X				X	
27	2025	X		X					X

(Shaded) Indicates future BMWD Development options which will deliver adequate supplies beyond year 2015.

Figure 6-24
South Bexar County Water Supply Study
Demand Versus Phased Development Option Supplies
Development Option 1

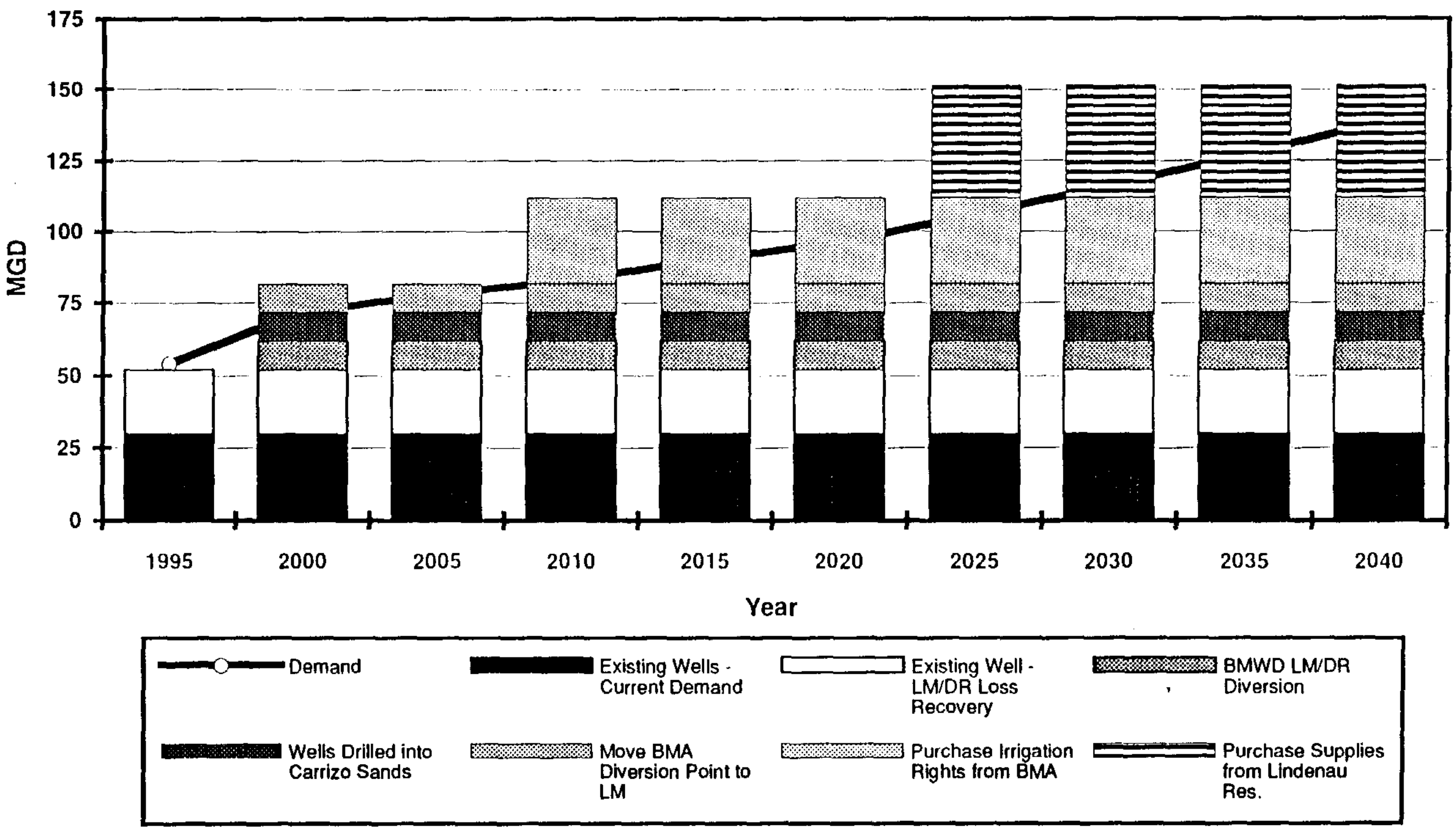


Figure 6-24
South Bexar County Water Supply Study
Demand Versus Phased Development Option Supplies
Development Option 1

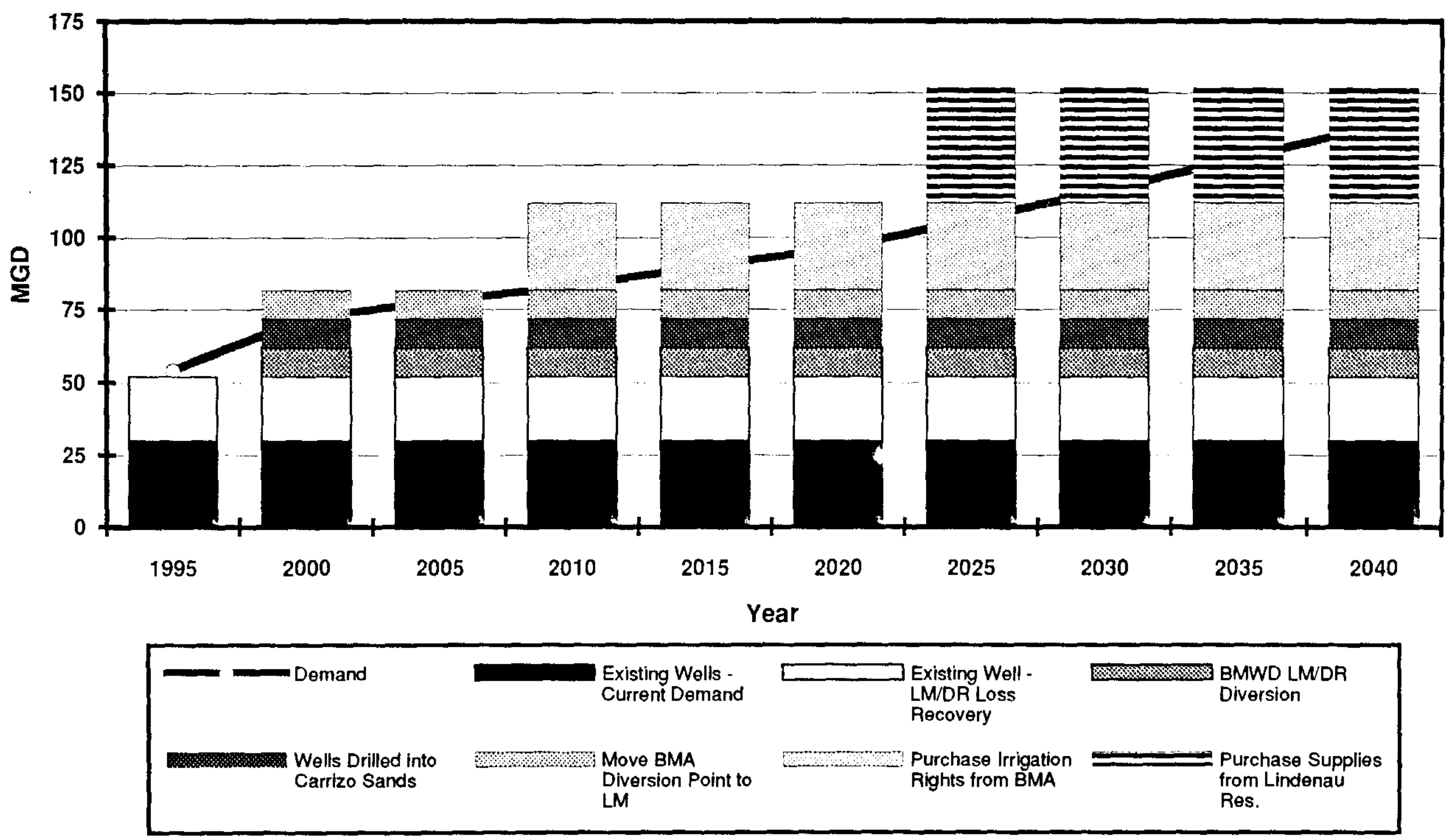


Figure 6-25
South Bexar County Water Supply Study
Demand Versus Phased Development Option Supplies
Development Option 2

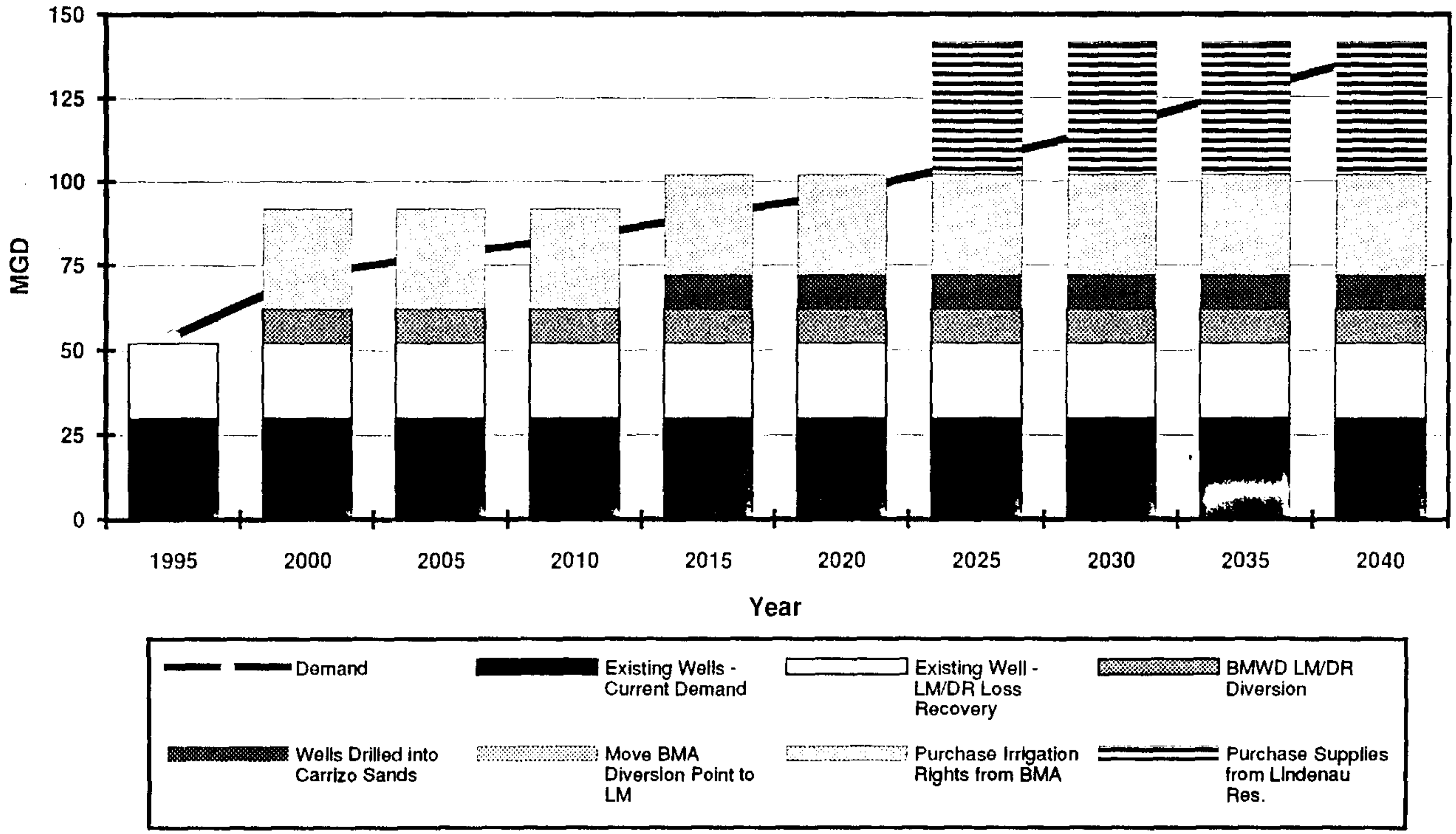


Figure 6-26
South Bexar County Water Supply Study
Demand Versus Phased Development Option Supplies
Development Option 3

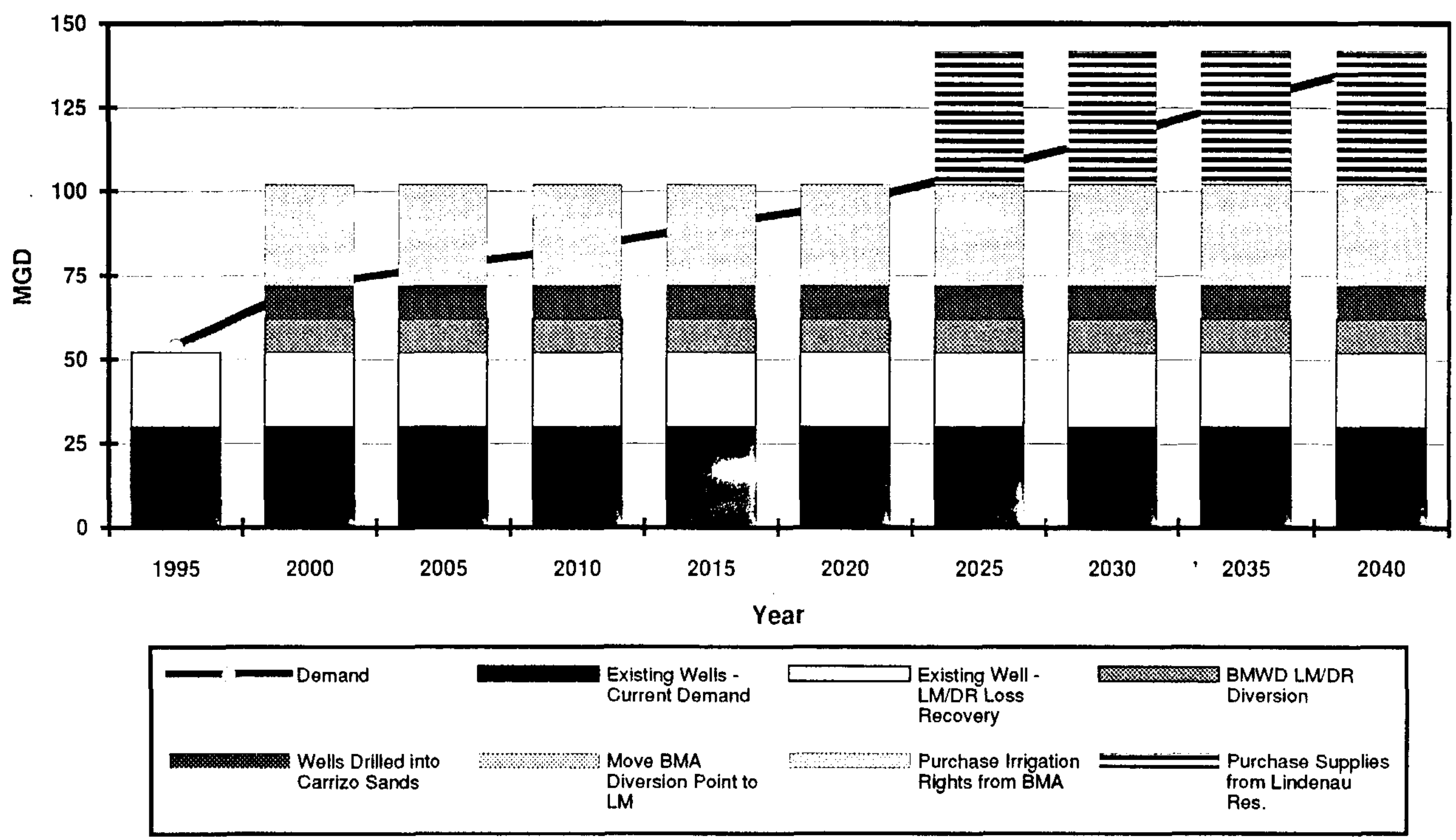
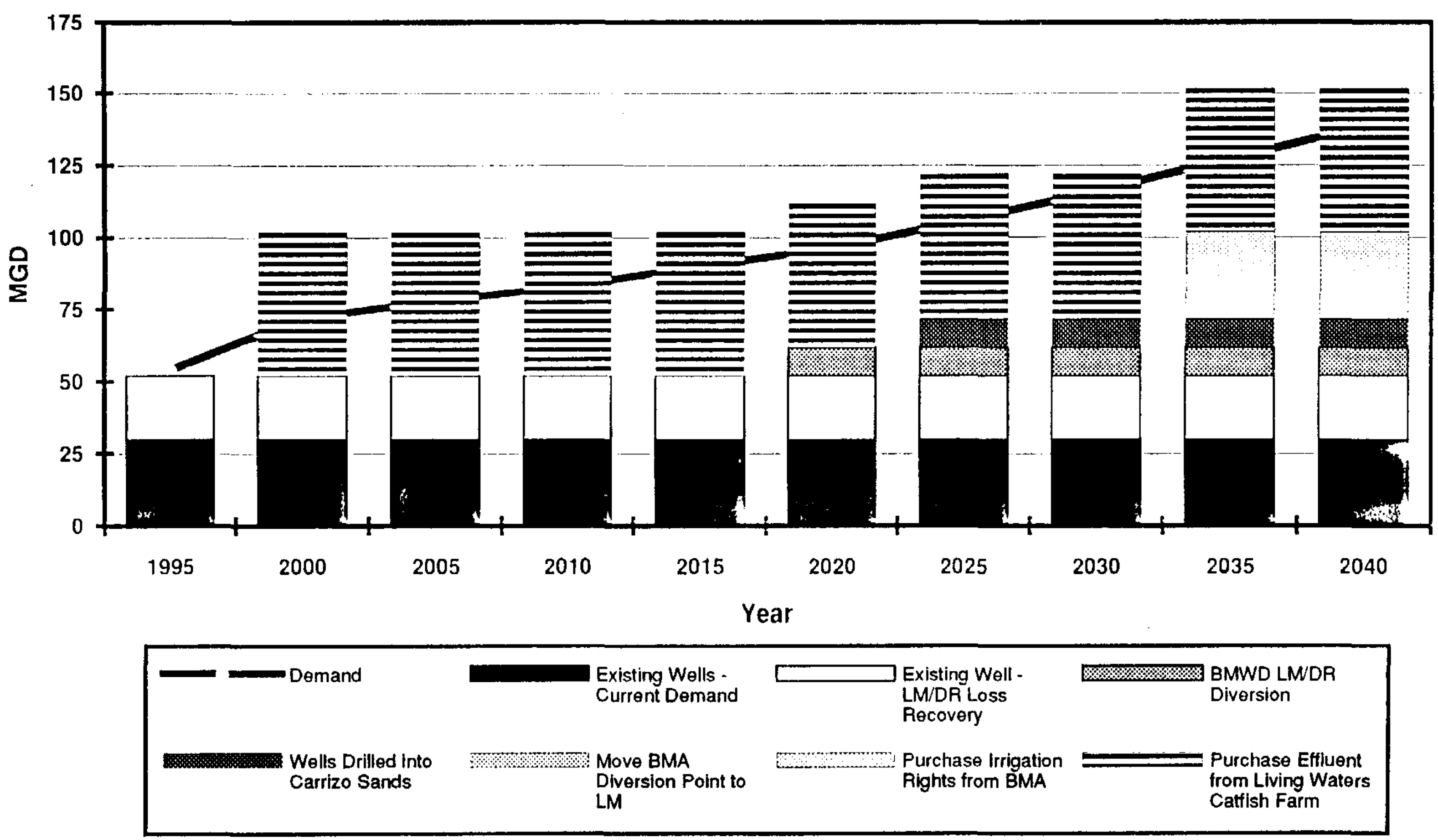


Figure 6-27
South Bexar County Water Supply Study
Demand Versus Phased Development Option Supplies
Development Option 4



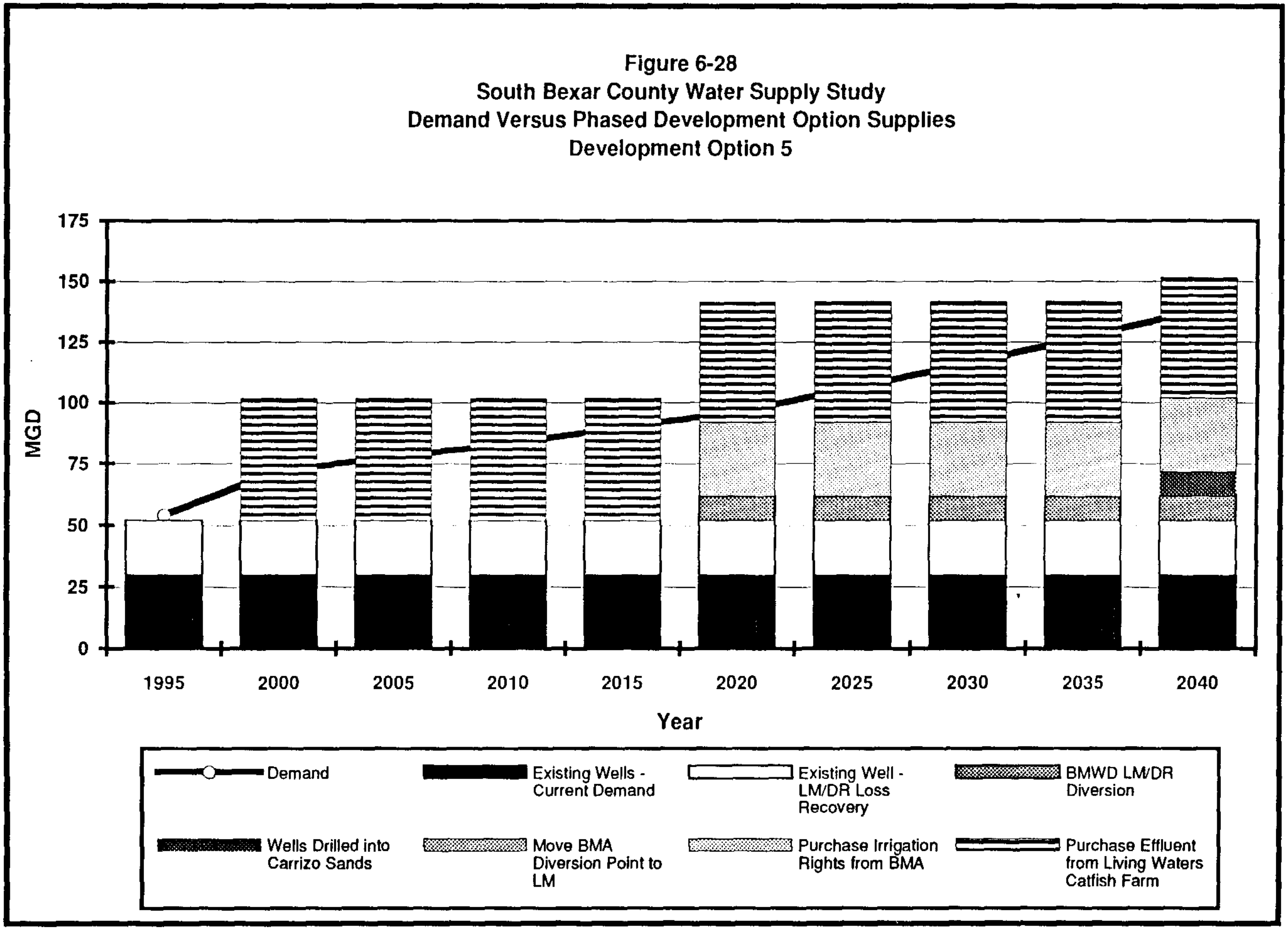
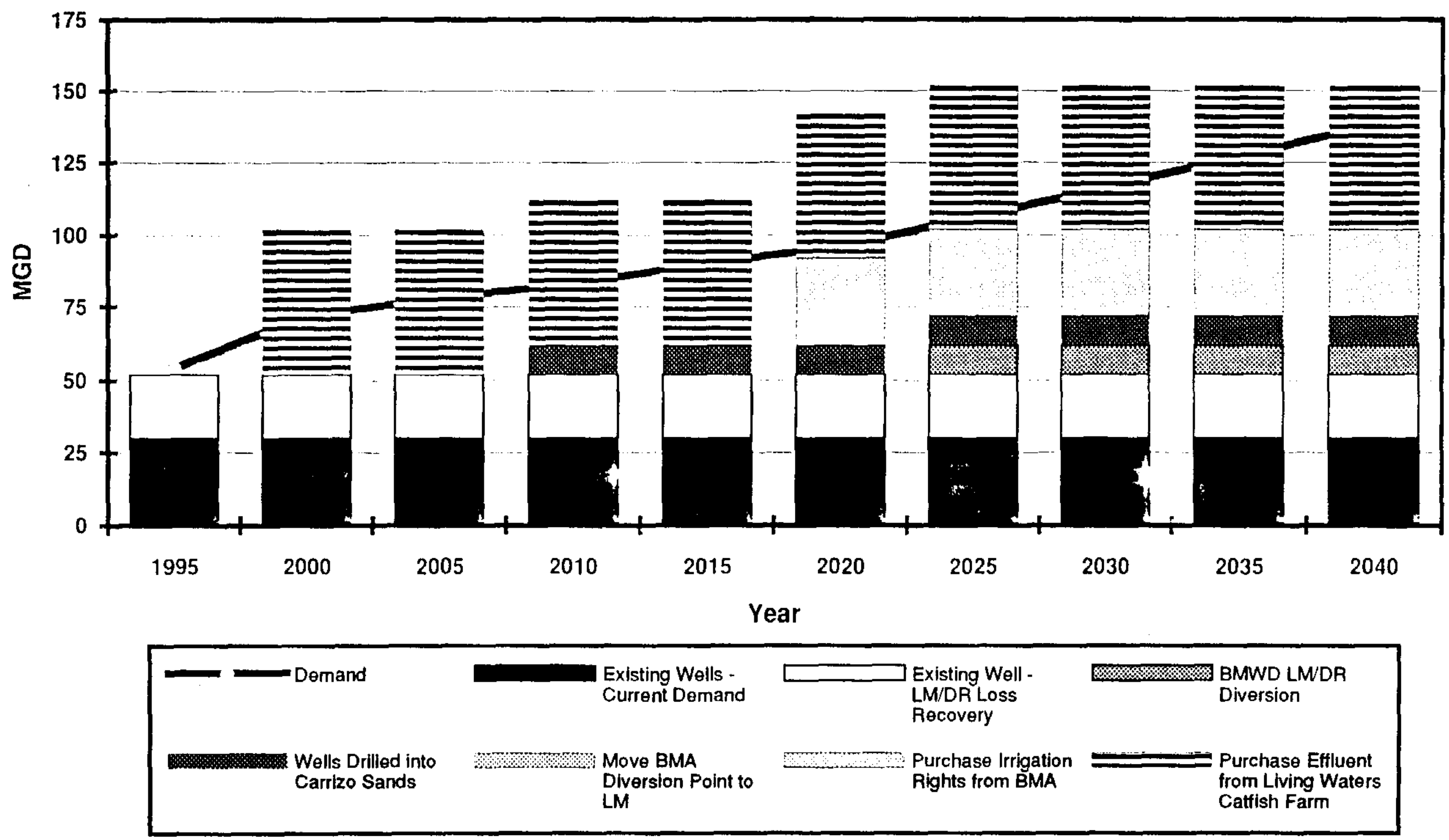


Figure 6-28
South Bexar County Water Supply Study
Demand Versus Phased Development Option Supplies
Development Option 5
175
150
125
100
75
50
25
0
MGD
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
Year
Demand
Existing Wells - Current Demand
Existing Well - LM/DR Loss Recovery
BMWD LM/DR Diversion
Wells Drilled into Carrizo Sands
Move BMA Diversion Point to LM
Purchase Irrigation Rights from BMA
Purchase Effluent from Living Waters Catfish Farm

Figure 6-29
South Bexar County Water Supply Study
Demand Versus Phased Development Option Supplies
Development Option 6



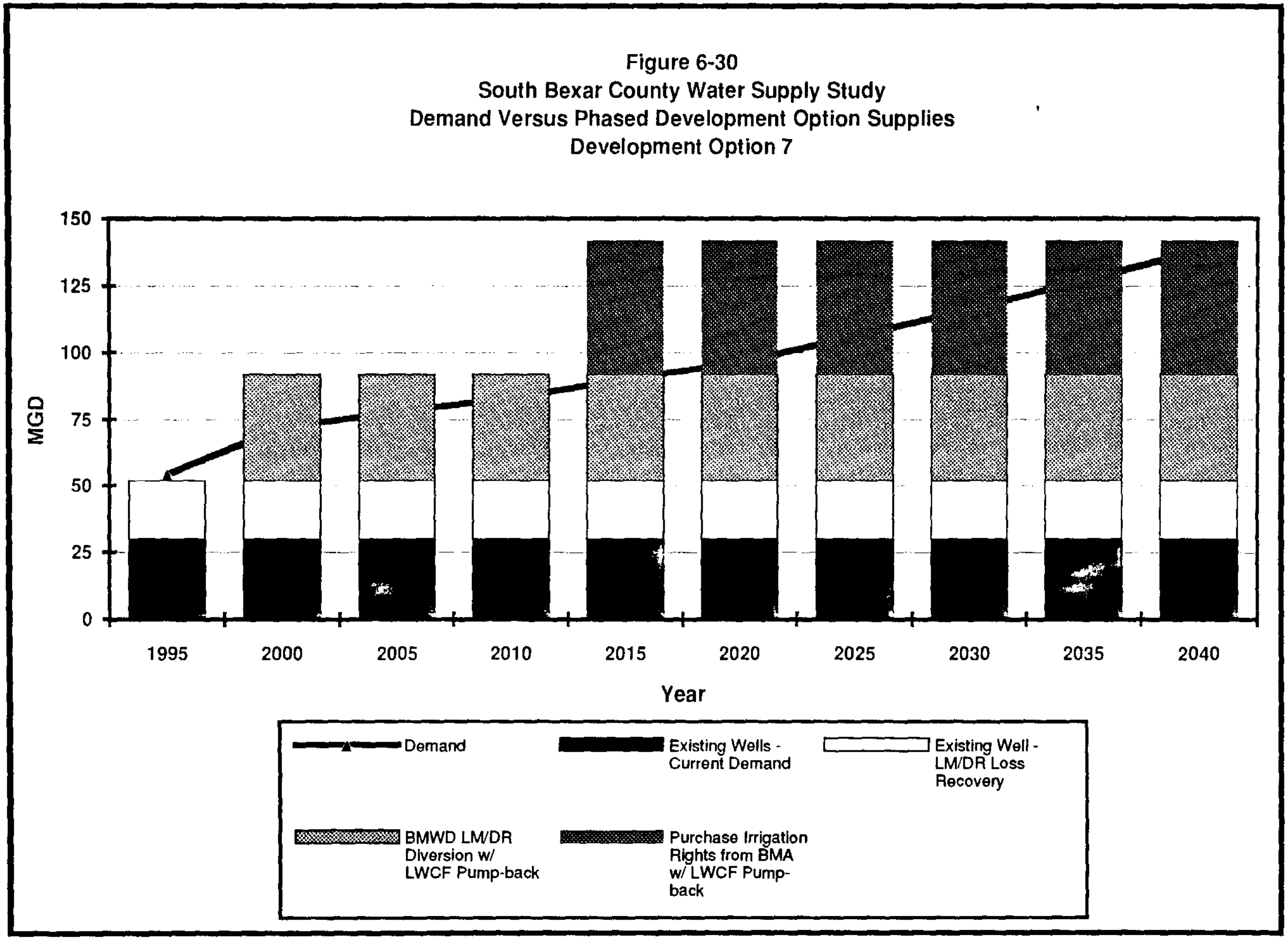
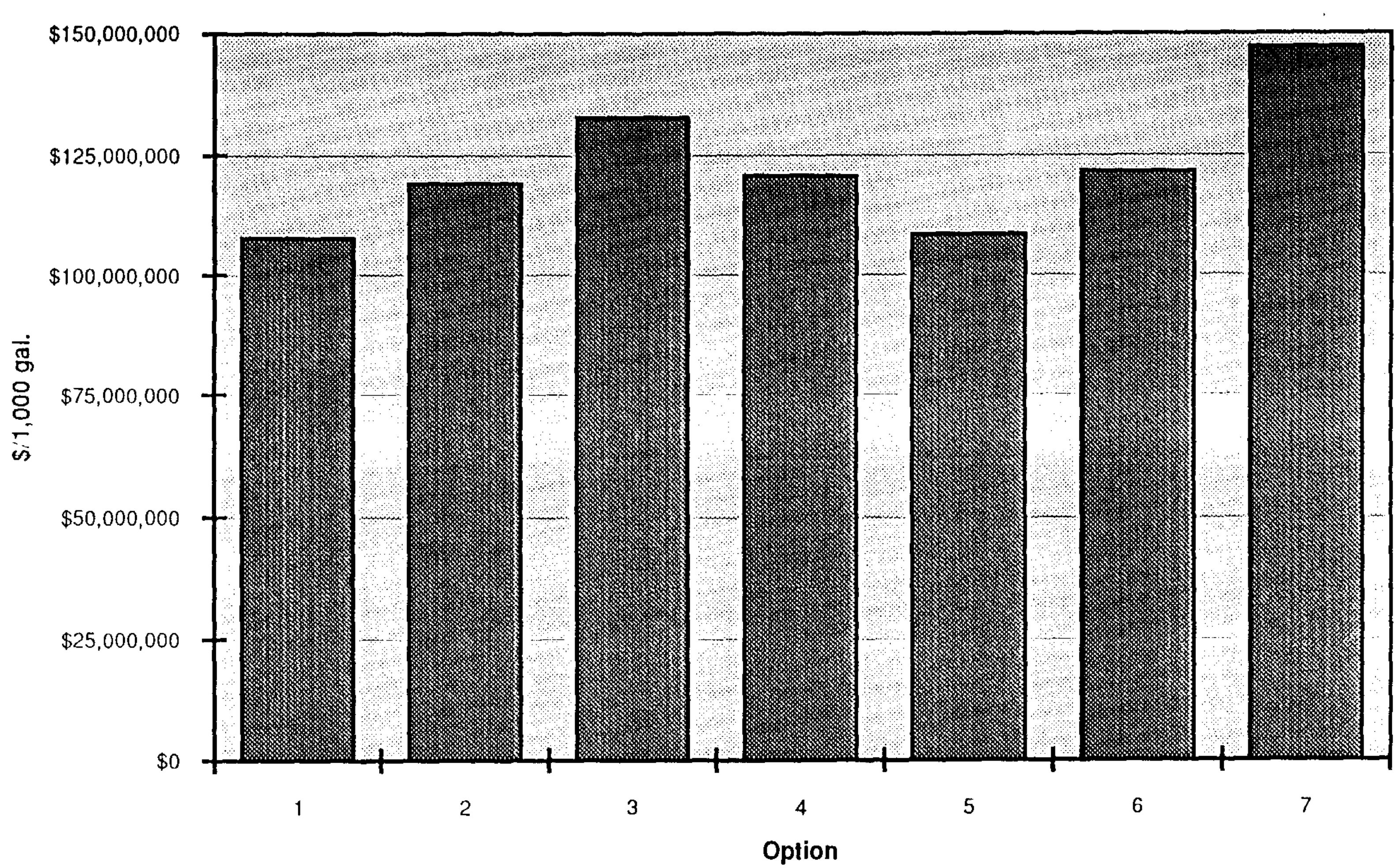


Figure 6-30
South Bexar County Water Supply Study
Demand Versus Phased Development Option Supplies
Development Option 7
150
125
100
75
50
25
0
MGD
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
Year
Demand
Existing Wells - Current Demand
Existing Well - LM/DR Loss Recovery
BMWD LM/DR Diversion w/ LWCF Pump-back
Purchase Irrigation Rights from BMA w/ LWCF Pump-back

Figure 7-1
Present Worth Cost of Each Future Development Option



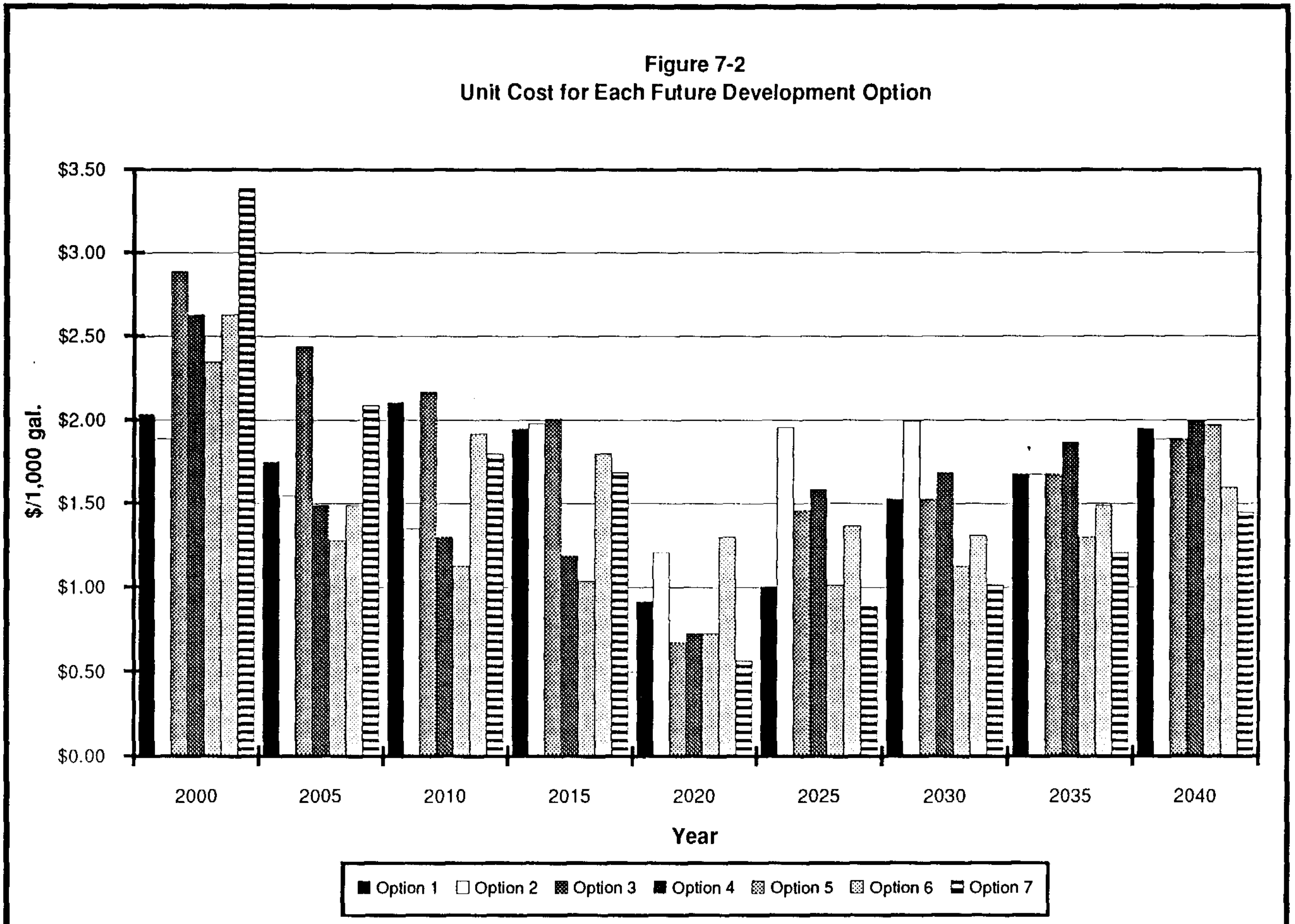


Figure 7-2
Unit Cost for Each Future Development Option
$3.50
$3.00
$2.50
$2.00
$1.50
$1.00
$0.50
$0.00
$/1,000 gal.
2000
2005
2010
2015
2020
2025
2030
2035
2040
Year
Option 1
Option 2
Option 3
Option 4
Option 5
Option 6
Option 7

)))

Figure 7-3
Average Unit Cost for Each Future Development Option

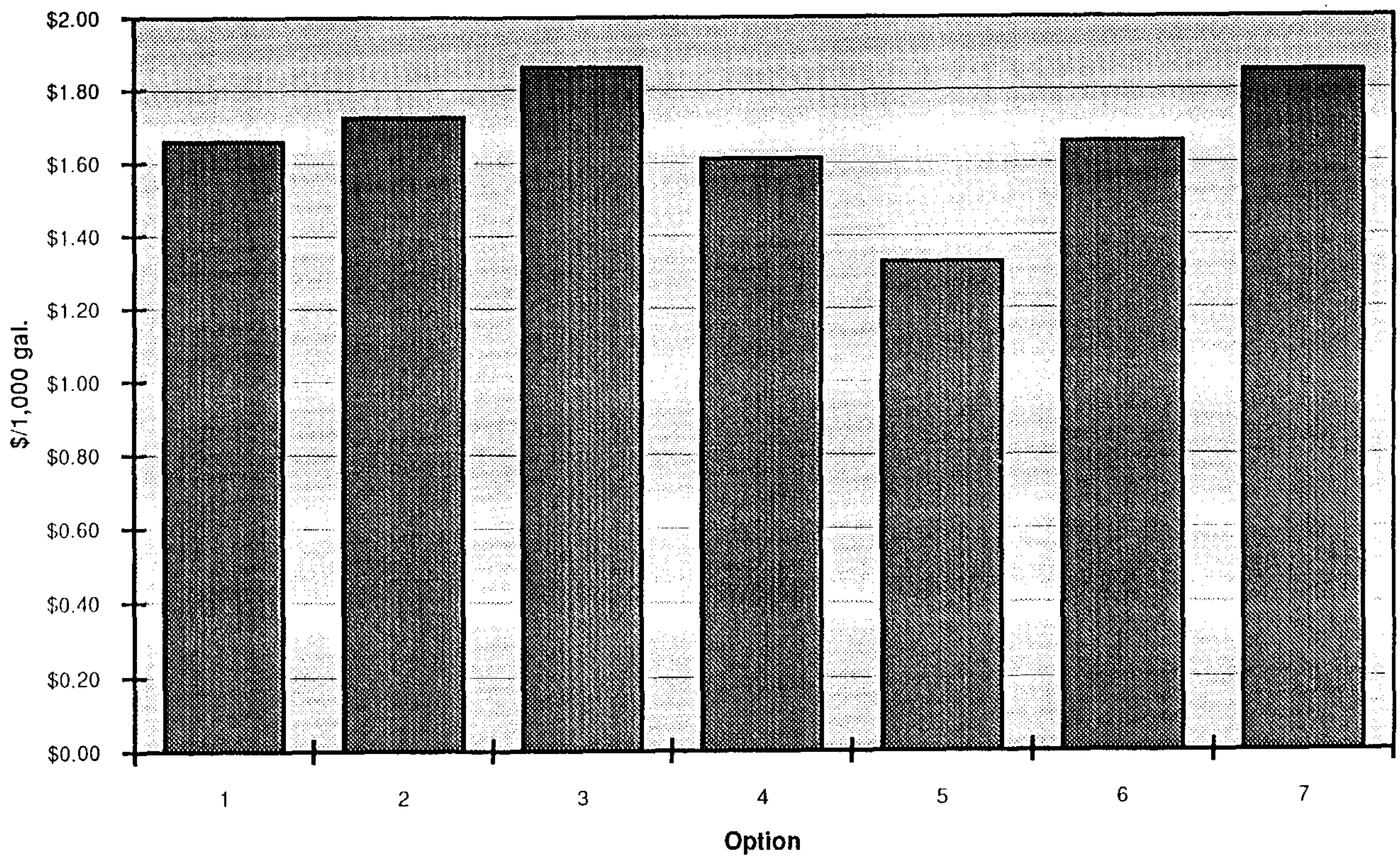


Figure 7-4
Unit Cost for Each Future Development Option

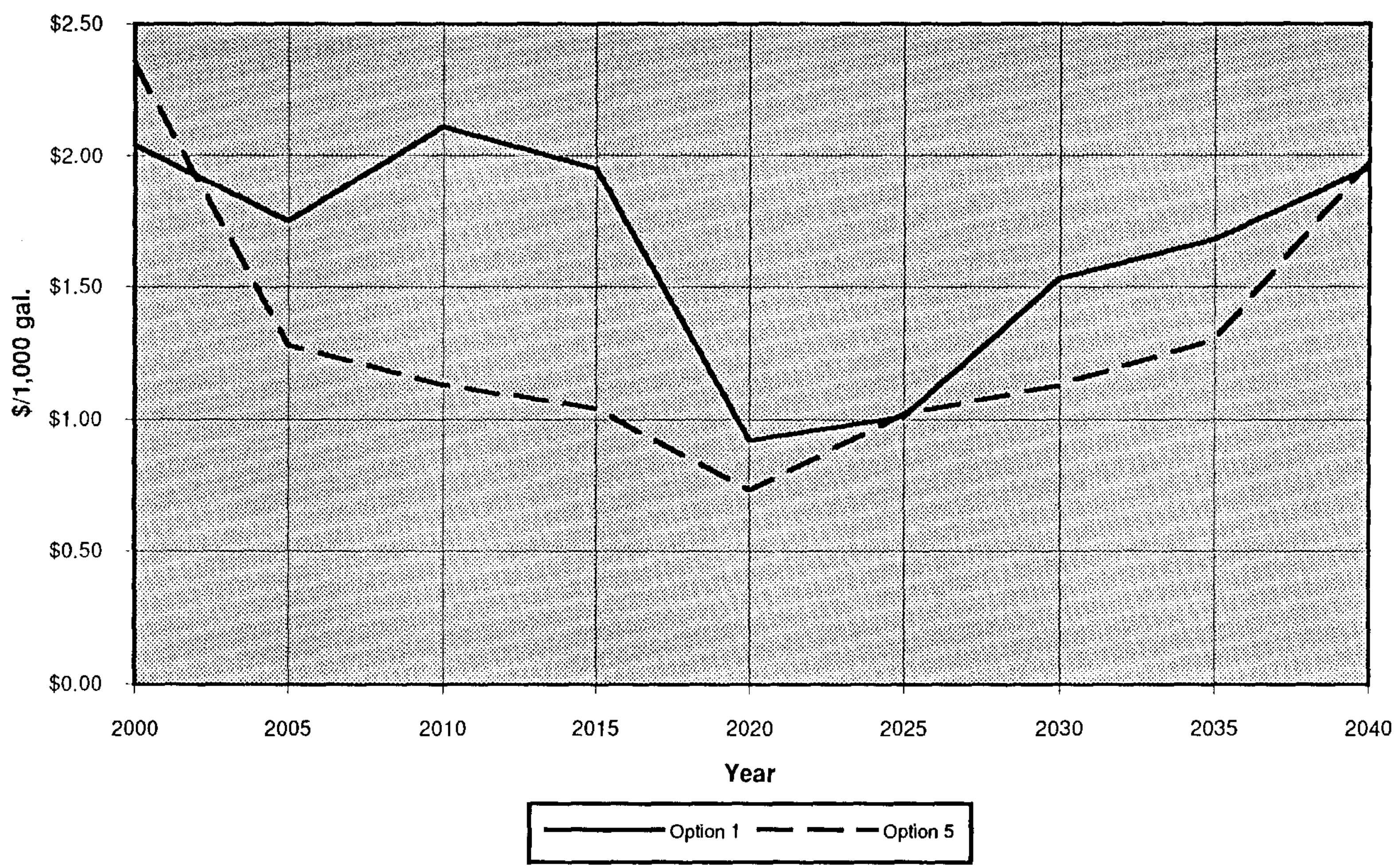


Figure 9-1
South Bexar County Water Supply Study
Projected Future Water Demand for BMWD and
Other Water Purveyors within the Study Area

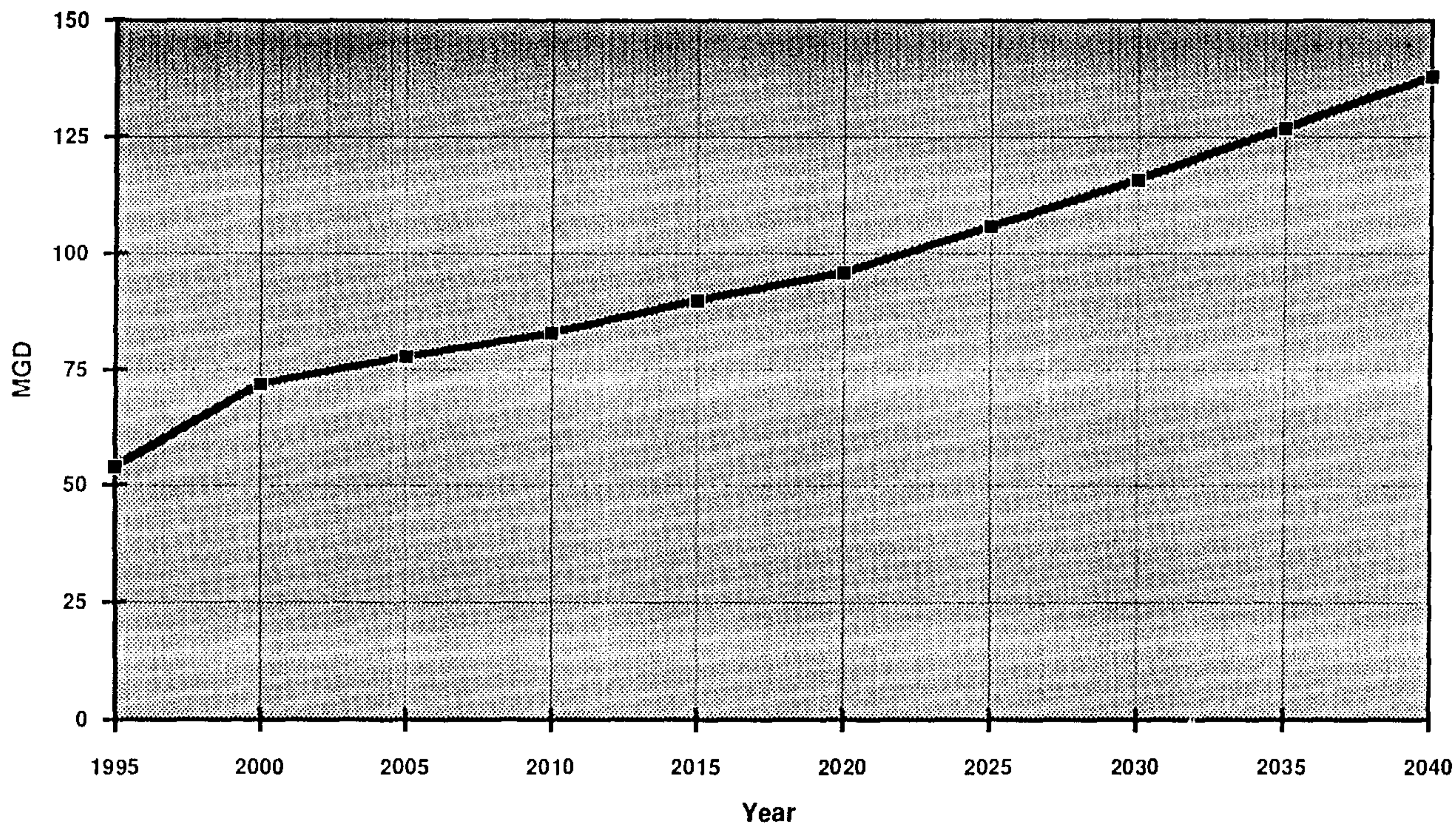
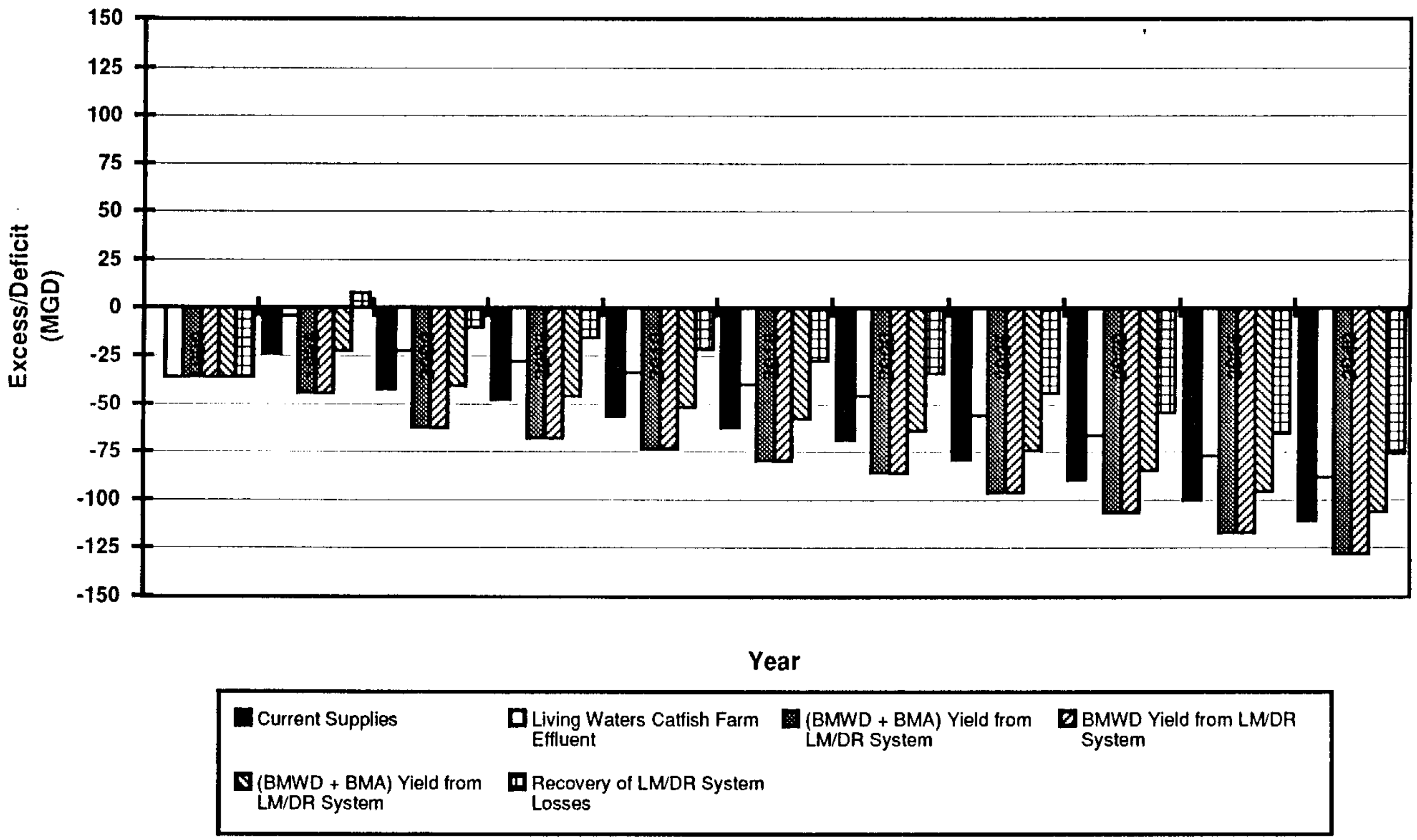


Figure 9-2
Excess/Deficit of Future BMWD Demands Satisfied by Single Options



APPENDIX A

Hydrologic Data for the Medina and San Antonio River Basins

Lake Medina Net Evaporation
(1940-1988)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1940	0.15	0.08	0.28	0.26	0.15	-0.12	0.58	0.81	0.63	0.09	0.12	-0.1	2.93
1941	0.11	-0.5	-0.19	-0.07	0.12	0.15	0.48	0.72	0.2	0.39	0.27	0.15	1.83
1942	0.19	0.17	0.34	-0.38	0.16	0.46	-0.07	0.5	-0.05	0.11	0.29	0.17	1.89
1943	0.18	0.28	0.3	0.31	0.22	0.25	0.57	0.85	0.42	0.44	0.15	0.08	4.05
1944	-0.06	0.04	0.15	0.39	0.08	0.49	0.67	0.17	0.53	0.42	0.02	-0.1	2.8
1945	-0.06	0.07	0.21	0.23	0.44	0.56	0.67	0.79	0.36	0.26	0.35	0.16	4.04
1946	-0.01	0.11	0.34	0.2	0.15	0.32	0.71	0.09	-0.08	0.16	0.17	0.04	2.2
1947	0.04	0.23	0.25	0.39	0.3	0.59	0.8	0.59	0.8	0.61	0.31	0.16	5.07
1948	0.19	-0.05	0.3	0.31	0.34	0.4	0.58	0.81	0.41	0.25	0.33	0.24	4.11
1949	0	-0.16	0.11	-0.31	0.36	-0.01	0.66	0.52	0.58	-0.08	0.35	-0.01	2.01
1950	0.06	0.1	0.38	0.15	0.19	0.2	0.63	0.6	0.52	0.54	0.39	0.29	4.05
1951	0.19	-0.02	0.14	0.33	-0.4	0.53	0.76	0.87	0.55	0.67	0.29	0.28	4.19
1952	0.23	0.15	0.13	0.24	0.3	0.47	0.61	0.96	-0.07	0.59	-0.03	0.1	3.68
1953	0.27	0.19	0.29	0.46	0.55	0.73	0.94	0.53	0.24	0.21	0.27	0.11	4.79
1954	0.16	0.37	0.43	0.33	0.43	0.59	0.75	0.87	0.77	0.34	0.29	0.34	5.67
1955	0.08	0.15	0.31	0.52	0.29	0.65	0.84	0.72	0.58	0.69	0.26	0.22	5.31
1956	0.13	0.16	0.38	0.36	0.6	0.83	0.94	0.74	0.74	0.49	0.33	0.26	5.96
1957	0.25	0.08	0.1	-0.37	-0.32	0.34	0.9	0.97	0.37	0.14	-0.07	0.13	2.52
1958	-0.24	-0.11	0.1	0.14	-0.37	0.38	0.71	0.73	-0.58	-0.18	0.19	0.12	0.89
1959	0.12	-0.12	0.3	0.06	0.18	0.07	0.3	0.58	0.47	-0.42	0.11	0.02	1.67
1960	0.09	0.05	0.01	0.18	0.29	0.53	0.35	0.3	0.52	-0.13	0.16	-0.17	2.18
1961	0	-0.01	0.23	0.3	0.5	-0.02	0.08	0.59	0.46	0.22	0.12	0.12	2.59
1962	0.14	0.22	0.25	-0.3	0.43	0.22	0.83	0.86	0.22	0.52	0.12	0	3.51
1963	0.05	-0.04	0.32	0.15	0.24	0.55	0.71	0.84	0.48	0.35	0.17	0.09	3.91
1964	-0.07	0.01	0.15	0.24	0.16	0.35	0.81	0.57	0.33	0.23	0.22	0.09	3.09
1965	0.14	-0.37	0.09	0.19	-0.12	0.37	0.82	0.6	0.68	0.2	0.23	-0.36	2.47
1966	0.07	-0.12	0.26	0.08	-0.46	0.45	0.75	0.16	0.29	0.49	0.45	0.29	2.71
1967	0.22	0.17	0.27	0.22	0.4	0.68	0.6	0.5	-0.41	0.38	0.09	0.08	3.2
1968	-0.3	0.06	0.09	0.15	0.23	0.35	0.53	0.64	0.13	0.42	0.15	0.12	2.57
1969	0.08	-0.16	0.13	0.22	-0.23	0.49	0.71	0.32	0.31	-0.41	0.13	0.02	1.61
1970	0.08	-0.1	-0.03	0.24	0.25	0.51	0.59	0.62	0.46	0.32	0.4	0.27	3.61
1971	0.26	0.24	0.44	0.33	0.44	0.19	0.75	-0.43	0.19	-0.1	0.2	0.07	2.58
1972	0.11	0.19	0.3	0.24	-0.35	0.29	0.59	0.18	0.25	0.24	0.18	0.17	2.39
1973	-0.02	-0.07	0.17	-0.21	0.42	0.01	0.15	0.48	-0.73	-0.27	0.26	0.3	0.49
1974	0.04	0.29	0.23	0.19	0.19	0.52	0.76	-0.38	0.37	0.13	0.16	0.01	2.51
1975	0.12	-0.08	0.31	0.14	0.14	0.39	0.1	0.5	0.33	0.32	0.39	0.13	2.79
1976	0.24	0.29	0.27	-0.6	0	0.42	-0.07	0.57	0.33	-0.3	0.07	-0.03	1.19
1977	-0.06	0.17	0.24	-0.07	0.15	0.31	0.75	0.76	0.52	0.43	0.02	0.25	3.47
1978	0.15	0.04	0.29	0.18	0.4	0.4	0.69	0.03	-0.11	0.42	-0.18	-0.06	2.25
1979	-0.03	0.08	-0.04	-0.03	0.28	0.14	0.37	0.46	0.58	0.6	0.24	-0.01	2.64
1980	0.12	0.14	0.31	0.37	-0.11	0.68	0.79	0.4	0.23	0.38	-0.01	0.16	3.46
1981	0.05	0.12	-0.04	0.01	-0.22	-0.56	0.51	0.68	0.53	0.13	0.31	0.19	1.71
1982	0.21	0.06	0.21	0.14	-0.24	0.45	0.76	0.6	0.53	0.3	0.1	0.11	3.23
1983	0.05	0.1	-0.09	0.46	0.17	0.3	0.31	0.37	0.57	0.3	0.21	0.2	2.95
1984	0.05	0.2	0.35	0.54	0.5	0.63	0.83	0.8	0.65	-0.13	0.18	0.1	4.7
1985	0.01	-0.05	0.01	0.1	0.29	0.08	0.62	0.9	0.44	-0.05	0.07	0.15	2.57
1986	0.18	0.15	0.38	0.37	-0.1	-0.43	0.82	0.69	0.25	-0.32	0.05	-0.16	1.88
1987	0.14	-0.16	0.12	0.26	-0.37	-0.31	0.4	0.57	0.43	0.55	0.17	0.1	1.9
1988	0.2	0.09	0.34	0.4	0.46	0.35	0.5	0.72	0.44	0.48	0.39	0.23	4.6
Max.	0.27	0.37	0.44	0.54	0.60	0.83	0.94	0.97	0.80	0.69	0.45	0.34	5.96
Min.	-0.30	-0.50	-0.19	-0.60	-0.46	-0.56	-0.07	-0.43	-0.73	-0.42	-0.18	-0.36	0.49
Mean	0.09	0.06	0.21	0.16	0.15	0.34	0.60	0.55	0.33	0.24	0.19	0.11	3.03
Std. Dev	0.12	0.17	0.14	0.25	0.28	0.28	0.25	0.30	0.32	0.29	0.13	0.14	1.24
Skew	-1.02	-0.95	-0.73	-1.19	-0.68	-1.23	-1.20	-1.43	-1.54	-0.69	-0.40	-1.00	0.41
Median	0.10	0.08	0.25	0.21	0.21	0.39	0.67	0.60	0.42	0.30	0.19	0.12	2.75

Source: Texas Water Development Board

Lake Medina Naturalized Inflows
(1940-1988)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1940	2,361	3,252	5,261	12,794	9,434	11,380	6,192	2,952	1,688	2,461	7,446	22,985	88,206
1941	8,268	40,936	36,945	51,773	64,738	20,162	13,471	6,442	9,261	14,610	7,585	6,509	280,700
1942	5,462	4,577	4,405	22,461	29,710	8,204	5,069	3,785	13,061	16,954	8,851	7,242	129,781
1943	5,855	4,504	5,152	6,538	4,378	10,618	4,646	1,728	1,930	2,196	2,057	2,869	52,471
1944	4,499	5,695	13,327	8,265	44,925	18,676	6,112	7,553	6,422	6,534	4,419	9,518	135,945
1945	20,763	15,429	22,852	22,373	10,851	6,074	4,280	1,910	6,440	8,418	4,220	8,711	132,321
1946	5,597	5,648	5,955	5,998	9,924	5,676	2,150	962	5,234	17,088	19,347	9,454	93,033
1947	17,922	11,890	10,613	10,823	10,190	20,499	6,548	3,580	2,033	1,685	2,250	2,830	100,863
1948	2,723	3,501	3,448	3,246	2,544	2,430	2,726	894	1,666	1,954	1,372	1,697	28,201
1949	2,471	19,476	12,094	15,329	12,270	8,592	4,261	6,650	5,423	4,870	3,841	3,956	99,233
1950	4,430	4,750	4,604	4,947	5,250	4,833	2,386	947	1,167	1,045	1,198	1,411	36,968
1951	1,517	1,585	2,912	2,215	14,536	6,161	930	275	410	487	980	1,087	33,095
1952	1,082	1,066	1,413	3,384	7,150	5,718	1,268	189	13,551	66	318	2,876	38,081
1953	3,237	1,940	1,900	1,227	589	132	763	3,451	10,366	15,409	3,732	2,702	45,448
1954	2,006	1,632	1,498	1,221	6,059	1,485	491	161	186	125	102	119	15,085
1955	684	1,552	922	672	5,524	664	4,642	1,606	340	226	161	253	17,246
1956	341	470	510	268	478	62	37	1,554	366	185	780	89	5,140
1957	86	188	7,648	46,890	28,658	26,840	3,770	1,196	13,111	31,189	22,632	14,481	196,689
1958	34,324	35,412	48,802	19,285	23,242	59,189	14,610	5,571	37,170	41,115	37,803	16,880	373,403
1959	10,652	8,071	6,628	11,740	8,332	18,746	10,328	3,909	2,606	26,441	7,855	6,885	122,193
1960	8,427	7,782	9,150	7,744	5,631	2,463	8,092	38,545	9,802	13,625	15,193	23,004	149,458
1961	22,177	37,708	23,392	11,877	6,552	17,083	9,827	6,839	4,280	3,898	4,077	4,184	151,894
1962	3,635	2,630	2,630	3,857	2,224	1,963	500	286	166	9,184	2,183	2,618	31,876
1963	2,027	1,791	1,933	2,467	2,217	1,046	490	371	197	165	413	1,279	14,396
1964	1,787	3,942	5,677	3,749	2,040	932	351	3,446	56,794	12,221	8,137	5,235	104,311
1965	4,061	11,057	8,694	12,992	26,667	12,429	4,133	1,712	2,245	7,349	3,269	6,589	101,197
1966	5,344	4,559	4,754	6,404	7,669	4,738	3,599	20,535	16,986	8,207	5,127	4,095	92,017
1967	3,360	2,647	2,557	2,414	1,189	601	258	448	8,417	14,935	15,232	8,144	60,202
1968	36,187	26,564	27,902	21,379	37,682	16,016	12,969	5,147	4,606	3,895	3,604	4,185	200,136
1969	3,356	3,201	3,868	8,918	8,174	3,275	1,239	1,022	1,710	50,242	11,373	14,740	111,118
1970	9,320	8,718	20,985	12,810	20,581	15,074	5,573	2,893	3,576	4,974	3,383	3,281	111,168
1971	2,820	2,296	2,202	1,958	1,878	1,152	977	168,532	16,115	53,080	27,207	15,607	293,824
1972	10,517	7,909	6,596	4,783	54,255	15,075	8,277	13,157	9,649	8,815	6,991	5,901	151,925
1973	5,777	7,986	11,642	11,234	9,786	23,942	168,711	29,086	16,319	56,126	23,338	12,710	376,657
1974	9,962	7,574	7,687	5,889	22,589	8,175	4,482	22,277	16,024	9,813	18,587	16,481	149,540
1975	19,110	64,128	22,598	14,875	48,993	31,781	20,069	10,868	6,529	5,657	4,858	4,628	254,094
1976	4,017	3,147	2,954	17,891	22,898	12,093	26,856	13,424	12,221	16,172	22,145	23,018	176,836
1977	21,389	21,778	17,321	30,910	43,115	21,096	10,724	5,221	3,478	3,912	11,774	6,150	196,868
1978	4,944	4,751	4,511	3,442	2,290	3,848	987	177,978	27,285	14,307	12,972	11,947	269,262
1979	15,535	19,971	44,383	41,175	23,802	56,035	18,494	9,837	5,351	4,070	3,937	4,165	246,755
1980	4,165	3,255	3,651	3,561	5,017	2,340	1,434	1,565	33,435	19,708	10,356	11,789	100,276
1981	9,007	6,398	25,798	41,392	30,520	88,471	29,608	12,454	8,923	91,815	15,181	11,416	370,983
1982	9,165	6,428	6,768	5,687	23,362	12,722	5,933	4,876	4,020	2,955	3,222	3,801	88,939
1983	3,445	3,534	5,330	4,068	4,291	12,086	5,241	2,405	1,901	3,697	8,389	3,816	58,203
1984	6,296	4,766	3,935	2,747	1,693	1,439	570	345	600	2,346	2,821	16,630	44,188
1985	32,324	14,061	23,326	15,323	21,990	12,784	7,602	3,207	3,860	12,160	7,869	9,755	164,261
1986	7,275	- 7,424	5,390	4,217	12,309	37,684	19,837	5,019	22,019	57,550	32,947	43,207	254,878
1987	33,942	18,753	28,730	18,886	63,519	246,028	34,774	14,254	9,443	7,290	7,365	6,548	489,532
1988	5,672	5,093	5,108	3,727	4,024	2,925	40,208	6,949	4,736	3,860	3,385	3,400	89,087
Max.	36,187	64,128	48,802	51,773	64,738	246,028	168,711	177,978	56,794	91,815	37,803	43,207	489,532
Min.	86	188	510	268	478	62	37	161	166	66	102	89	5,140
Mean	9,103	10,170	11,065	11,771	16,798	18,543	11,256	13,230	9,196	14,430	8,851	8,081	142,495
Std. Dev	9,477	12,512	11,597	12,417	17,086	37,625	25,006	34,622	10,938	18,984	8,908	7,744	110,654
Skew	1.69	2.51	1.67	1.79	1.35	5.06	5.58	4.38	2.45	2.29	1.52	2.34	1.17
Median	5,530	5,371	5,816	6,471	9.855	8.398	4,644	3,683	5,387	7,778	4,993	6,026	111,143

Source: HDR Trans-Texas Study

Medina Lake End of Month Content
USGS Gage No. 08179500

Year	January	February	March	April	May	June	July	August	September	October	November	December
1914	151,600	152,500	147,800	158,400	224,800	239,900	235,900	238,900	232,300	225,300	220,700	215,700
1915	211,200	208,100	205,100	258,100	258,100	250,000	239,400	234,400	233,400	226,800	219,200	214,200
1916	210,200	205,100	196,500	227,300	251,700	243,000	241,900	237,400	230,300	226,300	220,200	213,200
1917	208,100	203,100	192,500	184,900	182,300	173,100	163,400	152,500	145,700	136,800	132,900	125,100
1918	119,500	115,600	106,500	109,600	104,200	93,020	80,740	70,960	63,980	64,440	61,850	71,660
1919	75,150	77,010	77,940	80,740	85,160	92,450	117,400	217,700	260,400	259,800	256,300	255,700
1920	256,900	255,700	255,200	253,400	254,000	250,000	239,400	234,400	226,300	218,200	215,700	211,200
1921	207,600	202,600	201,600	200,100	194,000	218,200	206,600	194,500	203,100	196,500	190,700	186,100
1922	181,900	178,100	173,100	187,800	201,100	197,500	187,400	178,100	168,900	161,300	156,700	150,400
1923	145,000	145,700	144,300	152,100	148,200	137,200	126,900	117,700	124,100	125,500	139,000	158,800
1924	165,100	170,600	183,600	196,000	205,100	211,700	203,100	191,200	184,900	177,300	172,200	166,800
1925	160,900	155,000	145,700	137,200	135,100	120,500	108,500	105,300	101,300	106,200	108,200	103,900
1926	102,200	98,470	97,320	123,700	134,000	132,600	131,500	124,100	117,000	112,200	110,200	108,800
1927	105,900	110,200	118,800	128,700	126,900	126,900	125,100	118,100	108,800	103,100	97,320	93,020
1928	87,290	85,860	84,700	82,370	77,710	76,550	69,560	63,050	57,100	51,630	47,070	42,910
1929	40,070	37,240	33,260	29,920	29,590	46,160	51,260	47,620	40,780	34,680	29,590	25,950
1930	23,420	20,440	17,330	14,010	21,880	23,970	17,880	18,860	3,930	12,320	22,870	24,740
1931	32,840	48,160	62,580	77,710	120,200	120,900	127,300	121,300	111,900	104,800	99,040	97,610
1932	97,040	97,320	99,900	101,000	101,600	94,460	190,300	187,000	217,700	224,300	21,800	221,800
1933	229,800	232,800	233,400	229,800	223,300	215,200	202,600	191,600	183,200	173,500	165,100	157,100
1934	154,600	151,200	147,100	148,500	140,700	127,600	119,800	108,200	99,040	99,310	84,700	81,670
1935	79,810	79,810	72,120	71,190	103,900	219,700	248,200	244,200	256,900	254,600	252,300	254,600
1936	254,000	252,900	251,700	247,100	256,300	278,300	253,400	245,900	261,000	255,700	254,600	254,000
1937	254,000	253,400	254,000	252,900	241,900	252,300	244,700	231,300	219,200	210,200	200,600	197,500
1938	203,600	205,100	204,100	206,600	207,600	196,000	184,000	170,100	161,700	144,300	135,100	128,700
1939	126,900	122,700	114,200	102,500	88,730	77,710	79,340	70,960	60,020	59,300	54,370	49,440
1940	44,510	45,610	36,670	37,780	34,680	29,700	25,620	16,020	7,080	1,770	5,920	25,290
1941	25,070	61,850	84,230	112,800	153,700	156,700	149,200	145,000	142,200	142,200	137,900	135,100
1942	129,800	126,200	118,100	116,300	130,500	118,100	113,900	103,900	105,600	135,800	137,900	136,100
1943	133,300	126,900	120,200	115,900	117,000	118,100	110,200	95,890	90,160	82,600	76,550	73,520
1944	72,360	75,380	84,930	83,070	105,900	108,800	97,900	90,160	87,010	80,510	75,620	78,421
1945	94,170	105,900	113,900	123,400	132,200	107,600	94,460	78,880	80,970	80,898	84,460	82,600
1946	79,810	80,270	75,150	69,560	82,140	80,040	67,240	58,200	64,910	81,440	83,300	64,930
1947	97,900	104,500	105,600	101,600	94,460	86,150	72,820	60,750	46,880	29,700	21,320	15,600
1948	9,230	5,530	2,310	2,220	2,790	13,260	9,300	1,380	2,140	5,000	5,110	4,940
1949	6,290	14,430	18,910	31,700	39,820	48,160	41,780	37,380	30,990	28,710	25,620	24,630
1950	23,310	24,630	20,220	17,950	18,500	20,440	15,950	7,670	3,010	2,160	3,050	3,960
1951	4,330	5,130	5,850	7,410	14,360	15,880	14,570	13,120	11,570	10,080	9,620	9,180
1952	9,020	8,320	8,780	11,380	13,460	15,880	15,260	14,260	26,060	24,890	24,680	27,380
1953	28,600	29,040	25,320	19,450	12,580	11,180	10,890	14,630	25,510	34,400	35,740	36,100
1954	36,640	36,360	35,820	35,110	37,450	36,670	35,110	33,400	24,080	17,050	11,640	2,160
1955	2,720	3,770	4,250	4,330	9,100	9,100	11,570	12,280	11,700	11,120	10,780	10,340

Medina Lake End of Month Content
USGS Gage No. 08179500

Year	January	February	March	April	May	June	July	August	September	October	November	December
1956	10,010	9,620	9,360	8,900	8,320	7,600	6,780	7,660	7,130	6,730	7,410	7,020
1957	6,630	6,370	13,320	49,800	79,340	104,800	97,560	86,430	89,300	109,600	123,400	130,500
1958	155,000	179,400	212,200	218,700	233,400	255,200	250,500	238,900	255,700	258,600	254,600	254,000
1959	253,400	253,400	249,400	251,700	250,500	256,300	252,900	243,600	235,400	246,500	245,300	244,700
1960	244,700	243,600	244,700	243,600	238,400	227,300	226,300	245,300	341,400	244,700	250,000	255,700
1961	255,200	256,300	255,200	252,300	242,400	254,000	252,900	247,100	238,900	233,900	229,300	225,300
1962	218,200	214,200	205,100	202,100	192,500	183,600	171,000	156,300	147,100	145,000	139,300	134,000
1963	131,500	127,300	121,600	115,900	110,500	100,200	88,150	75,380	66,770	58,930	54,500	51,450
1964	48,340	49,260	50,350	48,530	41,780	37,940	26,060	19,120	59,300	62,220	67,240	66,300
1965	63,510	72,820	77,010	86,430	109,900	114,900	106,800	97,900	91,020	93,020	90,450	95,030
1966	95,600	96,460	95,030	95,030	98,760	92,450	85,160	95,030	102,800	101,000	97,320	93,310
1967	89,870	85,860	80,040	77,010	65,370	52,910	42,490	33,830	42,060	50,720	60,940	64,440
1968	92,740	110,500	130,800	145,700	173,100	179,000	179,400	169,300	167,200	161,700	156,700	155,000
1969	151,600	151,200	149,200	151,600	155,800	148,500	138,300	128,700	122,700	157,100	159,200	167,200
1970	169,300	172,700	185,700	189,900	200,600	204,100	197,000	188,200	182,700	179,400	172,200	166,800
1971	159,600	152,100	143,200	134,000	120,500	109,900	100,800	255,200	255,200	257,500	255,200	254,600
1972	252,900	250,500	245,900	236,900	255,200	253,400	248,200	252,900	251,700	249,400	245,300	240,900
1973	238,400	238,400	240,400	247,600	248,200	256,300	257,500	254,600	255,700	256,900	254,600	254,000
1974	254,000	251,700	248,800	241,900	254,000	245,900	234,400	254,000	254,000	254,600	254,600	255,700
1975	255,200	256,300	254,600	255,700	257,500	255,700	254,600	251,100	247,100	240,900	236,400	231,800
1976	227,300	220,700	213,700	233,900	252,300	255,200	255,700	255,200	255,200	258,600	255,700	256,300
1977	256,300	256,300	255,200	256,900	256,300	255,700	252,900	243,000	236,900	231,800	236,400	233,900
1978	230,300	228,300	223,300	219,700	211,700	203,100	188,600	254,000	255,200	253,400	254,000	252,900
1979	255,200	255,700	257,500	256,900	255,200	255,700	255,200	253,400	248,200	238,900	233,400	230,800
1980	227,800	223,800	216,200	207,600	207,600	192,500	177,700	169,300	191,600	196,000	197,000	199,600
1981	200,600	200,100	214,200	243,600	256,300	258,100	255,200	254,000	251,700	255,200	254,000	253,400
1982	249,400	246,500	243,000	236,400	248,200	241,900	228,800	218,700	206,600	198,600	193,500	190,300
1983	187,400	185,300	185,300	180,600	176,000	181,900	176,000	168,000	158,400	153,700	154,600	149,600
1984	147,100	145,000	137,900	127,300	114,200	105,600	90,730	79,110	68,630	68,170	67,930	70,960
1985	95,600	103,900	121,600	129,800	141,400	143,900	142,200	131,500	125,900	135,400	140,700	146,800
1986	148,900	152,500	148,900	142,500	145,300	186,500	187,400	178,500	181,100	218,200	234,400	258,600
1987	256,300	256,900	255,700	255,200	265,000	258,100	255,200	255,200	252,900	246,500	244,200	242,400
1988	239,400	236,900	232,300	225,300	213,200	201,100	217,700	209,700	202,100	192,500	184,900	178,100
1989	175,600	174,800	171,800	165,500	152,100	138,600	123,000	109,100	98,180	91,310	91,590	87,580
Max.	256,900	256,900	257,500	258,100	265,000	278,300	257,500	255,200	341,400	259,800	256,300	258,600
Min.	2,720	3,770	2,310	2,220	2,790	7,600	6,780	1,380	2,140	1,770	3,050	2,160
Mean	141,113	141,884	141,699	144,554	149,310	150,113	146,112	144,441	144,455	142,624	138,339	139,998
Std. Dev	84,031	82,311	81,610	81,769	82,025	82,898	82,772	85,491	88,737	85,995	85,909	85,403
Skew	-0.12	-0.13	-0.14	-0.15	-0.19	-0.16	-0.16	-0.15	0.00	-0.12	-0.05	-0.07
Median	148,000	148,450	143,750	139,850	143,350	141,250	140,250	148,750	143,950	143,250	138,450	141,450

APPENDIX B

Sanitary Surveys for Water Purveyors Within Primary Planning Area

Table B-1
Atascosa Rural Water Supply Corporation
System Component Summary (1)

CCN Number: 11366

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	CAPACITY (GPM)	CAPACITY (GPM)	DEPTH (FT)
Well # 1	10882 Jarratt Rd.	VT	1,000	900	2300
Well # 2	14450 Jarratt Rd.	VT	1,000	900	2300
TOTAL			2,000	1,800	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	CAPACITY (GPM)
Pump Station #1	1	675
	2	675
Pump Station #2	1	700
	2	700
Pump Station #3	1	431
	2	431
Pump Station #4	1	233
	2	233
Pump Station #5	1	196
	2	196
Pump Station #6	1	250
	2	250
TOTAL		4,970

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Pump Station #1	Ground	80,000
Pump Station #1	Ground	80,000
Pump Station #1	Pressure Tank	5,000
Pump Station #2	Ground	80,000
Pump Station #2	Pressure Tank	5,000
Pump Station #3	Ground	70,000
Pump Station #3	Pressure Tank	5,000
Pump Station #4	Ground	40,000
Pump Station #4	Pressure Tank	3,000
Pump Station #5	Ground	40,000
Pump Station #5	Pressure Tank	3,000
Pump Station #6	Ground	65,700
Pump Station #6	Pressure Tank	3,000

Total Ground Storage (GAL.)	455,700
Total Pressure Tank (GAL.)	24,000
Total Elevated Storage (GAL.)	N/A
Total Standpipe Storage (GAL.)	N/A
TOTAL STORAGE (GAL.)	479,700

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	N/A	N/A	N/A	N/A
Pressure Storage (GAL.)	N/A	N/A	N/A	N/A
Elevated Storage (GAL.)	N/A	N/A	N/A	N/A
Total Storage (GAL.)	N/A	N/A	N/A	N/A
Service Pumps (GPM)	N/A	N/A	N/A	N/A

MISCELLANEOUS DATA

Area Served	Rural S.W. Bexar County
Connections Served	1,608
Estimated Population Served	4,824
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (GAL.)	1,302,000
Average Daily Usage (GAL.)	539,000
System Pressure (PSI)	45-65
Interconnects	N/A
Date of Most Recent Sanitary Survey	1/14/91

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-2
Bexar County WCID #16
System Component Summary (1)

CCN Number: 11292
TDH ID Number: 0150060

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well # A1	Demya @ Horal Sts.	V.T.	1,200	1,030	1065
Well # B2	Stimmel @ Horal Sts.	V.T.	1,200	930	1065
TOTAL			2,400	1,960	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
N/A	N/A	N/A
TOTAL		0

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Well #1 Site	Elev.	50,000
Well #1	S. Pipe	173,000
Total Ground Storage (GAL.)	0	
Total Pressure Tank (GAL.)	0	
Total Elevated Storage (GAL.)	50,000	
Total Standpipe Storage (GAL.)	173,000	
TOTAL STORAGE (GAL.)	223,000	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	690	1,960	1,270	-
Pressure Storage (GAL.)	N/A	N/A	N/A	N/A
Elevated Storage (GAL.) (2)	120,000	110,000	-	10,000
Total Storage (GAL.) (3)	230,000	223,000	-	7,000
Service Pumps (GPM)	204	600	396	-

MISCELLANEOUS DATA

Area Served	San Antonio Metro. Health Dist.
Connections Served	1,150
Estimated Population Served	3,450
Estimated Potential No. of Connections	1,200
Maximum Daily Usage (GAL.)	1,415,000
Average Daily Usage (GAL.)	502,000
System Pressure (PSI)	42-48
Interconnects	N/A
Date of Most Recent Sanitary Survey	11/18/91

(1) Based on Texas Department of Health Sanitary Survey of System.
(2) 4.35% Deficient
(3) 3.04% Deficient.
Note: 1150 Conn. Report in previous Correspondence to be Maximum Due to WCID #16 Being Surrounded on All Sides by Other Water Systems. Therefore, Adequate at This Time. No Recommendations.

Table B-3
Bexar Metropolitan Water District - Castle Hills
System Component Summary (1)

CCN Number: 10675
TDH ID Number: 0150045

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
		-			
TOTAL			0	N/A	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
TOTAL		0

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Total Ground Storage (GAL.)	N/A	
Total Pressure Tank (GAL.)	N/A	
Total Elevated Storage (GAL.)	N/A	
Total Standpipe Storage (GAL.)	N/A	
TOTAL STORAGE (GAL.)	0	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	1636	9,600	7,964	-
Pressure Storage (GAL.)	N/A	N/A	N/A	-
Elevated Storage (GAL.)	273,000	1,250,000	977,000	N/A
Total Storage (GAL.)	550,000	3,250,000	2,700,000	-
Service Pumps (GPM)	5,456	6,200	744	-

MISCELLANEOUS DATA

Area Served	Castle Hills
Connections Served	2,728
Estimated Population Served	8,184
Estimated Potential No. of Connections	0
Maximum Daily Usage (MGD)	4.33
Average Daily Usage (MG)	1.81
System Pressure (PSI)	55-100
Interconnects	N/A
Date of Most Recent Sanitary Survey	4/17/91

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-4
Bexar Metropolitan Water District - South Side
System Component Summary (1)

CCN Number: 10675
TDH ID Number: 0150249

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well #A1	411 Carlisle (Station 1)	V.T.	1,800	N/A	1616
Well #B2	411 Carlisle (Station 1)	V.T.	2,000	N/A	1708
Well #C1	West Kirk St. (Station 2)	V.T.	500	N/A	1500
Well #D2	West Kirk St. (Station 2)	V.T.	1,900	N/A	1383
Well #E3	King Street (Station 3)	V.T.	2,000	N/A	1331
Well #F4	King Street (Station 3)	V.T.	2,000	N/A	1434
Well #G5	King Street (Station 3)	V.T.	4,000	N/A	1581
Well #H1	Guerida St. (Station 4)	V.T.	1,700	N/A	1409
Well #I1	W. Southcross	V.T.	1,500	N/A	1423
Well #J2	Plugged			N/A	1500
Well #K3	Zamora St. (Station 5)	V.T.	2,000	N/A	1644
Well #L4	Zamora St. (Station 5)	V.T.	4,800	N/A	1577
Well #M5	Zamora St. (Station 5)	V.T.	7,000	N/A	1727
Well #N1	Pitluk Ave. (Station 6)	Capped		N/A	1420
Well #O2	Pitluk Ave. (Station 6)	V.T.	1,500	N/A	1429
Well #P3	Pitluk Ave. (Station 6)	V.T.	1,500	N/A	1530
Well #Q4	Pitluk Ave. (Station 6)	V.T.	7,000	N/A	1220
Well #R1	Roselawn St. (Station 8)	V.T.	800	N/A	1479
TOTAL			42,000	N/A	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
Station #2	1	2,000
Station #2	2	1,000
Station #3	1	1,400
Station #3	2	1,400
Station #3	3	1,400
Station #5	1	3,200
Station #5	2	3,200
Station #5	3	4,000
Station #6	1	4,000
Station #6	2	3,000
Station #6	3	3,000
Station #6	4	2,000
Station #10	1	200
Station #10	2	500
Station #10	3	1,000
Station #10	4	(Standby) 250
Station #10	5	(Standby) 150
Station #11	1	(Standby) 200
Station #11	2	(Standby) 200
TOTAL		32,100

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Station #2	Ground	1,000,000
Station #5	Ground	2,200,000
Station #6	Ground	3,000,000
Station #3	Ground	500,000
Somerset Rd./ FM 1604 (Sta. 10)	Ground	300,000
City of Somerset (Sta. 11)	Ground	50,000
Gillette Blvd.	Standpipe	3,000,000
Vestal St.	Elevated	1,500,000
Hutchins St.	Elevated	500,000
McMullen St.	Elevated	250,000
Station #11	Elevated	100,000
Total Ground Storage (GAL.)	7,050,000	
Total Pressure Tank (GAL.)	N/A	
Total Elevated Storage (GAL.)	2,350,000	
Total Standpipe Storage (GAL.)	3,000,000	
TOTAL STORAGE (GAL.)	12,400,000	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	16451	42,000	25,549	-
Pressure Storage (GAL.)	N/A	N/A	N/A	-
Elevated Storage (GAL.)	2,742,000	3,350,000	608,000	N/A
Total Storage (GAL.)	5,484,000	12,400,000	6,916,000	-
Service Pumps (GPM)	54,838	32,100	-	22,738

MISCELLANEOUS DATA

Area Served	So. San Antonio & Somerset
Connections Served	27,419
Estimated Population Served	82,257
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (MGD)	18.14
Average Daily Usage (MG)	11.47
System Pressure (PSI)	55-82
Interconnects	N/A
Date of Most Recent Sanitary Survey	4/30/92

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-5
Brooks Airforce Base
System Component Summary (1)

CCN Number:	N/A
TDH ID Number:	0150112

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
N/A	N/A	N/A	N/A	N/A	N/A
TOTAL		-	0	0	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
N/A	N/A	N/A
TOTAL		0

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
N/A	N/A	N/A

Total Ground Storage (GAL.)	N/A
Total Pressure Tank (GAL.)	N/A
Total Elevated Storage (GAL.)	N/A
Total Standpipe Storage (GAL.)	N/A
TOTAL STORAGE (GAL.)	0

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	N/A	N/A	N/A	-
Pressure Storage (GAL.)	N/A	N/A	N/A	-
Elevated Storage (GAL.)	N/A	N/A	N/A	-
Total Storage (GAL.)	N/A	N/A	N/A	-
Service Pumps (GPM)	N/A	N/A	N/A	-

MISCELLANEOUS DATA

Supller and Source:	San Antonio City Water Board
Area Served	Brooks Airforce Base
Connections Served	320
Estimated Population Served	3,200
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (GAL.)	1,229,000
Average Daily Usage (GAL.)	542,000
System Pressure (PSI)	58-75
Interconnects	N/A
Date of Most Recent Sanitary Survey	10/1/91

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-6
Coolcrest Water System
System Component Summary (1)

CCN Number: 11106
TDH ID Number: 0150249

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well # A1	11926 Madrona Drive	SUB	170	N/A	680
Well # B2	12304 Poinciana	SUB	170	N/A	680
TOTAL		–	340	0	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
Well Site #1	1	200
	2	200
Well Site #2	3	200
TOTAL		400

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Well Site #1	Ground	10,000
Well Site #1	Ground	10,000
Well Site #1	P.T.	8,400
Well Site #2	Ground	10,000
Well Site #2	P.T.	2,000
Total Ground Storage (GAL.)	30,000	
Total Pressure Tank (GAL.)	10,400	
Total Elevated Storage (GAL.)	N/A	
Total Standpipe Storage (GAL.)	N/A	
TOTAL STORAGE (GAL.)	40,400	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	138	340	202	-
Pressure Storage (GAL.)	5,000	11,000	6,000	-
Elevated Storage (GAL.)	N/A	N/A	N/A	N/A
Total Storage (GAL.)	50,000	30,000	-	20,000
Service Pumps (GPM)	462	600	138	-

MISCELLANEOUS DATA

Area Served	Coolcrest Subd.
Connections Served	231
Estimated Population Served	693
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (GAL.)	N/A
Average Daily Usage (GAL.)	71,000
System Pressure (PSI)	40-55
Interconnects	N/A
Date of Most Recent Sanitary Survey	2/6/91

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-7
City of Elmendorf
System Component Summary (1)

CCN Number:	10684
TDH ID Number:	0150048

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well # A1	West Third Street	SUB	200	210	500
Well #B2	Kilowatt Road	SUB	200	220	500
Well # C3	FM 1604	SUB	200	242	500
TOTAL			600	672	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
Well Site #1 (o/ol/serv)	1	400
Well Site #1	2	450
Well Site #2	1	150
	2	200
	3	200
Well Site #3	1	225
	2	225
TOTAL		1,850

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Well Site #1	Ground	68,000
Well Site #1	P.T.	5,000
Well Site #2	Ground	45,000
Well Site #2	P.T.	8,000
Well Site #3	Ground	36,000
Well Site #3	P.T.	2,500
Total Ground Storage (GAL.)	149,000	
Total Pressure Tank (GAL.)	15,500	
Total Elevated Storage (GAL.)	N/A	
Total Standpipe Storage (GAL.)	N/A	
TOTAL STORAGE (GAL.)	164,500	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	232	672	440	-
Pressure Storage (GAL.)	7,700	15,500	7,800	-
Elevated Storage (GAL.)	N/A	N/A	N/A	N/A
Total Storage (GAL.)	80,000	149,000	69,000	-
Service Pumps (GPM)	772	1,850	1,078	-

MISCELLANEOUS DATA

Area Served	City fo Elmendorf
Connections Served	386
Estimated Population Served	1,158
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (GAL.)	N/A
Average Daily Usage (GAL.)	N/A
System Pressure (PSI)	42-62
Interconnects	N/A
Date of Most Recent Sanitary Survey	12/16/91

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-8
Kelly Airforce Base
System Component Summary (1)

CCN Number:	N/A
TDH ID Number:	0150113

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well #A314	N/A	V.T.	1,250	1,000	1597
Well# B1044	N/A	V.T.	350	525	1548
Well #C1556	N/A	V.T.	650	700	970
Well #D1638	N/A	V.T.	1,600	1,300	1606
Well #E30100	N/A	V.T.	1,300	950	1120
Well #F1536	N/A	V.T.	600	700	1018
Well #313	Plugged	V.T.	N/A	N/A	N/A
Well #141	Plugged	V.T.	N/A	N/A	N/A
TOTAL			5,750	5,175	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
N/A	N/A	N/A
TOTAL		0

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
#246	Elevated	750,000
#879	Elevated	314,000
#1577	Elevated	500,000
#2002	Elevated	500,000
#3105 (Fire Protection Only)	Elevated	75,000
#3835	Elevated	500,000
Total Ground Storage (GAL.)	0	
Total Pressure Tank (GAL.)	0	
Total Elevated Storage (GAL.)	2,639,000	
Total Standpipe Storage (GAL.)	N/A	
TOTAL STORAGE (GAL.)	2,639,000	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	1290	6,800	5,510	-
Pressure Storage (GAL.)	N/A	N/A	N/A	N/A
Elevated Storage (GAL.)	210,000	2,139,000	1,929,000	N/A
Total Storage (GAL.)	430,000	2,139,000	1,709,000	N/A
Service Pumps (GPM)	N/A	N/A	N/A	N/A

MISCELLANEOUS DATA

Area Served	Kelly Airforce Base
Connections Served	2,150
Estimated Population Served	2,150
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (MGD)	4.821
Average Daily Usage (MGD)	3.221
System Pressure (PSI)	45-72
Date of Most Recent Sanitary Survey	9/19/91

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-9
Kings Point Water System
System Component Summary (1)

CCN Number:	10683
TDH ID Number:	0150146

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well # A1	4193 King Hill Drive	SUB	70	N/A	400
Well #B2	4193 King Hill Drive	SUB	70	N/A	400
Well # C3	4193 King Hill Drive	SUB	70	N/A	400
TOTAL			210	N/A	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
Well Site	1	270
	2	270
TOTAL		540

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Well Site	Ground	10,000
Well Site	Ground	10,000
Well Site	Ground	10,000
Well Site	P.T.	5,600
Total Ground Storage (GAL.)	30,000	
Total Pressure Tank (GAL.)	5,600	
Total Elevated Storage (GAL.)	N/A	
Total Standpipe Storage (GAL.)	N/A	
TOTAL STORAGE (GAL.)	35,600	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	109	210	101	-
Pressure Storage (GAL.)	3,600	5,600	2,000	-
Elevated Storage (GAL.)	N/A	N/A	N/A	N/A
Total Storage (GAL.)	30,000	30,000	0	-
Service Pumps (GPM)	362	470	108	-

MISCELLANEOUS DATA

Area Served	Kings Point Subd.
Connections Served	181
Estimated Population Served	543
Estimated Potential No. of Connections	2
Maximum Daily Usage (GAL.)	N/A
Average Daily Usage (GAL.)	49,000
System Pressure (PSI)	40-55
Interconnects	N/A
Date of Most Recent Sanitary Survey	3/26/91

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-10
Lackland Airforce Base - Main
System Component Summary (1)

CCN Number:	N/A
TDH ID Number:	1050114

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well #A1	Building #1016	V.T.	1,350	1,325	1609
Well #B2	Building #5709	V.T.	750	750	1191
Well #C3	Building #3106	- V.T.	1,750	1,750	1755
Well #D4	Building #4070	Out of Service	1,400	1,600	1545
Well #E5	Building #4380	V.T.	1,655	1,650	1500
TOTAL			6,905	7,075	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
Building #1506	1	800
Interconnection	2	800
TOTAL		800

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Building #1506	Elevated	500,000
Building #5084	Elevated	500,000
Building #5710	Elevated	500,000
Total Ground Storage (GAL.)	0	
Total Pressure Tank (GAL.)	0	
Total Elevated Storage (GAL.)	1,500,000	
Total Standpipe Storage (GAL.)	N/A	
TOTAL STORAGE (GAL.)	1,500,000	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	1800	7,075	5,275	-
Pressure Storage (GAL.)	N/A	N/A	N/A	N/A
Elevated Storage (GAL.)	300,000	1,200,000	900,000	N/A
Total Storage (GAL.)	60,000	1,200,000	1,140,000	N/A
Service Pumps (GPM)	N/A	N/A	N/A	N/A

MISCELLANEOUS DATA

Area Served	Lackland Airforce Base
Connections Served	3,000
Estimated Population Served	16,476
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (MGD)	3.794
Average Daily Usage (MGD)	2.932
System Pressure (PSI)	30-75
Date of Most Recent Sanitary Survey	10/1/91

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-11
Lackland Airforce Base - Annex
System Component Summary (1)

CCN Number:	N/A
TDH ID Number:	0150480

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well #A1	Building #104	V.T.	700	520	1543
Well #B3	Building #246	-V.T.	1,050	1,375	1712
TOTAL			1,750	1,895	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
N/A	N/A	N/A
TOTAL		0

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Building #232	Elevated	125,000
Building #165	Elevated	250,000
Total Ground Storage (GAL.)	0	
Total Pressure Tank (GAL.)	0	
Total Elevated Storage (GAL.)	375,000	
Total Standpipe Storage (GAL.)	N/A	
TOTAL STORAGE (GAL.)	375,000	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	192	1,750	1,558	-
Pressure Storage (GAL.)	N/A	N/A	N/A	N/A
Elevated Storage (GAL.)	30,000	375,000	345,000	N/A
Total Storage (GAL.)	60,000	375,000	315,000	N/A
Service Pumps (GPM)	N/A	N/A	N/A	N/A

MISCELLANEOUS DATA

Area Served	Lackland Airforce Base Annex
Connections Served	320
Estimated Population Served	3,200
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (MGD)	1.040
Average Daily Usage (MGD)	0.382
System Pressure (PSI)	35-50
Date of Most Recent Sanitary Survey	10/1/91

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-12
Lackland City - Columbia
System Component Summary (1)

CCN Number:	10734
TDH ID Number:	0150171

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well #A13	9731 Bear Cr./Saddle Brook	V.T.	2,000	1,890	671
Well #B14	9800 Adams Hills (STBY)	V.T.	3,000	N/A	1150
Well #C16	Tippicanoe/Filmore	V.T.	2,000	1,950	998
Well #D17	Bear Springs/Marbach (STBY)	Sub.	270	N/A	943
Well #E17	Bear Springs/Marbach	V.T.	1,650	1,770	948
TOTAL			8,920	5,610	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
Well #17A	1	600
Well #17A	2	3,200
Well #17A	3	3,800
TOTAL		7,600

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Potranco Lane	Elevated	2,000,000
Well 17A Site	Ground	250,000
Well 17A Site	P.T.	10,000
Total Ground Storage (GAL.)	250,000	
Total Pressure Tank (GAL.)	10,000	
Total Elevated Storage (GAL.)	2,000,000	
Total Standpipe Storage (GAL.)	N/A	
TOTAL STORAGE (GAL.)	2,260,000	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	4180	8,880	4,700	-
Pressure Storage (GAL.)	N/A	N/A	N/A	N/A
Elevated Storage (GAL.)	700,000	2,000,000	1,300,000	N/A
Total Storage (GAL.)	1,390,000	2,250,000	860,000	N/A
Service Pumps (GPM)	13,932	7,600	N/A	6,332

MISCELLANEOUS DATA

Area Served	Columbia, Adams Hill, Medow
Connections Served	6,966
Estimated Population Served	20,898
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (MGD)	4.692
Average Daily Usage (MGD)	2.710
System Pressure (PSI)	50-75
Date of Most Recent Sanitary Survey	4/30/92

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-13
Lackland City Water Company - Park Village
System Component Summary (1)

CCN Number:	10734
TDH ID Number:	0150084

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well #A9	6869 Gibb Sprawls	V.T.	3,000	3,000	1000
Well #15	6751 Montgomery Ln.	V.T.	2,000	1,850	900
Well #18	9623 New World	V.T.	4,400	3,500	900
Well #D7	5825 Midcrown (STBY)	V.T.	1,750	N/A	998
Well #E19	9623 New World	Capped	N/A	N/A	900
TOTAL			11,150	8,350	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
Well #18	1	500
Well #18	2	1,000
TOTAL		1,500

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
9623 New World	Elevated	2,000,000

Total Ground Storage (GAL.)	N/A
Total Pressure Tank (GAL.)	N/A
Total Elevated Storage (GAL.)	2,000,000
Total Standpipe Storage (GAL.)	N/A
TOTAL STORAGE (GAL.)	2,000,000

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	N/A	N/A	N/A	N/A
Pressure Storage (GAL.)	N/A	N/A	N/A	N/A
Elevated Storage (GAL.)	810,000	2,000,000	1,190,000	N/A
Total Storage (GAL.)	1,620,000	2,000,000	380,000	N/A
Service Pumps (GPM)	16,170	1,500	N/A	14,670

MISCELLANEOUS DATA

Area Served	Park Village, Camelot
Connections Served	8,085
Estimated Population Served	24,255
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (MGD)	4.336
Average Daily Usage (MGD)	2.820
System Pressure (PSI)	45-62
Date of Most Recent Sanitary Survey	4/30/92

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-14
City of Lytle
System Component Summary (1)

CCN Number:	11007
TDH ID Number:	0070004

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well #A1	City Yard	V.T.	550	560	2033
Well #B2	F.M. 2790	V.T.	550	560	2379
TOTAL		-	1,100	1,120	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
Well #1	1	500
	2	500
FM 2790	1	750
	2	750
TOTAL		2,500

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Well #1	Ground	175,000
Well #1	Elevated	50,000
FM 2790 @ Lane & Prairie Sts.	Elevated	150,000
FM 2790 @ Lane & Prairie Sts.	Ground	500,000
Total Ground Storage (GAL.)	675,000	
Total Pressure Tank (GAL.)	N/A	
Total Elevated Storage (GAL.)	200,000	
Total Standpipe Storage (GAL.)	N/A	
TOTAL STORAGE (GAL.)	875,000	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	550	1,100	550	-
Pressure Storage (GAL.)	N/A	N/A	N/A	N/A
Elevated Storage (GAL.)	90,000	200,000	110,000	N/A
Total Storage (GAL.)	180,000	750,000	570,000	N/A
Service Pumps (GPM)	1,834	2,500	666	N/A

MISCELLANEOUS DATA

Area Served	City of Lytle
Connections Served	917
Estimated Population Served	2,751
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (MGD)	1.674
Average Daily Usage (MGD)	0.454
System Pressure (PSI)	40-72
Date of Most Recent Sanitary Survey	10/1/91

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-15
Meadowood Acres
System Component Summary (1)

CCN Number: 10657
TDH ID Number: 150072

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well # A1	1 Block S. of Storage	SUB	1,000	N/A	N/A
Well #B2	North Side of Subd.	SUB	500	N/A	N/A
TOTAL			1,500	N/A	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
Well #2	2	530
	3	530
TOTAL		1,060

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Well Site #2	Ground	42,000

Total Ground Storage (GAL.)	42,000
Total Pressure Tank (GAL.)	0
Total Elevated Storage (GAL.)	N/A
Total Standpipe Storage (GAL.)	N/A
TOTAL STORAGE (GAL.)	42,000

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	108	1,500	1,392	-
Pressure Storage (GAL.)	3,600	0	-	3,600
Elevated Storage (GAL.)	N/A	N/A	N/A	N/A
Total Storage (GAL.)	40,000	42,000	2,000	-
Service Pumps (GPM)	360	1,060	700	-

MISCELLANEOUS DATA

Area Served	Meadowood Acres
Connections Served	180
Estimated Population Served	540
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (GAL.)	N/A
Average Daily Usage (GAL.)	N/A
System Pressure (PSI)	30-60
Interconnects	N/A
Date of Most Recent Sanitary Survey	6/25/91

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-16
Randolph Airforce Base
System Component Summary (1)

CCN Number: 12321
TDH ID Number: 150115

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well #A1	Facility #6402	V.T.	400	225	700
Well #B2	Facility #6403	V.T.	1,250	1,330	563
Well #C7	Facilty #6404	V.T.	750	620	583
Well #D10	Facility #6405	V.T.	1,250	1,050	524
Well #E11	Facilty #6406	V.T.	1,600	1,490	544
TOTAL			5,250	4,715	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
N/A	N/A	N/A
TOTAL		0

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Bldg #100	Elevated	500,000
Bldg #864	Elevated	500,000
Total Ground Storage (GAL.)	N/A	
Total Pressure Tank (GAL.)	N/A	
Total Elevated Storage (GAL.)	1,000,000	
Total Standpipe Storage (GAL.)	N/A	
TOTAL STORAGE (GAL.)	1,000,000	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	665	4,715	4,050	-
Pressure Storage (GAL.)	111,000	1,000,000	889,000	-
Elevated Storage (GAL.)	N/A	N/A	N/A	N/A
Total Storage (GAL.)	220,000	1,000,000	780,000	-
Service Pumps (GPM)	N/A	N/A	N/A	N/A

MISCELLANEOUS DATA

Area Served	Randolph Airforce Base
Connections Served	1,109
Estimated Population Served	11,091
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (MGD)	5.271
Average Daily Usage (MGD)	1.134
System Pressure (PSI)	47-65
Date of Most Recent Sanitary Survey	6/3/92

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-17
Rio Medina Estates
System Component Summary (1)

CCN Number: 11671
TDH ID Number: 1630022

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well # A1	West Part of Subdv.	SUB	200	178	900
TOTAL			200	N/A	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
At Well	1	100
	2	100
TOTAL		200

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
At Well Site	Ground	6,600
At Well Site	Ground	6,600
At Well Site	P.T.	2,500
Total Ground Storage (GAL.)	13,200	
Total Pressure Tank (GAL.)	2,500	
Total Elevated Storage (GAL.)	N/A	
Total Standpipe Storage (GAL.)	N/A	
TOTAL STORAGE (GAL.)	15,700	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	39	178	139	-
Pressure Storage (GAL.)	1,300	2,500	1,200	-
Elevated Storage (GAL.)	N/A	N/A	N/A	N/A
Total Storage (GAL.)	13,200	13,200	0	-
Service Pumps (GPM)	132	200	68	-

MISCELLANEOUS DATA

Area Served	Rio Medina Mobile Home Park
Connections Served	64
Estimated Population Served	192
Estimated Potential No. of Connections	66
Maximum Daily Usage (GAL.)	N/A
Average Daily Usage (MGD)	.022
System Pressure (PSI)	35-50
Interconnects	N/A
Date of Most Recent Sanitary Survey	1/27/92

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-18
San Antonio City Water Board
System Component Summary (1)

CCN Number:	10640
TDH ID Number:	0150018

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
N/A	N/A	N/A	N/A	N/A	N/A
TOTAL		–	0	N/A	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER		RATED CAPACITY (GPM)
N/A	N/A	N/A	
TOTAL			0

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
N/A	N/A	N/A

Total Ground Storage (GAL.)	N/A
Total Pressure Tank (GAL.)	N/A
Total Elevated Storage (GAL.)	N/A
Total Standpipe Storage (GAL.)	N/A
TOTAL STORAGE (GAL.)	0

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	N/A	N/A	N/A	N/A
Pressure Storage (GAL.)	N/A	N/A	N/A	N/A
Elevated Storage (GAL.)	N/A	N/A	N/A	N/A
Total Storage (GAL.)	N/A	N/A	N/A	N/A
Service Pumps (GPM)	N/A	N/A	N/A	N/A

MISCELLANEOUS DATA

Supplier and Source (2)	San Antonio City Water Board - Ground
Area Served	N/A
Connections Served (2)	2,023
Estimated Population Served	7,708
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (GAL.)	N/A
Average Daily Usage (GAL.)	N/A
System Pressure (PSI)	48-72
Date of Most Recent Sanitary Survey	1/31/92

(1) Based on Texas Department of Health Sanitary Survey of System.
(2) No facilities - All water received from service level 3 through pressure reducing valves. This service level includes one wholesale connection (Palm Park) with 248 connections. There are an additonal 1775 retail connections. System capacity requirements included in service level 3 calculations.

Table B-19
Silver Muntain Water company
System Component Summary (1)

CCN Number: 12321
TDH ID Number: 0150429

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well # A1	Silverwing St.	SUB	300	N/A	600
Well #B2	Silverwing St.	SUB	200	N/A	425
TOTAL			500	N/A	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
Well Site	1	80
Well Site	2	110
TOTAL		190

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Well Site	Ground	63,000
Well Site	P.T.	11,900
Well Site	P.T.	315
Total Ground Storage (GAL.)	63,000	
Total Pressure Tank (GAL.)	12,215	
Total Elevated Storage (GAL.)	N/A	
Total Standpipe Storage (GAL.)	N/A	
TOTAL STORAGE (GAL.)	75,215	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	14	500	486	-
Pressure Storage (GAL.)	480	12,215	11,735	-
Elevated Storage (GAL.)	N/A	N/A	N/A	N/A
Total Storage (GAL.)	48,000	63,000	15,000	-
Service Pumps (GPM)	48	190	142	-

MISCELLANEOUS DATA

Area Served	Silver Mountain Subd.
Connections Served	24
Estimated Population Served	72
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (GAL.)	N/A
Average Daily Usage (GAL.)	N/A
System Pressure (PSI)	40-60
Date of Most Recent Sanitary Survey	4/26/91

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-20
Twin Valley Water System
System Component Summary (1)

CCN Number: 10682
TDH ID Number: 0150147

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well # A1	Twin Valley Drive	SUB	80	85	404
Well #B2	Twin Valley Drive	SUB	80	85	412
TOTAL			160	170	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
Well Site	1	270
Well Site	2	200
Well Site	1	200
Transfer Pumps	2	160
TOTAL		830

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Well Site	Ground	10,000
Well Site	P.T.	5,600
Well Site	Ground	10,000
Total Ground Storage (GAL.)	20,000	
Total Pressure Tank (GAL.)	5,600	
Total Elevated Storage (GAL.)	N/A	
Total Standpipe Storage (GAL.)	N/A	
TOTAL STORAGE (GAL.)	25,600	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	81	175	94	-
Pressure Storage (GAL.)	2,700	5,600	2,900	-
Elevated Storage (GAL.)	N/A	N/A	N/A	N/A
Total Storage (GAL.)	30,000	20,000	-	10,000
Service Pumps (GPM)	272	470	198	-

MISCELLANEOUS DATA

Area Served	Twin Valley Subd.
Connections Served	136
Estimated Population Served	408
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (GAL.)	N/A
Average Daily Usage (GAL.)	41,000
System Pressure (PSI)	40-55
Date of Most Recent Sanitary Survey	9/26/91

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-21
Vos Water Company
System Component Summary (1)

CCN Number:	11987
TDH ID Number:	0150007

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well # A1	13901 IH 35 S.	SUB	150	N/A	70
Well # B2	13901 IH 35 S.	SUB	150	N/A	70
TOTAL			300	0	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
Well Site	1	300
	2	300
TOTAL		600

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Well Site	Ground	45,000
Well Site	Pressure Tank	5,700
Total Ground Storage (GAL.)	45,000	
Total Pressure Tank (GAL.)	5,700	
Total Elevated Storage (GAL.)	N/A	
Total Standpipe Storage (GAL.)	N/A	
TOTAL STORAGE (GAL.)	50,700	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	61	300	239	-
Pressure Storage (GAL.)	2,000	5,700	3,700	-
Elevated Storage (GAL.)	N/A	N/A	N/A	N/A
Total Storage (GAL.)	20,000	45,000	25,000	-
Service Pumps (GPM)	204	600	396	-

MISCELLANEOUS DATA

Area Served	Vos Water Co.
Connections Served	102
Estimated Population Served	306
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (GAL.)	N/A
Average Daily Usage (GAL.)	31,000
System Pressure (PSI)	40-55
Date of Most Recent Sanitary Survey	2/6/91

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-22
Waterwood Utilities, Inc.
System Component Summary (1)

CCN Number:	12082
TDH ID Number:	0150480

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well # A1	At Entrance to Subdivisic	SUB	150	95	910
TOTAL		–	150	95	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
Well Site	1	200
	2	200
Well Site	1	100
Trans. Pumps	1	100
TOTAL		400

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Well Site	Ground	42,500
Well Site	P.T.	5,000
Well Site (Settling Tank)	Ground	12,500
Well Site (Settling Tank)	Ground	12,500
Total Ground Storage (GAL.)	67,500	
Total Pressure Tank (GAL.)	5,000	
Total Elevated Storage (GAL.)	N/A	
Total Standpipe Storage (GAL.)	N/A	
TOTAL STORAGE (GAL.)	72,500	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	71	95	24	-
Pressure Storage (GAL.)	0	5,000	5,000	-
Elevated Storage (GAL.)	N/A	N/A	N/A	N/A
Total Storage (GAL.)	20,000	42,000	22,000	-
Service Pumps (GPM)	238	400	162	-

MISCELLANEOUS DATA

Area Served	Waterwood Subdivision
Connections Served	119
Estimated Population Served	357
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (GAL.)	N/A
Average Daily Usage (GAL.)	31,000
System Pressure (PSI)	45-72
Date of Most Recent Sanitary Survey	5/9/91

(1) Based on Texas Department of Health Sanitary Survey of System.

Table B-23
Windy's Water Works
System Component Summary (1)

CCN Number: 10641
TDH ID Number: 0150183

WELL PUMP CAPACITY

NO.	LOCATION	TYPE	RATED CAPACITY (GPM)	TESTED CAPACITY (GPM)	WELL DEPTH (FT)
Well #1	Crestwood Acres PS-N	SUB	75	37	400
Well #2	Crestwood Acres PS-S	SUB	55	30	435
Well #3	Wispering Winds PS	SUB	65	52	400
Well #4	Wispering Winds PS	SUB	80	N/A	530
Well #5	Pleasanton Oaks PS	SUB	100	65	435
Well #6	Highland Oaks PS	SUB	180	160	845
Well #7	Sherwood Forest PS	SUB	140	83	430
TOTAL			695	427	

HIGH SERVICE PUMP CAPACITY

LOCATION	PUMP NUMBER	RATED CAPACITY (GPM)
Crestood Acres PS	1	290
	2	100
Sherwood Forest PS	1	225
	2	225
Wispering Winds PS	1	100
	2	100
Pleasanton Oaks PS	1	150
	2	100
TOTAL		1,040

STORAGE FACILITIES

LOCATION	TYPE	CAPACITY (GAL.)
Crestwood Acres PS	Ground	44,000
Crestwood Acres PS	Ground	44,000
Wispering Winds PS	Ground	4,950
Wispering Winds PS	Ground	8,000
Wispering Winds PS	Ground	42,500
Pleasanton Oaks PS	Ground	55,500
Highland Oaks PS	Elevated	300,000
Sherwood Forest PS	Standpipe	77,700
Total Ground Storage (GAL.)	198,950	
Total Pressure Tank (GAL.)	N/A	
Total Elevated Storage (GAL.)	300,000	
Total Standpipe Storage (GAL.)	77,700	
TOTAL STORAGE (GAL.)	576,650	

EVALUATION OF SYSTEM CAPACITIES (MINIMUM REQUIREMENTS)

ITEM	AMOUNT REQUIRED	AMOUNT PROVIDED	EXCESS	DEFICIT
Well Pump Capacity (GPM)	406	427	21	-
Pressure Storage (GAL.) (2)	68,000	0	N/A	68,000
Elevated Storage (GAL.)	N/A	N/A	N/A	N/A
Total Storage (GAL.)	135,000	877,000	742,000	-
Service Pumps (GPM)	1,354	1,450	96	-

MISCELLANEOUS DATA

Area Served	S. Bexar and N.E. Atascosa Counties
Connections Served	677
Estimated Population Served	1,770
Estimated Potential No. of Connections	N/A
Maximum Daily Usage (MGD)	0.325
Average Daily Usage (MGD)	0.231
System Pressure (PSI) (2)	19-100
Date of Most Recent *Sanitary Survey*	10/30/91

(1) Based on Texas Department of Health Sanitary Survey of System.
(2) At the time of this survey, the lowest pressure found in the system was 19 psi at 1303 DuPont Road. Immediate action must be taken t correct an elevated storage capacity defficiency, no elevated storage capacity can be credited to this system based on the elevation of the connections that are served on Dupont Road and the current configuration of this system.

APPENDIX C

Bexar Metropolitan Water District
Water Conservation and
Emergency Water Demand Management Plan

APPENDIX C

1.0 WATER CONSERVATION AND EMERGENCY WATER DEMAND MANAGEMENT FOR THE BEXAR METROPOLITAN WATER DISTRICT

1.1 Introduction

The Texas Water Development Board has promulgated Financial Assistance Rules that require water conservation planning for any entity receiving financial assistance from the Board. The origin of these requirements is HB 2 and HJR 6, passed by the 65th Texas Legislature in 1985. On November 5th, 1985, Texas voters approved an amendment to the Texas Constitution that provided for the implementation of HB 2.

More specifically, Sections 15.106(b), 15.607, 16.136(4), 17.125(b), 17.277(c), and 17.857(b) of the Texas Water Code and Sections 363.59 and 375.37 of Chapter 31 of the Texas Administrative Code (TAC) require that applicants for financial assistance from the Texas Water Development Board (TWDB) submit a water conservation and emergency water demand management plan to the Board for approval, either with the application for financial assistance or after loan approval. In either case, the plan and resulting adopted program must be approved by TWDB before loan funds can be released.

The legislation is intended to encourage cost-effective regional water supply and wastewater treatment facility development. Since the early 1960s, per capita water use in the state has increased approximately four gallons per capita per day per decade. More importantly, per capita water use during droughts is typically about one third greater than during periods of average precipitation. Water use in the residential and commercial sectors involves day-to-day activities of all citizens of the state, and includes drinking, bathing, cooking, toilet flushing, fire protection, lawn watering, swimming pools, laundry, dishwashing, car washing and sanitation. In addition, rural areas carry the additional demands of supporting small-scale private livestock production and the, often not-so-small, family garden.

Thus, the goals of the program are to reduce overall water usage through water conservation practices and to provide for a reduction in water usage during times of shortage. The quantity of water required for daily activities can be dramatically reduced through implementation of efficient water use practices that are outlined in the following water conservation plan. The emergency water demand management program provides procedures for both voluntary and mandatory actions to temporarily reduce usage demand during a water shortage crisis. Emergency water demand management procedures include water conservation and prohibition of certain uses.

This chapter is designed to stand alone for submittal to the TWDB as a comprehensive water conservation and emergency water demand management plan for the Bexar Metropolitan Water District (BMWD) and to serve as a guide in the development of local or regional programs that are within the scope of the study planning area. Because this section is intended to be submitted under separate cover, some information has been duplicated from other chapters for the sake of clarity.

The actual TWDB guidelines, which are listed in the TWDB publication "Guidelines for Municipal Water Conservation and Emergency Water Demand Management," are presented in Table C-1 and are offered as an outline for this section. Two copies of this water conservation and emergency water demand management plan, including two copies of the official adopted plan and documentation of local adoption, should be submitted to:

Mr. Craig Pederson, Executive Director
Texas Water Development Board
P.O. Box 13231, Capitol Station
Austin, Texas 78711-3231

1.1.1 Description of the Planning Area and Project

The primary planning area is located in the southern portion of Bexar County and is comprised of 22 water purveyors, five of which are military bases. Of these water purveyors, only four lie outside of the contiguous boundary of the primary planning area. These outlying water purveyors are: Castle Hills, which is operated by the Bexar Metropolitan Water District and is located in central San Antonio; Brooks Air Force Base, which is located within the city limits of San Antonio and is just east of the primary planning area; Randolph Air Force Base, which is located in the Northeastern portion of Bexar County; and Fort Sam Houston Army Base, which is located in central San Antonio. Figure C-1 graphically displays the Planning Area boundary and the water purveyors located within this boundary.

The vast majority of water supplies within the primary planning area are obtained from the San Antonio portion of the Edwards Aquifer via water wells. Nine of the water purveyors, however, obtain water from other sources: four purveyors (Brooks Air Force Base, Lackland City Water Company-Columbia, Silver Mountain Water Company and Waterwood Utilities) purchase supplemental water from outside sources ; three purveyors (City of Elmendorf, Twin Valley Water System, and Windy's Water Works - Palo Alto Park/Whispering Winds-Crestwood Acres) obtain water via water wells from the Trinity Aquifer ; and one purveyor (Kings Point Water System) obtains water via water wells from the Corizo-Wilcox Aquifer.

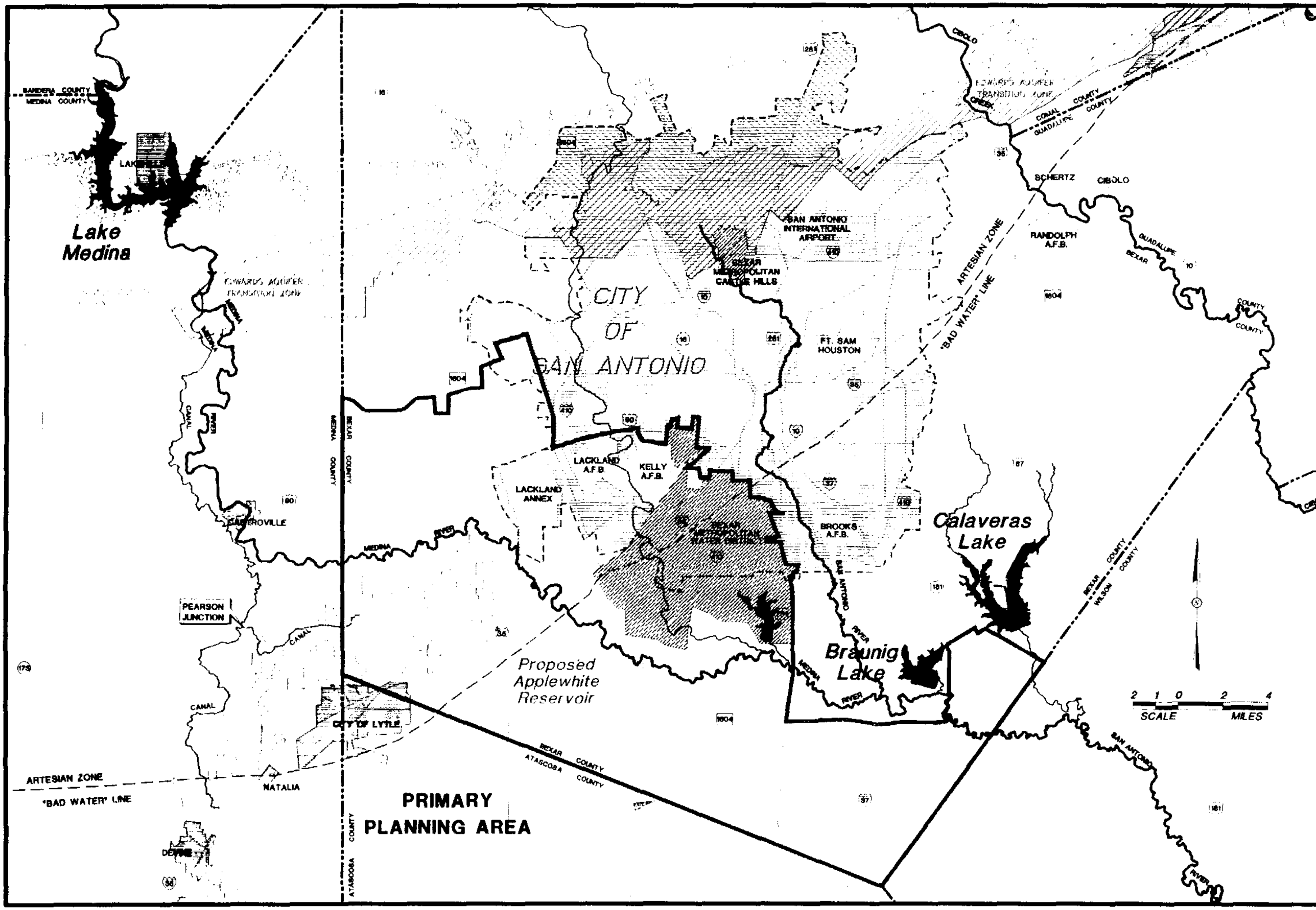
Table C-1

Texas Water Development Board Outline for Water Conservation and Emergency Water Demand Management Planning

Table C-1 (Cont.)

Texas Water Development Board Outline for Water Conservation and Emergency Water Demand Management Planning

Source: Texas Water Development Board
Note: Check marks indicate completed sections located in this section of the report.



MICHAEL SULLIVAN & ASSOC., INC.
Engineering & Environmental Consultants
Air - Water Quality - Water Resources

FIGURE C-1

STUDY AREA MAP

SUBMITTED TO:
Bexar Metropolitan Water District
FOR:
Southern Bexar County
Medina Valley Surface Water Supply Study

DATE: AUGUST 1992
DRAWN BY: DWS

Table C-2 lists the water purveyors located within the primary planning area, population served, number of connections, average daily use and per capita use, as recorded by the Texas Department of Health (TDH).

The overall objective of this study is to determine the adequacy of surface and ground water supplies available to the BMWD and surrounding water purveyors and to develop options for future supply acquisition and distribution infrastructure development. Given that additional capacity will be needed, cost estimates will be determined for various alternative development scenarios. This section describes water conservation and emergency water demand management measures that could have an impact on projected water supply demands and phasing of projects throughout the primary planning area.

1.1.2 Utility Evaluation Data

Texas Department of Health (TDH) Sanitary Surveys, Texas Water Development Board (TWDB) Historical Water Use Reports and 1990 Census Tract Data were utilized to evaluate current levels of service within the planning study area. Sanitary surveys provide information regarding water treatment plant capacity, high service pumping capacity, storage capacity, and ability to meet minimum pressure requirements. TWDB Historical Water Use Records were used to establish historical water consumption for the utilities surveyed. Census Tract Data was used to determine current population, total area within the primary planning area, and number of households within the Planning Area.

The primary planning area encompasses 371 square miles with 22 active water suppliers, serving a population of 215,845 persons through 61,721 connections. Table C-2 contains a summary of the water supply systems within the planning area, population served, number of connections served and water use data.

Sanitary surveys performed by personnel from the Texas Department of Health during 1990 and 1991 found that all of the identified water supply systems meet or exceed State minimum requirements for well pump capacity; two (Meadowood Acres and Windy's Waterworks) were found deficient in pressure storage capacity , and three (Bexar County WCID 16, Coolcrest Water System and Twin Valley Water System)were found deficient in total storage capacity. Additional utility information for the Bexar Metropolitan Water District, such as water uses, water rates, and other data that is required by the TWDB is presented in Table C-3.

1.1.3 Need for and Goals of Program

The water conservation plan outlined below will have the overall objective of reducing water consumption in the BMWD service area and will provide a guideline for other water purveyors located within the primary

Table C-2
Water Supply System Populations and Water Uses for Primary Planning Area

Water Supply System	CCN No.	Population Served	Number of Connections	Persons Per Connection	Average Daily Use (mgd)
Atascosa Rural Water Supply Corp.	11366	4,824	1,608	3.00	0.539
Bexar County WCID 16	11292	3,450	1,150	3.00	0.502
Bexar Metropolitan Water District-Castle Hills	10675	4,198	2,728	1.54	1.805
Bexar Metropolitan Water District-South San Antonio	10675	82,257	27,419	3.00	11.47
Brooks Air force Base	AFB	3,200	320	10.00	0.542
Coolcrest Water System	11106	693	231	3.00	0.071
Elmendorf, City of	10684	1,158	386	3.00	N/A
Ft. Sam Houston Army Base	AB	18,261	1,826	10.00	3.803
Kelly Air force Base	AFB	2,150	2,150	1.00	3.221
Kings Point Water System	10683	543	181	3.00	0.049
Lackland Air force Base	AFB	16,476	3,000	5.49	2.932
Lackland Air force Base - Annex	AFB	3,200	320	10.00	0.382
Lackland City Water Company - Columbia	10734	20,898	6,966	3.00	2.71
Lackland City Water Company - Park Village	10734	24,255	8,085	3.00	2.82
Lytle, City of	11007	2,751	917	3.00	0.454
Meadowood Acres Water Corp.	10657	540	180	3.00	N/A
Oakland Utility Company	11668	N/A	N/A	N/A	N/A
Randolph Air force Base	AFB	11,091	1,109	10.00	1.134
Rio Medina Water Corp	11671	192	64	3.00	0.022
San Antonio City Water Board	10640	7,708	2,023	3.81	N/A
Silver Mountain Water Co., Inc.	12321	72	24	3.00	N/A
Twin Valley Water System	10682	408	136	3.00	0.041
Vos Water Company	11987	306	102	3.00	0.031
Waterwood Utilities, Inc.	12082	357	119	3.00	0.031
Windy's Water Works, Inc.	10641	1,770	677	2.61	0.231
Source: Texas Department of Health Sanitary Surveys	**Total**	210,758	61,721	4	2

Table C-3

UTILITY EVALUATION DATA
BEXAR METROPOLITAN WATER DISTRICT

The following checklist provides a convenient method to insure that the most important items that are needed for the development of a conservation and drought contingency program are considered.

1. Utility Evaluation Data

   A. Population of service area — 130,000 (Number)

   B. Area of service area — 68.90 (Sq. mi.)

   C. Number and type of equivalent 5/8" Meter connections in service area — 26,586 (Residential)

      (3/4 " Only) — 1,933 (Commercial)

      ______ (Industrial)

   D. Net rate of new connection additions per year (new concoctions less disconnects) — 70 (Residential / Commercial / Industrial)

   E. Water Use information:

      1) Water production for the last year — 4,860,596,200 (gal./yr.)

      2) Average water production for last 2 years — 5,227,619,540 (gal./yr.)

      3) Average monthly water production for last 2 years — 405,049,683 (gal./mo.)

      4) Estimated monthly water sales by user category (1000 gal.) Use latest typical year:

Month	Year	Residential	Commercial-Institutional	Industrial	Total
January	1991				336,316,584
February	1991				278,409,156
March	1991				274,133,764
April	1991				328,535,596
May	1991				316,696,914
June	1991				374,317,072
July	1991				385,635,825
August	1991				425,618,029
September	1991				415,474,541
October	1991				344,246,444
November	1991				359,014,686
December	1991				311,971,166
Total					4,150,369,777

5) Average daily water use (Res./Comm./Ind.) 17,637,149 (gpd)

6) Peak daily use (Res./Comm./Ind.) 22,208,455 (gpd)

7) Peak to average use ratio (average daily Summer sue divided by annual average daily use) 1.26

8) Unaccounted for water (% of water production) 7 (%)

F. Wastewater Information N/A

1) Percent of your potable water customers sewered by your wastewater treatment system ______ (%)

2) Percent of potable water customers who have septic tanks or other privately operated sewage disposal systems ______ (%)

3) Percent of potable water customers sewered by another wastewater utility ______ (%)

4) Percent of total potable water sales to the three categories in F (1), F (2), F(3).

a) Percent of total sales to customers you serve ______ (%)

b) Percent of total sales to customers who are on septic tanks or private disposal systems ______ (%)

c) Percent of total sales to customers who are on other wastewater treatment systems ______ (%)

5) Average daily volume of wastewater treated ______ (gal.)

6) Peak daily wastewater volumes ______ (gal.)

7) Estimated percent of wastewater flows to your treatment plant that originate from the following categories:

Residential ______ (%)
Industrial and Manufacturing ______ (%)
Commercial/Institutional ______ (%)
Storm Water (I/I) ______ (%)
Other - Explain ______ (%)

G. Safe annual yield of water supply ______ (gal.) X 1000 (* Developed by TWDB)

H. Peak daily design capacity of water system ______ (gal.) X 1000

I. Major high-volume customers: (List) Quantity (cal/yr):

______ ______
______ ______
______ ______
______ ______

J. Population and water use or wastewater volume projections N/A

Year	Population Potential	Daily Average MGD	Daily Maximum MGD
1990			
1995			
2000			

K. Percent of water supply connection in system metered

100 (%) (Residential)

100 (%) (Commercial)

100 (%) (Industrial)

L. Water rate structure / Existing rate structure

Residential & Commercial	Residential & Commercial (Outside the City)	Industrial
	SEE ATTACHED SCHEDULE	

M. Average annual revenues from water and wastewater rates:

Water 5,343,153 (Dollars)

Wastewater ______ (Dollars)

N. Average annual revenue from non-rate derived sources:

805,169 (Dollars)

O. Average annual fixed costs of operation:

3,355,697 (Dollars)

P. Average annual variable costs of operation:

1,208,551 (Dollars)

Q. Average annual water or wastewater revenues for other purposes (if applicable):

5,696,545 (Dollars)

R. Applicable local regulations:

1979 Uniform Plumbing Code as amended for San Antonio

S. Applicable State, Federal or other regulations as a Public Water Supply, the BMWD must abide by the rules of the following agencies:

1)
2)
3)

2706 WEST SOUTHCROSS
POST OFFICE BOX 3577
SAN ANTONIO, TEXAS 78211-0577
922-1221 924-9229

BEXAR METRO WATER DISTRICT
SAN ANTONIO, TEXAS

RATES EFFECTIVE MARCH 1, 1992

SOUTHSIDE & SOMERSET ANNUAL RATE SCHEDULE

SMALL METER SERVICE CHARGE		PLUS CONSUMPTION PER 100 CU. FT.	
5/8"	$4.54	0 - 1500 CU. FT	$ .76
3/4"	$4.69	NEXT 8500 CU. FT	$ .82
1"	$5.34	OVER 10,000 CU. FT	$1.92
1-1/2"	$6.14		

LARGE METER SERVICE CHARGE		PLUS CONSUMPTION PER 100 CU. FT.	
2"	$ 8.36	0 - 1500 CU. FT	$ .76
3"	$24.65	NEXT 8500 CU. FT	$ .82
4"	$30.66	OVER 10,000	$1.15
6"	$44.75		
8"	$60.84		

CASTLE HILLS & NORTH SAN ANTONIO ANNUAL RATE SCHEDULE

SMALL METER SERVICE CHARGE		PLUS CONSUMPTION PER 100 CU. FT.	
5/8"	$4.54	0 - 1500 CU. FT	$ .76
3/4"	$4.69	NEXT 8500 CU. FT	$ .88
1"	$5.34	OVER 10,000 CU. FT	$2.31
1-1/2"	$6.14		

LARGE METER SERVICE CHARGE		PLUS CONSUMPTION PER 100 CU. FT.	
2"	$ 8.36	0 - 1500 CU. FT	$ .76
3"	$24.65	NEXT 8500 CU. FT	$ .88
4"	$30.66	OVER 10,000 CU. FT	$1.72
6"	$44.75		
8"	$60.84		

SERVICE CENTER
411 CARLISLE
SAN ANTONIO, TEXAS 78225

BEXAR METROPOLITAN WATER DISTRICT

PHONE 922-2141 FAX 921-2577

planning area. It will have the added advantage of reducing the amount of wastewater needing treatment and disposal. Although the impetus for this study is regional planning for water supply needs, the study focuses on measures that specifically reduce the amount of water used and, ultimately, on the amount of wastewater produced. Such measures will have the effect of extending the time until additional water and wastewater treatment capacity must be provided.

Various cities throughout the country have adopted water conservation techniques and technologies depending upon the severity of their water supply situation. In particular, California has taken significant steps to reduce water consumption, and here in Texas, the City of Austin has adopted an aggressive water conservation program. Drawing on the experiences of some of these cities, we can make some assumptions about the feasibility, cost and effectiveness of specific measures.

According to Texas Water Development Board high population series figures, the population of the Planning Area is expected to increase 183% percent over the period 1990 to 2040. With such high rates of growth, it is evident that the greatest savings in water usage can be realized by adopting stringent plumbing codes for new construction. Throughout the nation, utilities are finding that revised plumbing codes that reduce new water usage by 25-30 percent can have a significant impact on reducing the high cost of renovating and constructing water and wastewater treatment facilities. However, because water use in rural areas is less weighted toward domestic functions, lesser reductions, on the order of 10-15 percent, can be expected.

Existing plumbing facilities can also be retrofitted in order to reduce water consumption. Although this may involve an initial capital outlay, all of the measures are cost-effective in the long-term, and various methods have been devised to recover the costs. For instance, a plan for San Antonio assumes that a two percent increase in water and wastewater rates for 5 years would raise enough money to cover a $100 rebate for each customer retrofitting a toilet to flush on 1.5 gallons (resulting in an overall savings on the customer's water and wastewater bill). An aggressive retrofit program can result in water savings of 15-25 percent per residence. With market penetration typically running at 20-50 percent, this would result in an overall water consumption savings of around 5 percent. In its water conservation program, the City of Austin estimates a 6.7 percent savings within 5 years. This program consists of substituting low-flow shower heads, installing toilet dams, and checking for leaks. The benefit/cost ratio is estimated at more than ten, with an average savings to the customer of $52/year from reductions in water, wastewater and electricity.

Figure C-2 shows water demand through the year 2040 for Bexar Metropolitan Water District for drought conditions without implementation of water conservation measures. Also shown are the flows that would

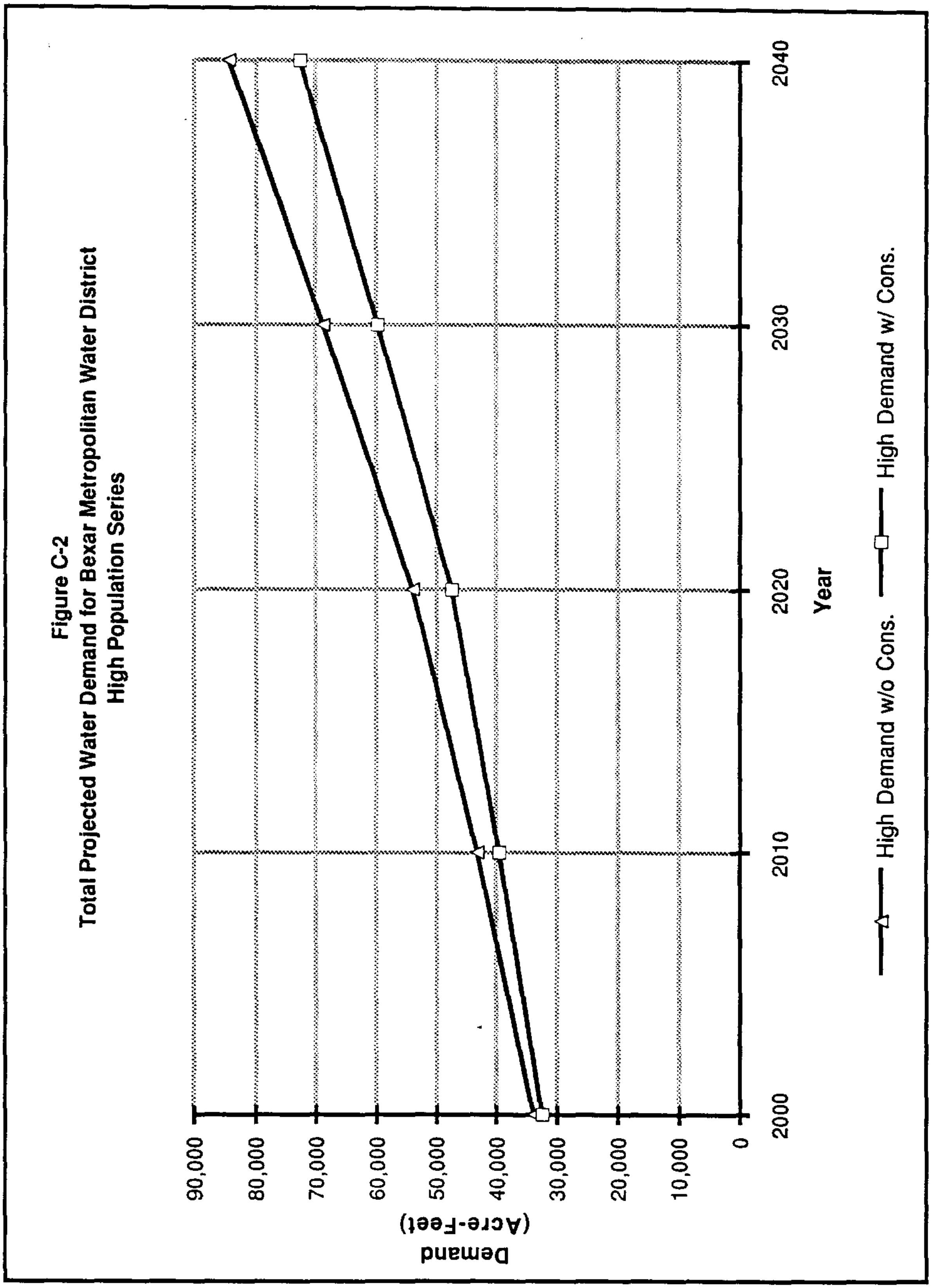


Figure C-2
Total Projected Water Demand for Bexar Metropolitan Water District
High Population Series

result from the adoption of the two measures outlined above. Overall savings by 2040 are approximately 14 % or 11,796 AF/yr. The assumptions made are:

- adoption of a code that would reduce water consumption in all new construction ;
- this code would be phased in during the 1990s and early 2000s (a net water savings of 2% by 1995; 5% by 2000; 7-1/2% by 2005; 10% by 2010; 12-1/2% by 2015 and 15% by 2020);
- existing uses could be reduced by 5 percent through retrofitting and other conservation measures.

The emergency water demand management program (See Section 1.3 of Appendix C) includes those measures that can cause BMWD to significantly reduce water use on a temporary basis. These measures involve voluntary reductions, restrictions, and/or elimination of certain types of water use and water rationing. Because the onset of an emergency condition is often rapid, it is important that the BMWD be prepared in advance. Further, the citizen or customer must know that certain measures not used in the water conservation program may be necessary if a drought or other emergency condition occurs.

1.2 Long-term Water Conservation

Eleven principal water conservation methods are delineated as part of the proposed water conservation plan.

1.2.1 Education and Information

The most readily available and lowest cost method of promoting water conservation is to inform water users about ways to save water inside of homes and other buildings, in landscaping and lawn maintenance, and in recreational uses. An effective education and information program can be easily and inexpensively administered by the BMWD. Information will be distributed to water users as follows:

1.2.1.1 First-Year Program

- The initial year will include the distribution of educational materials. A fact sheet detailing water savings methods that can be practiced by the individual water user is recommended and is available from the TWDB.

- Distribution of a fact sheet explaining the newly-adopted Water Conservation Program and the elements of the emergency water demand management Plan. The initial fact sheet will be included with the first distribution of educational material.

- In addition to activities scheduled in the Long-Term Program, an outline of the program and its benefits will be distributed either through the mail or as a door-to-door hand-out.

1.2.1.2 Long-Term Program

Distribution of educational materials will be made semi-annually, timed to correspond with peak summer demand periods. Such material will incorporate information available from the American Water Works Association (AWWA), Texas Water Development Board (TWDB) and other similar associations in order to expand the scope of this project. A wider range of materials may be obtained from:

CONSERVATION
Texas Water Development Board
P.O. Box 13231 - Capitol Station
Austin, Texas 78711-3231

1.2.1.3 Information to New Customers

New customers will be provided with a similar package of information as that developed for the first year, namely, educational material, a fact sheet explaining both the Water Conservation Program and the elements of the Emergency water demand management Plan, and a copy of "Water Saving Methods That Can Be Practiced by the Individual Water User".

1.2.2 Conservation-Oriented Water Rate Structure

The structure of rates is as important as the rate itself in sending appropriate signals to consumers. There are over 20 different types of rate structures used throughout the nation, some of which can be used in combination. Some rate structures encourage conservation; others discourage it. Prices should be set to reflect the actual cost of service, including all costs associated with property, hardware, operations, maintenance and personnel. These costs should include depreciation of capital assets and needed planning expenses. Prices should not be hidden in property taxes, as this eliminates a direct incentive for conservation.

There is little consensus regarding what pricing structures are most effective in encouraging conservation. However the following are known about consumer behavior:

- If a new pricing structure results in an unchanged total bill, there will be no response by the users.
- When prices do go up, response is delayed until bills are received.
- The initial response to higher rates may exceed the long term response if the perceived price impact is greater than the ultimate reality.
- If prices are too low in the first place, a price increase may have little impact on demand.

BMWD is currently studying the myriad of conservation-oriented rate structures and will select a system that will most effectively serve the particular needs of their system.

1.2.3 Universal Metering and Meter Repair and Replacement

All water users in the BMWD service area are currently metered. All new construction, including multi-family dwellings, is separately metered. The program of universal metering will continue, and is made part of the Water Conservation Plan.

The BMWD, through their billing system, currently monitors water consumption and inspects meters that vary from previously established norms. In addition, the BMWD will establish the following meter maintenance and replacement programs that are recommended by the TWDB :

Meter Type	Test and Replacement Period
Master meter	Annually
Larger than 1 1/2 inch	Annually
1 1/2 inch and less	Every 10 years

BMWD will continue to maintain a successful meter maintenance program, coupled with computerized billing and leak detection programs.

1.2.4 Water Audits and Leak Detection

BMWD will utilize modern leak detection techniques in locating and reducing leaks. Through their billing program, BMWD will audit and identify excessive usage and take steps to determine whether it is a result of leakage. Once located, all leaks will be immediately repaired. A continuous leak detection and repair program is vital to profitability.

1.2.5 Means of Implementation and Enforcement

The staff of the BMWD will administer the Water Conservation Program. They will oversee the execution and implementation of all elements of the program and supervise the keeping of adequate records for program verification.

The plan will be enforced through the adoption of the Water Conservation Plan by the BMWD in the following manner:

- Water service taps will not be provided to customers unless they have met the plan requirements;
- The proposed rate structure will encourage retrofitting of old plumbing fixtures that use large quantities of water; and

- The building inspector will not certify new construction that fails to meet plan requirements.

BMWD will adopt the final approved plan and commit to maintaining the program for the duration their financial obligation to the State of Texas.

1.2.6 Periodic Review and Evaluation

On a biannual basis, BMWD will re-evaluate water use rates and per capita consumption figures to determine if there is evidence of increased losses in the system through mechanical breakdown or leakage and if the stated water conservation goals of the original plan are being achieved.

1.2.7 Water Conserving Landscaping

In order to reduce the demands placed on the water system by landscape, livestock and garden watering, the BMWD, through its information and education program, will encourage customers and local landscaping companies to utilize water saving practices during installation of landscaping, gardens and stock watering facilities for residential and commercial institutions. The following methods which are recommended by the TWDB will be promoted by the education and information program:

- Encourage subdivisions and landscape architects to require drought-resistant grasses and plants that require less water and efficient irrigation systems.
- Initiate a program to encourage the adoption of xeriscaping.
- Encourage licensed irrigation contractors to use drip irrigation systems, when possible, and to design all irrigation systems with conservation features such as sprinklers that emit large drops rather than a fine mist and a sprinkler layout that accommodates prevailing wind patterns.
- Encourage commercial establishments to use drip irrigation for landscape watering, when practical, and to install only ornamental fountains that use minimal quantities of water, including recycling features.
- Encourage local nurseries to offer adapted, drought-resistant plants and grasses and efficient watering devices.
- Establish landscape water audit programs, demonstration gardens and related programs.
- Practice other outdoor conservation practices such as covering pools and spas to reduce evaporation.

1.2.8 Distribution System and/or Customer Service Pressure Control

Pressure reductions will help save water by reducing the amount of water that will flow through an opened valve or faucet in a given period of time. Water is also saved by reducing excessive mechanical stress on plumbing fixtures and appliances and on distribution systems. Faucet seats and washers last longer, washing machine and dishwasher valves will break less frequently, pipe joints will be less susceptible to failure, and leaks in the distribution system will loose water more slowly at lower pressure.

BMWD will evaluate if excessive pressure in parts of the distribution system is a problem and, if it is, provide information on plans to reduce the problem of excessive pressure. It is recommended that pressure in customer service not exceed 80 pounds per square inch.

1.2.9 Recycling and Reuse

Reuse utilizes treated effluent from an industry, municipal system or agricultural return flows to replace an existing use that currently requires fresh water from a utility's supply. Recycling utilizes in-plant process or cooling water to reduce the amount of fresh water required by other industrial operations. BMWD currently collects the wastewater for its service area, but the effluent is treated by the San Antonio Water Board. Therefore, reuse is not currently an option for the BMWD System.

1.2.10 Water Conservation Retrofit Program

The BMWD will make available, through its education and information programs, pertinent information for the purchase and installation of plumbing fixtures, lawn watering equipment and appliances. The advertising program will inform existing users of the advantages of installing water saving devices. The BMWD will contact local plumbing and hardware stores and encourage them to stock water conserving fixtures, including retrofit devices.

In addition, the BMWD will embark upon an aggressive retrofit program. Several alternatives are summarized in Tables C-4 and C-5. Market penetration is based on the experience of other cities offering such programs. Savings are calculated based on TWDB's high series population projections for the year 2040 (5,830 persons in BMWD-Castle Hills and 288,681 persons in BMWD-South Side) and an assumed household size of 2.51 and 4.61 persons per household, respectively. The assumed household size was taken from an in-depth study entitled, "Equity in Drought Management: Residential Water Use Characteristics of Major Bexar County Purveyors" by Gregg A. Eckhardt, July 1990.

Table C-4

Expected Savings to the BMWD-Castle Hills Service Area Through Implementation of a Water Use Retrofit Program

Action	Cost Per House a/	Savings Per House b/ (gpd)	Penetration c/	Total Savings d/ (gpd)	Total Cost e/	Cost Per gpd f/
Distribution of Water Savings Kits g/	$1.00	18.4	50%	21,369	$1,161	$0.05
Vouchers for Shower Heads and Toilet Dams h/	$8.00	38.2	20%	17,746	$3,716	$0.21
Installation of Shower Heads and Toilet Dams i/	$20.00	33.9	50%	39,370	$23,227	$0.59
Refund for Replacing Toilets j/	$400.00	45.7	10%	10,615	$92,908	$8.75

a/ Assumes two bathrooms per single-family residence.

b/ Based on 291 gpcd and 2.51 persons per residence as reported in Gregg Eckhard's Study "Equity in Drought Management: Residential Water Use Characteristics fo Major Bexar County Purveyors".

c/ Percentage of residences participating fully in the program.

d/ Based on 2040 projections of 5,830 persons in BMWD-Castle Hills Service Area (2,323 residences).

e/ Total Program implementation cost.

f/ Cost per gpd saved.

g/ Assumes free distribution to all services area residences @ two kits per residence.

h/ Assumes participant retrieval of kits @ two kits per residence.

i/ Assumes installation by BMWD personnel or private contractors.

j/ Assumes $200 per toilet.

Table C-5

Expected Savings to the BMWD-South Side Service Area Through Implementation of a Water Use Retrofit Program

Action	Cost Per House a/	Savings Per House b/ (gpd)	Penetration c/	Total Savings d/ (gpd)	Total Cost e/	Cost Per gpd f/
Distribution of Water Savings Kits g/	$1.00	18.4	50%	576,110	$31,310	$0.05
Vouchers for Shower Heads and Toilet Dams h/	$8.00	38.2	20%	478,421	$100,193	$0.21
Installation of Shower Heads and Toilet Dams i/	$20.00	33.9	50%	1,061,419	$626,206	$0.59
Refund for Replacing Toilets j/	$400.00	45.7	10%	286,176	$2,504,824	$8.75

a/ Assumes two bathrooms per single-family residence.

b/ Based on 75 gpcd and 4.61 persons per residence as reported in Gregg Eckhard's Study "Equity in Drought Management: Residential Water Use Characteristics fo Major Bexar County Purveyors".

c/ Percentage of residences participating fully in the program.

d/ Based on 2040 projections of 288,681 persons in BMWD-Castle Hills Service Area (62,621 residences).

e/ Total Program implementation cost.

f/ Cost per gpd saved.

g/ Assumes free distribution to all services area residences @ two kits per residence.

h/ Assumes participant retrieval of kits @ two kits per residence.

i/ Assumes installation by BMWD personnel or private contractors.

j/ Assumes $200 per toilet.

The least-cost alternative is to deliver two packages/house containing two flow restrictors, a plastic restrictor for a shower head, a toilet bag and two dye tablets. Based on past experience, the toilet bags are the most acceptable to customers and could be expected to realize savings of 4.8 gpcd in participating households. A more acceptable and more permanent option is to provide customers with low-flow shower heads and toilet dams. Because of the greater costs associated with providing these items, vouchers could be included in the water bill to be exchanged at convenient locations for each customer. It is assumed that most of the equipment claimed through this mechanism would be installed. Another more fool-proof system, used extensively in the City of Austin, involves the installation of low-flow shower heads and toilet dams at no charge to the customer. In Austin, market penetration has exceeded 50 percent and in participating households has resulted in water savings of around 15 percent. A fourth option is to provide rebates of $100 to customers who replace their toilets with those that flush 1.5 gallons.

1.2.11 Water Conservation Plumbing Codes

The BMWD study area generally adheres to and enforces the 1979 Southern Building Code's Standard Plumbing Code, as amended for San Antonio. BMWD will adhere to the legislation, passed by the 72nd Texas Legislature, that requires that plumbing fixtures sold in Texas after January 1, 1992, meet the following standards:

- showers shall be equipped with approved flow control devices to limit total flow to a maximum of 2.75 gallons per minute (gpm) at 80 pounds per square inch of pressure;
- sink faucets shall deliver water at a rate not to exceed 2.2 gpm at 60 pounds per square inch of pressure;
- wall mounted, Flushometer toilets shall use a maximum of 2.0 gallons per flush;
- all other toilets shall use a maximum of 1.6 gallons per flush;
- urinals shall use a maximum of 1.0 gallons per flush;
- and drinking water fountains must be self closing.

1.3 EMERGENCY WATER DEMAND MANAGEMENT RESPONSE MEASURES

1.3.1 Introduction

Drought and other uncontrollable circumstances can disturb the normal availability of a community or utility water supply. As a result of this study and subsequent activities, BMWD will be more fortunate than most local water purveyors; BMWD will have access to both ground and surface water. The BMWD will be able to conjunctively draw on ground and surface water sources. Selective BMWD wells will be maintained and will be used to augment or replace surface supplies during extreme drought periods. Some wells may be replaced with new wells for use during droughts.

A drought management condition triggering criteria has been established, predicated on both available storage in Lake Medina and water levels in the Edwards Aquifer. Drought management practices will be implemented when either, or both, of these indicators correspond to the trigger criteria. Section 1.3.2 of Appendix C outlines a three-stage normal-use curtailment plan that will be enacted at specific Lake Medina storage and/or Edwards Aquifer well levels.

A revised BMWD - Drought Management Plan will be developed as a result of this surface water availability study and the selection and implementation of a preferred BMWD surface water development program. That Drought Management Plan will be submitted to the TWDB under separate cover. Drought trigger levels and Management Response Measures may vary slightly from those contained in this document as a result of plan implementation.

1.3.2 Trigger Condition and Level of Severity

1.3.2.1 Mild Drought Condition

Lake Medina Trigger Level - Lake Medina Storage reaches, on its falling stage, 180,000 ac-ft (Figure C-3) for 14 consecutive days (moving average). This trigger level could be discontinued when lake levels rise above 180,000 ac-ft for more than 14 consecutive days or, in the judgment of the BMWD, that this condition no longer exists.

Edwards Aquifer Trigger Level - Edwards Aquifer Level reaches 649 ft MSL, on its falling stage, measured at Observation Well J17 located at Fort Sam Houston.

1.3.2.2 Moderate Condition

Lake Medina Trigger Level - Lake Medina Storage reaches, on its falling stage, 150,000 ac-ft (see Figure C-3) for 14 consecutive days (moving average). This trigger level could be discontinued when lake levels rise above 150,000 ac-ft for more than 14 consecutive days or, in the judgment of the BMWD, that this condition no longer exists.

Edwards Aquifer Trigger Level - Edwards Aquifer Level reaches 637 ft MSL, on its falling stage, measured at Observation Well J17 located at Fort Sam Houston.

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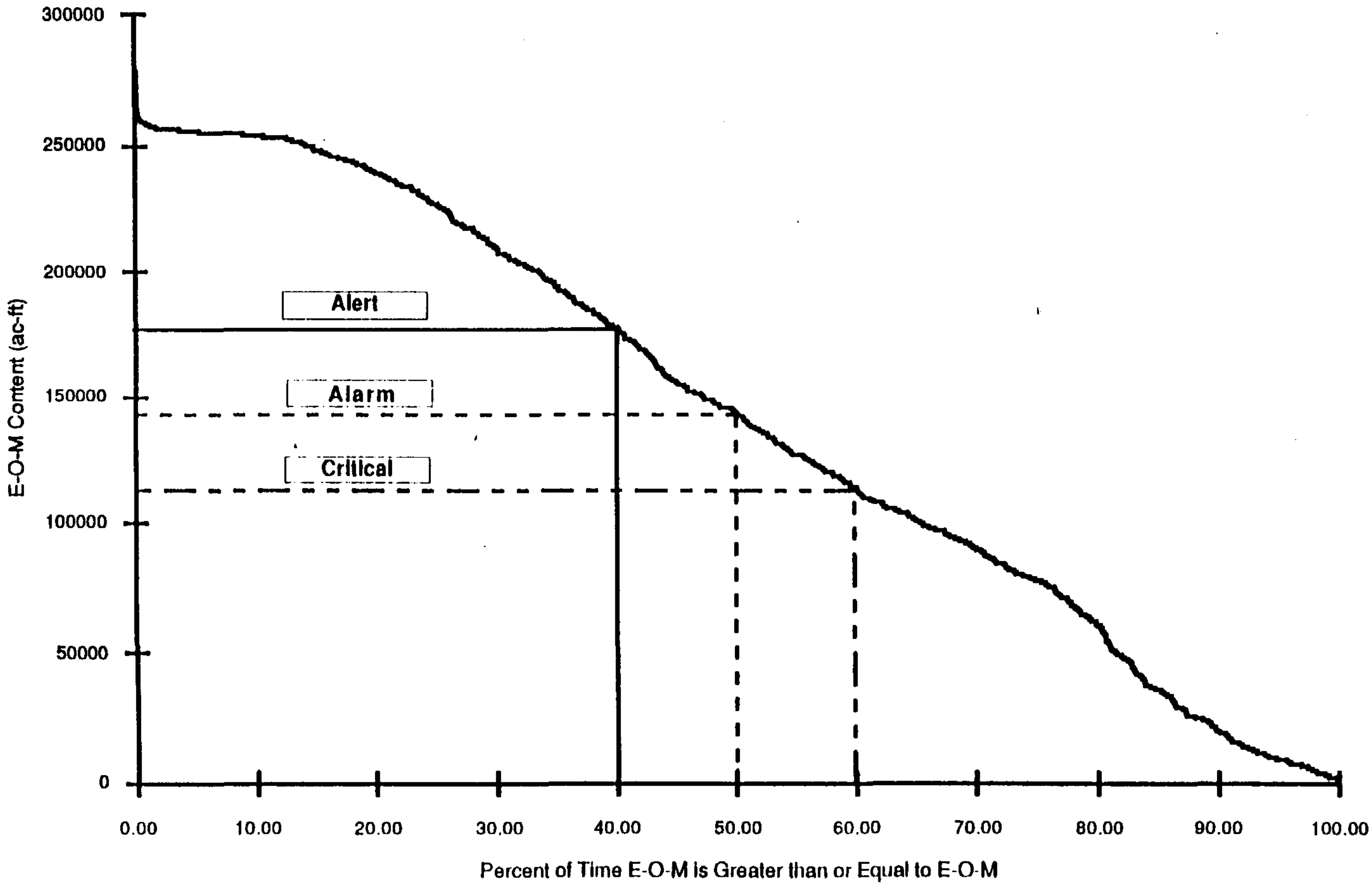
Medina Valley Surface Water Supply Study
Bexar Metropolitan Water District
Bexar-Medina-Atascosa Water Control and Improvement District

Figure C-3
Medina Lake End of Month Content Frequency Curve



Michael Sullivan and Assoc., Inc.
Engineering and Environmental Consultants
Austin, Texas

MSA 91023

1.3.2.3 Severe Condition

Lake Medina Trigger Level - Lake Medina Storage reaches, on its falling stage, 120,000 ac-ft (see Figure C-3) for 14 consecutive days (moving average). This trigger level could be discontinued when lake levels rise above 120,000 ac-ft for more than 14 consecutive days or, in the judgment of the BMWD, that this condition no longer exists.

Edwards Aquifer Trigger Level - Edwards Aquifer Level reaches 625 ft MSL, on its falling stage, measured at Observation Well J17 located at Fort Sam Houston.

Under all three drought conditions, if hydrologic events unfold more rapidly than within 14 days, the BMWD may respond as necessary.

1.3.3 Emergency Water Demand Management Response Measures

The BMWD southern service area typically uses only 53% of the per capita daily water use as compared to the City of San Antonio. Thus, the margin for drought condition water conservation is considerably less than that enjoyed by the remainder of the metropolitan area. In addition, within the BMWD service area there are currently no major water-consuming industries where significant reductions can be attained; all water savings are derived from residential users. This limits the amount of drought condition demand reductions that can be reasonably expected from the BMWD southern service area.

1.3.3.1 Mild Drought Condition

Under mild drought conditions, water conservation measures will be voluntary. Conservation measures to be instituted by BMWD will include:

- BMWD will inform its customers through notice of mild drought conditions.
- Voluntary curtailment of excessive water use activities will be encouraged.
- BMWD staff will contact major water users and request cooperation in unnecessary use curtailment.

Voluntary conservation measures typically result in only a 0-2% reduction in total M&I demand.

1.3.3.2 Moderate Drought Condition

Under moderate drought conditions, water conservation measures will be mandatory. Mandatory conservation measures will include:

- BMWD will inform the public of moderate drought conditions. The notice will be posted as well as advertised through the news media.

- BMWD will require reduction of certain outdoor water uses.

Winter reductions will only amount to about 5% of total use; summer reductions will be larger and account for about 10% of total use.

1.3.3.3 Severe Condition

Under severe drought conditions, water conservation will be mandatory. Conservation measures will include:

- BMWD will inform the public of severe drought conditions. The notice will be posted as well as advertised through the news media.
- BMWD will require curtailment of certain outdoor water uses. Lawn watering will be reduced through a mandatory odd/even house address schedule. If drought conditions persist, all outdoor watering may be banned.

- Utilities will be encourage to curtail all large scale water consumption activities.

Severe drought condition reductions can be expected to near 10% in winter; however, summer reductions can approach 20%.

Drought condition water conservation reductions proposed for the BMWD southern service area are shown in Table C-6.

1.3.4 Information and Education

As a component of the Information and Education section in the Water Conservation Plan, the purpose and effect of the Drought Contingency Plan will be to communicate to the public through articles in the local newspaper, radio and television media.

1.3.5 Initiation Procedures

When trigger conditions appear to be approaching, the public will be notified through publication of articles in the local news paper, radio and television media.

1.3.6 Termination Notification Actions

When trigger conditions have passed, the local newspapers, radio and television media will publish notification that the drought contingency measures are abated for that condition.

Table C-6
Drought Condition BMWD Municipal & Industrial Demand Reductions

	BMWD Municipal & Industrial Drought Demand Reductions (%)					
	Mild Drought		Moderate Drought		Severe Drought	
Month	Winter	Summer	Winter	Summer	Winter	Summer
January	0-2		5		10	
February	0-2		5		10	
March		0-2		10		20
April		0-2		10		20
May		0-2		10		20
June		0-2		10		20
July		0-2		10		20
August		0-2		10		20
September		0-2		10		20
October		0-2		10		20
November	0-2		5		10	
December	0-2		5		10	

Throughout the period of trigger conditions, regular articles will appear to explain and educate the public on the purpose, cause and methods of conservation for that condition. Also, information will be provided daily to the local media to relate how much water was used the previous day.

1.3.7 Means of Implementation

It will be the responsibility of BMWD to monitor the status of the water storage in Medina Lake and water levels in Observation Well J17. When a trigger condition is reached, BMWD will notify each entity and begin implementation of the Drought Contingency Plan.

The BMWD will continue to monitor the water emergency until it is determined that a trigger condition no longer exists and then advise all entities of the change in condition.

1.4 Legal and Regulatory Components

1.4.1 Plan Adoption Resolution (Required)

BMWD Follow-up Needed

1.4.2 Emergency Water Demand Management Ordinance/Regulation (Required)
BMWD Follow-up Needed

1.4.3 Means to Pass Requirements on to Customer Utilities if Project Will Be Used by Other Utilities (Required for Regional Projects)

BMWD Follow-up Needed

1.4.4 Water Conservation Plumbing Code Ordinances/Regulation (Required if Plumbing Regulations are Implemented)

BMWD Follow-up Needed

1.4.5 Plumbing Fixture Retrofit Ordinance/Regulation (Optional)

1.4.6 Conservation-Oriented Rate Ordinance/Regulation (Optional)

1.4.7 Water Conservation Landscape Ordinance/Regulation (Optional)

1.5 Contracts With Other Political Subdivisions

The BMWD will, as part of a contract for sale of water to any other political subdivision, require that entity to adopt applicable provisions of the BMWD's water conservation and emergency water demand management plan or already have a plan in effect. These provisions will be through contractual agreement prior to the sale of water to the political subdivision.

1.6 Annual Reports

The TWDB requires financial assistance recipients that implement a program of water conservation to submit an annual report to the Executive Administrator describing the implementation, status, and quantitative effectiveness of the water conservation program until its financial obligations to the State have been discharged (31 TAC §363.71). BMWD will submit an annual report within sixty (60) days after the anniversary date of the loan closing.

APPENDIX D

Bexar-Medina-Atascosa WCID No. 1
Water Conservation and
Emergency Water Demand Management Plan

APPENDIX D

1.0 WATER CONSERVATION AND EMERGENCY WATER DEMAND MANAGEMENT FOR THE BEXAR-MEDINA-ATASCOSA WATER CONTROL AND IMPROVEMENT DISTRICT NO. 1

1.1 Introduction

The Bexar-Medina-Atascosa Water Control and Improvement District No. 1 (BMA) owns and operates a surface water irrigation system located in parts of Bexar, Medina and Atascosa Counties, Texas. The operation and service area of the BMA entails the Planning Area for this Water Conservation and Emergency Water Demand Management Program.

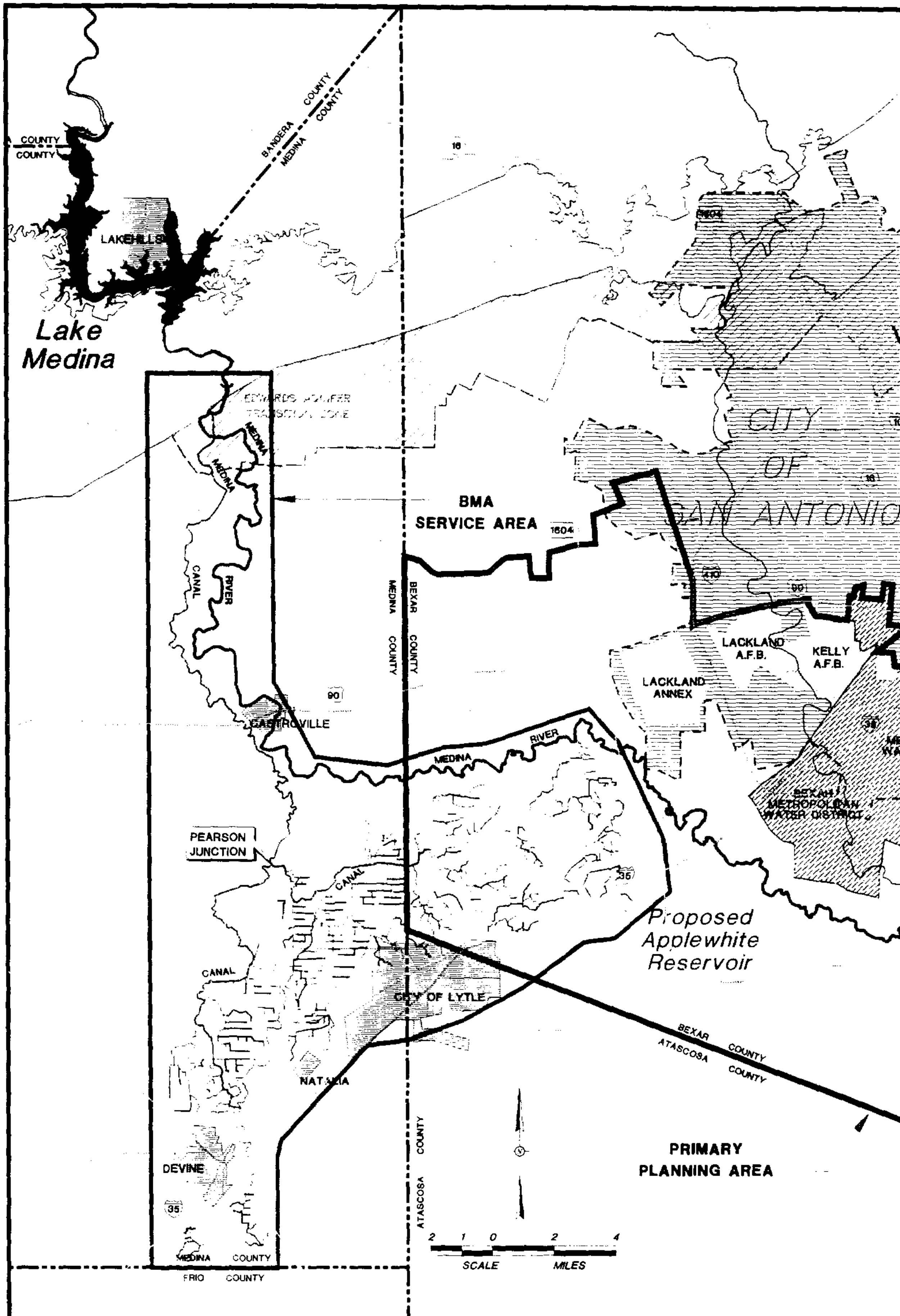
The BMA, a non-profit political subdivision of the State of Texas, and its predecessor entities began organization in 1910. The BMA irrigation system is comprised of Medina Lake and Medina Diversion Lake, both located on the Medina River approximately 30 miles northwest of San Antonio, and an extensive system of mostly earthen irrigation canals and laterals (Figure D-1).

Medina Lake, with a capacity of 254,000 ac-ft, is the primary source of water supply for the BMA irrigation system. Water is released from Medina Lake to the Medina Diversion Lake via three 60-inch diameter outlet pipes, and subsequently diverted into the BMA Canal System (Figure D-1). The canal system is comprised of approximately 266 mi of unlined, open channels. This system delivers water by gravity flow to over 34,000 acres of land.

Water from the Medina Diversion Lake is diverted into the BMA Main Canal via control gates. The course of the Main Canal roughly parallels that of the Medina River, primarily on its west side, for most of the way to the City of Pearson. The bed material of the canal is earthen, except for an initial concrete-lined section of approximately 0.5 mi in length extending from Medina Diversion Lake. The Main Canal branches at Pearson (the "Pearson Junction"), into two canals: A-1 Canal and D-1 Canal.

Irrigation water usage along the Main Canal is minimal. It is estimated that a maximum of 300 ac of land are irrigated directly from the Main Canal. In addition, water from the Main Canal is used to provide supplemental water to 3 stock tanks, which have an estimated total capacity of less than 25 ac-ft. The Main Canal requires a high level of continual maintenance by BMA. The canal levee frequently fails, causing significant water losses. In addition, there are frequent occurrences of land slides into the canal from the higher elevation hills from which the canal is cut.

The A-1 and D-1 Canals supply water directly to irrigators and to a complex series of lateral canals (Figure D-1). The A-1 canal flows in an easterly direction for a distance of 5.8 mi where it provides water



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Air - Water Quality - Water Resources

FIGURE D-1

BMA SERVICE AREA MAP

SUBMITTED TO:
Bexar Metropolitan Water District
FOR:
Southern Bexar County
Medina Valley Surface Water Supply Study

DATE: AUGUST 1992

DRAWN BY: DWS

to an estimated 152.6 mi of canals and laterals. D-1 Canal flows in a southwesterly direction for a distance of 11.4 mi. This canal provides water to an additional 74.0 mi of canals and laterals.

D-1 Canal also provides water to Chacon Reservoir, located on Chacon Creek about 4 mi north of Natalia. Chacon Reservoir, owned and operated by the BMA, has a storage capacity of about 2,000 ac-ft. This reservoir impounds a small amount of runoff from Chacon Creek, but is primary used to store surplus water from the Main Canal and D-1 Canal. Stored water is released from Chacon Reservoir to downstream BMA irrigators.

1.1.2 Utility Evaluation Data

Data and information compiled by the BMA, the U.S. Geological Survey (USGS), U.S. Bureau of Reclamation (BuRec), Texas Water Commission (TWC) and Texas Water Development Board (TWDB) were utilized to evaluate BMA system components and current levels of service within the BMA planning study area.

1.1.2.1 BMA's Water Rights

The BMA holds three primary water rights in the Medina River Basin. BMA is recognized under Certified Filing (CF) No. 18 the right to impound 237,874 ac-ft and 4,500 ac-ft of water in Medina Lake and Medina Diversion Lake, respectively. Under CF No. 18, BMA has the right to divert from the Medina Diversion Lake 63,098 ac-ft per yr for the purpose of irrigating 31,549 ac within BMA's boundaries. In addition, BMA is recognized the right to divert from Lake Medina and/or Medina Diversion Lake 750 ac-ft per yr for domestic and livestock purposes for use by inhabitants in BMA's boundaries. BMA may also under CF No. 18 perfect the diversion and use of an additional 2,902 ac-ft of water per year from Medina Lake and/or Medina Diversion Lake for irrigation of an additional 1,451 acres of land located within the BMA boundaries. In essence, BMA has water rights in Lake Medina and Medina Diversion Lake to store a total of 242,374 ac-ft of water, to divert a total of 66,750 ac-ft/yr for irrigation, domestic and livestock purposes, and to irrigate a total of 33,000 acres located within BMA boundaries. With a priority date November 16, 1910, CF No. 18 is the most senior water right in the Medina River Basin.

Under Certified Filing No. 19, the BMA is recognized the right to impound 730 ac-ft of water in Chacon Reservoir and to annually divert and use, at a maximum diversion rate of 22.2 cfs, 2,000 ac-ft for the irrigation of 1,000 ac of land located within the BMA boundaries. CF No. 19 has a priority date of March 20, 1912.

Therefore, BMA's water rights (CF Nos. 18 and 19) within the Medina River Basin total an annual diversion rate of 68,750 ac-ft from a combined storage capacity (Lake Medina, Medina Diversion Lake and Chacon Reservoir) of 243,104 ac-ft.

1.1.2.2 Historical Water Use

None of the water deliveries to individual irrigators is metered by BMA. BMA has only one gauge to measure the total water diverted from Medina Lake to the Main Canal. This gauge, maintained by the USGS, is located on the Main Canal approximately 0.25 mi downstream of the head gates at the Medina Diversion Lake.

Table D-1 presents a tabulation of monthly and annual water diverted to the BMA Main Canal for the period 1958 through 1990. During this period, BMA diverted an average of 35,793 ac-ft/yr from the Medina Diversion Lake. This ranged from a low of 16,616 ac-ft in 1973 to a high of 62,235 ac-ft in 1989. A plot of total annual diversions for this time period is shown in Figure D-2.

On an annual average basis, irrigation of corn and grasses represents about 62 percent of the water used within the BMA system; grain, vegetables and other crops account for the remaining 38 percent. Also, BMA supplies an average of about 1,445 ac-ft of water per year to supplement farm/stock tanks.

Based on a 1988 BMA inventory, the following irrigation use information was compiled:

Total Irrigated Acres on BMA Books as of January 1, 1988	34,386.50 ac
Total Number of Land Owners	1,950
Total Water Diverted Through BMA Main Canal at Diversion Lake	59,819.00 ac
Total Acres Irrigate One or More Times	16,689.00 ac
Total Acres Irrigated During 1988	32,095.50 ac

Based on this inventory, BMA assessed taxes on a total of 34,386.50 ac, owned by 1,950 land owners. This yields an average acreage per land owner of 17.63 ac. However, 39 of the 1,950 land owners (irrigators) collectively own 6,844.26 acres. This means that the remaining 1,911 (1,950 - 39) property owners have an average tract size of 14.41 ac (27,542.24/1,911). Therefore, the BMA service area is comprised primarily of many small acreage tracts, which have access to irrigation water through the extensive BMA canal and lateral system.

Since BMA does not meter water sales to individual irrigators, BMA does not have records of water applied to the field. BMA sells water on the basis of acreage. Table D-2 summarizes, on an annual

Table D-1
Monthly Diversions (ac-ft) To BMA Main Canal

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1958	75	250	696	2,570	2,170	5,141	3,500	6,041	1,040	463	740	2,800	25,487
1959	2,230	315	2,490	2,570	2,360	5,241	4,941	4,871	3,610	2,640	2,230	1,360	34,859
1960	1,540	1,110	2,050	2,810	5,031	6,951	2,330	3,860	4,540	3,610	1,060	510	35,404
1961	853	660	4,500	6,021	8,411	4,590	2,820	3,250	4,801	3,490	953	1,430	41,780
1962	3,320	2,450	4,600	2,430	5,691	5,551	7,711	7,881	4,280	5,561	3,490	3,030	55,996
1963	114	2,850	3,250	3,610	3,860	7,081	6,411	8,821	4,460	4,160	1,870	414	46,903
1964	1,660	473	1,540	1,980	4,891	3,290	8,591	5,741	2,830	2,240	253	757	34,247
1965	1,590	201	569	636	536	3,250	6,901	4,981	4,490	611	1,280	171	25,217
1966	388	401	1,530	2,470	680	5,941	5,801	2,890	1,310	2,650	3,210	2,760	30,032
1967	2,280	2,660	5,611	2,010	7,751	9,021	6,161	6,341	616	1,170	400	365	44,386
1968	1	117	587	931	980	3,820	4,030	6,681	657	2,510	2,030	612	22,958
1969	994	735	1,040	1,820	1,010	4,811	6,031	5,251	2,190	1,180	843	550	26,455
1970	716	583	337	2,150	2,290	3,610	4,290	4,350	2,980	1,730	3,680	2,910	29,629
1971	440	4,610	5,861	7,391	9,661	7,991	5,401	1,030	1,040	182	806	250	44,663
1972	1,133	922	4,849	7,821	1,329	3,024	5,291	2,285	3,400	2,822	665	895	34,436
1973	370	521	955	292	4,141	3,199	1,203	2,301	878	109	723	1,949	16,642
1974	1,658	2,519	4,440	6,618	2,050	6,354	8,049	2,801	306	1,473	281	789	37,337
1975	747	609	3,238	2,157	205	1,985	3,010	4,698	2,225	3,564	2,225	2,312	26,977
1976	1,623	4,462	2,802	393	220	5,226	1,513	4,145	3,059	167	110	3	23,723
1977	5	388	2,405	1,068	1,010	5,429	4,755	6,927	2,202	2,382	1,460	2,082	30,113
1978	1,878	1,260	4,105	3,124	4,272	7,405	10,992	3,354	385	2,729	601	837	40,942
1979	137	144	805	758	4,652	4,197	4,020	3,153	3,388	4,757	2,729	927	29,668
1980	1,435	1,902	5,364	5,628	1,947	9,406	9,265	3,471	2,246	3,536	1,670	377	46,246
1981	878	938	1,109	2,322	5,315	1,036	4,581	4,993	2,745	1,699	2,298	2,283	30,195
1982	2,076	2,413	2,447	4,323	2,204	8,408	7,627	6,001	5,636	2,732	1,745	789	46,402
1983	716	1,156	1,081	3,694	5,513	4,300	5,069	3,803	4,301	2,841	2,955	2,227	37,656
1984	54	1,753	5,200	7,137	7,920	7,121	9,624	7,212	5,646	1,142	325	0	53,134
1985	0	712	1,155	1,269	3,147	4,478	5,327	2,257	1,549	1,270	904	1,148	23,216
1986	1,246	1,290	4,170	6,292	3,520	842	5,606	6,746	2,564	700	826	520	34,324
1987	711	559	819	2,971	1,294	1,453	5,572	5,844	2,834	4,466	2,108	1,644	30,274
1988	5,075	3,427	2,957	2,679	2,586	2,618	2,340	2,187	1,880	6,312	3,885	3,784	39,729
1989	2,699	1,071	2,840	3,825	8,658	9,037	9,794	9,162	7,843	6,465	0	937	62,332
1990	3,875	2,338	599	962	3,809	9,673	5,295	5,588	4,168	0	0	0	36,308
Avg	1,288	1,388	2,606	3,113	3,609	5,196	5,571	4,816	2,912	2,466	1,465	1,255	35,687
Max	5,075	4,610	5,861	7,821	9,661	9,673	10,992	9,162	7,843	6,465	3,885	3,784	62,332
Min	0	117	337	292	205	842	1,203	1,030	306	0	0	0	16,642

Source: USGS Water Resources Data, Texas, Volume 3 Gage No. 08180000 - Medina Canal near Rio Medina

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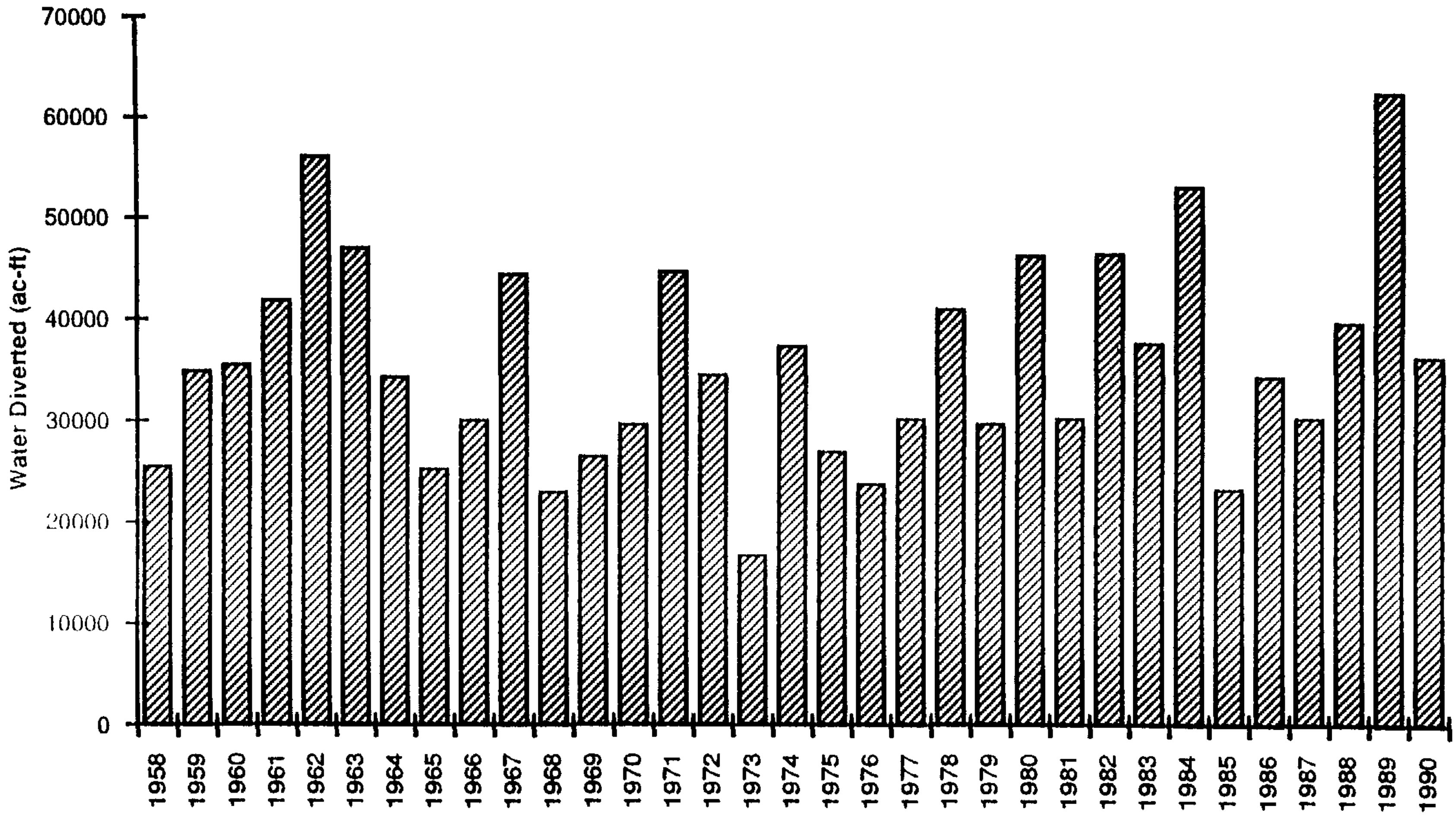
Figure D-2
BMA Total Annual Diversion (ac-ft) to the Main Canal from Diversio Lake



Source: USGS gage for Medina River near Riomedina

Table D-2
Tabulation of Annual Fixed Assessments and Water Sales to BMA Irrigators for the Period 1980 - 1990

Year	Fixed Water Assessments ($)	Flat Tax ($/ac.)	Total Acreage (ac.)	Irrigation Water Sales ($)	Water Charges ($/ac.)	Total Water Sold (ac.)
1980	204250.00	6.00	34041.67	141485.00	4.00	35371.25
1981	205821.00	6.00	34303.50	64498.00	4.00	16124.50
1982	205973.00	6.00	34328.83	147637.00	6.00	24606.17
1983	205671.00	6.00	34278.50	124557.00	6.00	20759.50
1984	205925.00	6.00	34320.83	261273.00	6.00	43545.50
1985	275752.00	8.00	34469.00	95160.00	6.00	15860.00
1986	206925.00	6.00	34487.50	118856.00	6.00	19809.33
1987	275642.00	8.00	34455.25	73727.00	6.00	12287.83
1988	275009.00	8.00	34376.13	205101.00	6.00	34183.50
1989	308943.00	9.00	34327.00	258169.00	6.00	43028.17
1990	308815.00	9.00	34312.78	180796.00	7.00	25828.00
Average	243520.55	7.09	34336.45	151932.64	5.73	26491.25

Source: Bexar-Medina-Atascosa Counties Water Control and Improvement District No. 1 - Audited Financial Statements 1980 - 1990 basis, the total amount of acres for which water was sold. Based on annual water sales revenue for the 11 year period from 1980 through 1990, BMA sold water for application to an average of 26,491 ac per year. This ranged from a maximum of 43,545 ac in 1984 to a minimum of 12,287 ac in 1987. It should be noted that individual acreage or tracts of land are watered more than once during any given year. Based on the 1988 BMA inventory (shown above), the ratio of the area of land actually irrigated (16,689 ac) to the total acres for which payment for water has been made (32,095 ac) is 0.52 (some tracts being irrigated more than one time during the year). This ratio, (approximately 50%) of acreage actually irrigated to total acreage paid for, corresponds with the working experience of BMA personnel (personal communication with Ms. Evelyn Sollock, BMA accountant/bookkeeper and Mr. Kirk Decker, BMA Operations Manager).

In an effort to evaluate total water diverted and total BMA acres irrigated, a statistical correlation was performed for the 11 year period 1980 through 1990. Using linear regression procedures, total water diverted at Medina Diversion Lake was regressed against total acreage receiving water (Table D-3) on an annual basis. As shown in Table D-3, there is a strong positive correlation between these two variables, with a correlation coefficient (R-squared) of 0.80. The mathematical relationship for these variables is shown in the following equation:

$$TARW = 0.87 * TWD - 8{,}210.62 \qquad [D\text{-}1]$$

where; TARW = Total Acres Receiving Water and

TWD = Total Water Diverted as measured at the USGS gage in the Main Canal.

Using Equation D-1, total acres irrigated (some tracts irrigated more than one time per year) for the period 1958 through 1979 can be estimated. Figure D-3 shows total acres irrigated (projected and actual data) and water diverted into the BMA canal for the period 1959 - 1990. For this period total water diverted into the BMA Main Canal averaged 35,793 ac-ft/yr. Total acres irrigated averaged 22,762 acres, based on actual (1980 - 1990) and projected (1958 - 1979) data. Using the ratio of 0.52 for acres actually irrigated to total acres paid to be irrigated (see BMA 1988 inventory above), yields an annual average number of acres actually irrigated of 11,836.

Table D-4 gives a listing of the TWDB's irrigation inventory (TWDB 1975) in Medina and Bexar Counties for entities using surface water sources. As shown in this table, Medina and Bexar Counties have an average irrigation application rate (surface water sources only) of 2.17 ac-ft per ac and 1.37 ac-ft per ac, respectively, or a combined average of 1.77 ac-ft per ac. Applying the combined average of 1.77 ac-ft per ac, since the BMA service area is situated almost equally in Medina and Bexar Counties (see Figure D-1),

Table D-3
Mathematical Relationship between Total Acres Receiving Water and Total Water Diverted

Year	Total Water Sold (ac)	Total Water Diverted (ac-ft)
1980	35,371.25	46,246.23
1981	16,124.50	30,194.78
1982	24,606.17	46,401.90
1983	20,759.50	37,655.89
1984	43,545.50	53,134.45
1985	15,860.00	23,216.39
1986	19,809.33	34,323.88
1987	12,287.83	30,274.28
1988	34,183.50	39,728.98
1989	43,028.17	62,332.22
1990	25,828.00	36,308.29
AVG	26,491.25	39,983.39

Regression Output

Constant	-8210.63
Std Err of Y Est	5223.87
R-Squared	0.80
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	0.87
Std. Err. of Est.	0.15

TARW = 0.97*TWD - 8,210.63

Where:
TARW = Total Acres Receiving Water
TWD = Total Water Diverted as measure at the USGS gage in the main Canal

Figure D-3
Total Projected Irrigated Acres (1958-1979) and
Total Measured Water Diverted (1958-1980) and Total Irrigated Acres (1980- 1990)

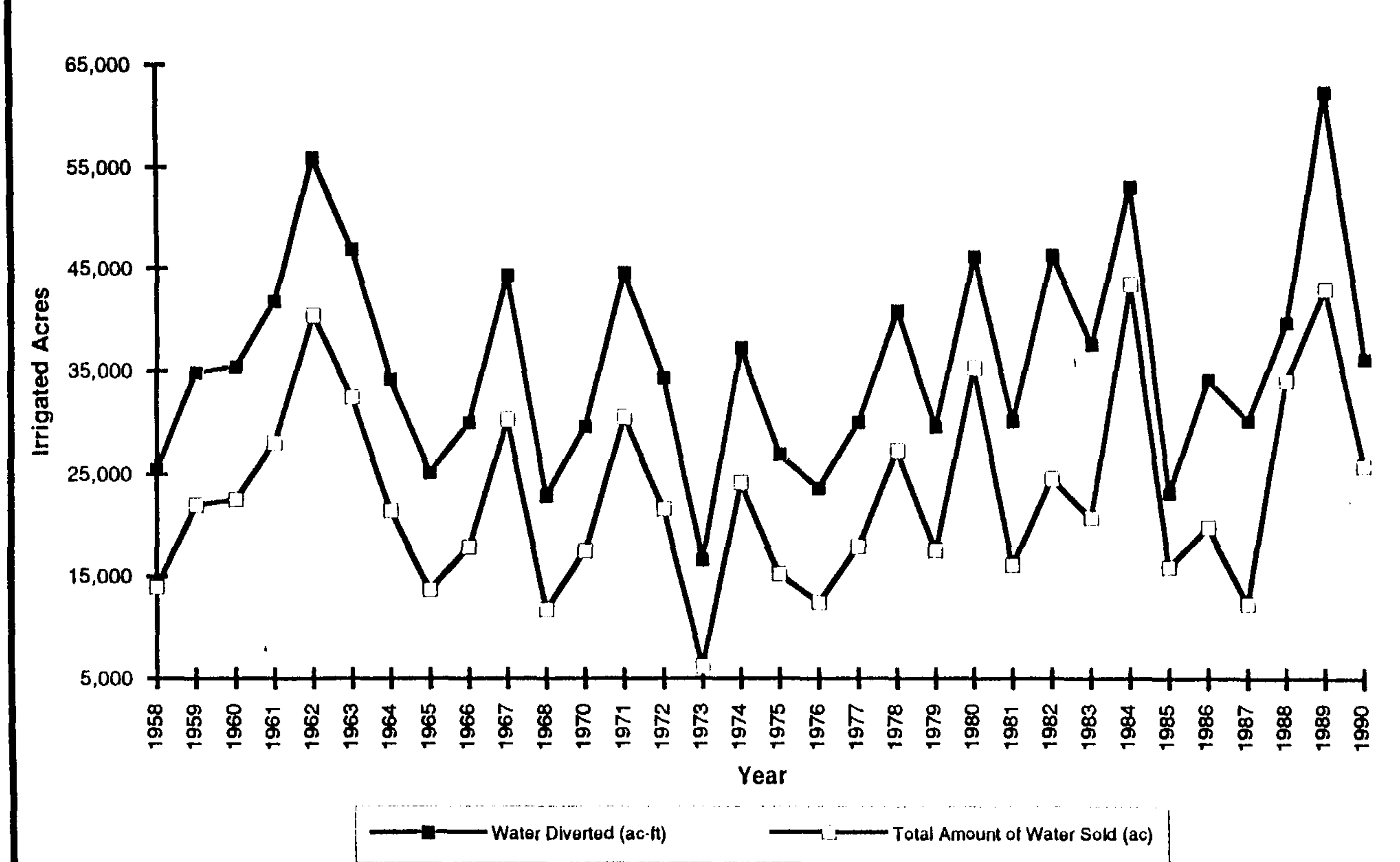


Table D-4
Irrigation Summary for Medina and Bexar Counties
1958, 1964, and 1974: Surface Water Irrigation Only

	Medina County			Bexar County		
Year	Acres	Acre-Feet	Acre-Feet Application Rate (ac-ft/ac)	Acres	Acre-Feet	Acre-Feet Application Rate (ac-ft/ac)
1958	5,400	10,661	1.97	10,500	14,845	1.41
1964	10,500	23,708		14,700	29,371	2.00
1969	13,100	29,967	2.29	6,573	7,053	1.07
1974	13,250	28,634	2.16	14,128	13,953	0.99
		Average Per County	2.17			1.37
		Average for Both Counties	1.77			

to an annual average of 11,836 ac irrigated, results in an estimated average annual usage (irrigation water actually applied to the fields) in the BMA system of 20,950 ac-ft.

1.1.2.3 BMA Water Losses

As discussed above, the estimated actual average annual irrigation usage within the BMA system is 20,950 ac-ft. With an average annual diversion of 35,793 ac-ft into the BMA canal system, unaccounted for and/or water losses of approximately 14,843 ac-ft/yr (42 percent) are apparent. Some of this 14,843 ac-ft is in transient storage in the BMA canal system and in Chacon Reservoir.

The design storage capacity of the BMA canal system is estimated to be 427 ac-ft. Allowing for transient canal storage (427 ac-ft) and replenishing the storage in Chacon Reservoir of approximately 1,000 ac-ft/yr[1], provides for a total estimated average yearly system storage capacity of 1,427 ac-ft. Adding the 1,427 ac-ft of annual canal system storage to the 20,950 ac-ft of average annual actual water use results is an estimated 22,377 ac-ft of "accounted for" water. This leaves 13,416 ac-ft/yr (35,793 - 22,377) of "lost and unaccounted for" water (37.5 percent of total diverted water).

1.1.2.4 Projected Water Use

BMA's agricultural water requirements depend on the acreage currently in irrigated production, the extent of urbanization of farm/ranch lands, the current water usage per acre, water costs and water availability. As shown in Table D-2, BMA's total acreage has not significantly changed over the last decade. BMA, due to its proximity to the City of San Antonio, will in the future experience increasing urbanization pressure. Larger agricultural tracts will be subdivided into smaller sections with an overall increase in population density and decrease in irrigation water use. BMA's irrigated lands, like all irrigated lands in Texas, will probably decline following the state-wide trend.

For purposes of projecting future irrigation water requirements, it is assumed that demand for irrigation water in BMA's service area will parallel statewide declines projected by the TWDB (1990) in their report titled "Water for Texas - Today and Tomorrow". In this report, the TWDB performed a low case and high case forecast for irrigated acreage in Texas. In estimating the future water needs of irrigated agricultural, the TWDB took into account: the total acreage suitable for irrigation; acreage currently in irrigated production; water use per acre; water costs; the economics of dryland versus irrigated production; and national and international demands for food and fiber. Based on these factors, the TWDB projected a

[1] This assumes that one-half of the storage in Chacon Reservoir (1,000 af) is replenished each year by water from the Medina Diversion Lake.

decline in total farmland irrigated from 6.75 million ac in 1985 to 4.71 million ac for the low case and 5.82 million ac for the high case 2040 forecast.

Applying the TWDB low and high forecast trends to the BMA service area yields a decrease in actual annual average acres irrigated from 11,836 ac in 1990 to 10,033 ac and 10,977 acre in the year 2020, respectively (Table D-5). This decrease in average annual acres irrigated results in a corresponding decrease in average annual water diverted (without additional water conservation measures) from Medina Diversion Lake into the BMA Main Canal from 35,687 ac-ft in 1990 to 31,691 ac-ft in 2020[2] for the low case forecast, and 33,783 ac-ft in 2020 for the high case (see Table D-5). As explained later in this report, the BMA could implement additional water conservation measures that could result in 20 percent water savings. Applying the 20 percent water conservation measures, at a rate of 1 percent per year for the first 20 years (see Table D-5), results in a decrease in water diverted into the BMA Main Canal from 35,687 ac-ft in 1990 (low and high cases) to 25,352 ac-ft in 2020 for the low case and 27,026 ac-ft in 2020 for the high case. The low and high case forecast projections for BMA water requirements (with and without additional water conservation) is are shown in Figure D-4.

1.1.3 Need for and Goals of the Program

There is an immediate need for the BMA, as well as other irrigation districts, to develop a comprehensive and effective water conservation plan. On a statewide basis, irrigation currently represents about 57 percent of all annual water use requirements (14.8 million ac-ft; TWDB, 1990). It accounts for approximately 8.5 million ac-ft, of which only 60 - 70 percent actually reaches the crops. The rest is lost through inefficient irrigation equipment, delivery systems and practices. Within the BMA system, approximately 56% of the water released from Lake Medina is lost before its reaches the crops. Of this, 18.5% in Medina Diversion Lake and 37.5% in the BMA canal system. This water conservation plan describes readily available technology and water conservation practices that could improve irrigation efficiency by 75 - 80%, while maintaining the same irrigated acreage.

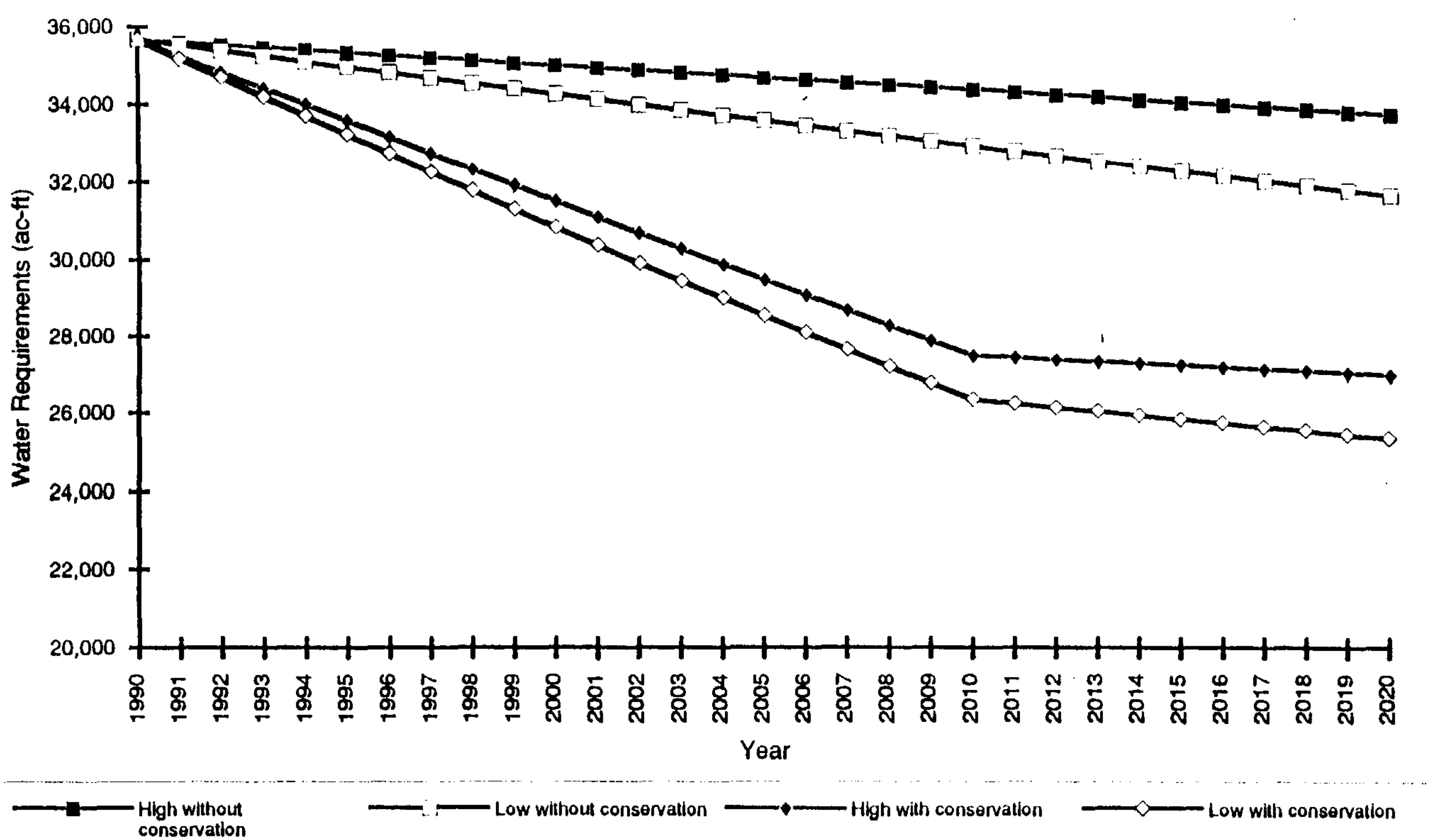
The water conservation plan outlined herein has the overall goal of reducing water consumption within the BMA system through increased operational efficiencies. Water savings will result in a lower cost of water to the irrigator and provide major opportunities for diverting saved water to other uses, such as municipal. Competition for water and the need to wisely utilize existing water resources is prominent in Bexar and Medina Counties. In addition, this agricultural water conservation can be used as a model for other irrigation districts in a statewide effort to conserve agricultural irrigation water.

[2] Total water diverted into the BMA Main Canal from Medina Diversion Lake is performed by applying Equation 1 and the ratio of 0.52 to for lands actually irrigated to total acres paid.

Table D-5
Projection of BMA Irrigation Lands and Water Requirements

Year	Actual Acres Irrigated High Case (ac)	Actual Acres Irrigated Low Case (ac)	Total Acres Receiving Water One or more Times High (ac)	Total Acres Receiving Water One or more Times Low (ac)	High Projected Without Conservation (ac-ft)	Low Projected Without Conservation (ac-ft)	High Projected With Conservation (ac-ft)	Low Projected With Conservation (ac-ft)
1990	11,836	11,836	22,762	22,762	35,687	35,687	35,687	35,687
1995	11,688	11,514	22,478	22,143	35,359	34,974	33,591	33,225
2000	11,542	11,201	22,197	21,542	35,036	34,281	31,532	30,852
2005	11,398	10,897	21,920	20,956	34,717	33,606	29,509	28,565
2010	11,256	10,601	21,647	20,387	34,401	32,950	27,521	26,360
2015	11,116	10,313	21,376	19,833	34,090	32,312	27,272	25,849
2020	10,977	10,033	21,110	19,294	33,783	31,691	27,026	25,352

Figure D-4
Projection of BMA Water Requirements
With and Without Conservation



1.2 Long-term Conservation

There are numerous water conservation methods described in this section that could be implemented by the BMA.

1.2.1 Education and Information

The first step in developing an effective BMA water conservation plan is to implement a comprehensive public education and information program. With only 1,950 irrigation users, an effective education and information program can be easily and inexpensively administered by the BMA. Information will be distributed as follows:

1.2.1.1 First-Year Program

During the first year, the BMA program will include the development and distribution of educational materials on irrigation water conservation practices and procedures. Water conservation pamphlets or flyers will be provided for public distribution through the following sources:

- BMA Offices: - Given to irrigators when applying for water deliveries or taxes;
- Ditch Riders - Given to irrigators when ditch riders make water deliveries;
- Mailings - Bill stuffers with ideas on water conservation and good water management practices forwarded with tax notices and other billings or mailings; and
- Directors Meetings - Attendees will be given water conservation flyers and information.

1.2.1.2 Long-Term Program

During the course of the first year of the program, the BMA will develop other activities to supplement those described above. These include the following activities:

- Updating and distributing public information described above;
- Public speaking on water conservation by district officials;
- Developing field demonstrations of water conservation and management measures;
- Providing public information displays on water conservation and management at various community activities and fairs;
- Implementing and financing model water conservation measures on demonstrations farms

- Sponsoring loan programs, potentially funded by state and local sources, to implement on farm water conservation measures;
- Adopting rules and regulations requiring mandatory water conservation and demand reduction measures by BMA irrigators; and
- Pursuing alternative funding sources to design and implement non-structural and structural infrastructure improvements designed to eliminate or reduce internal system losses and inefficient irrigation delivery practices;
- Offering various economic incentives to help encourage water conservation, including pricing structures or loans and grants to water users for installing water conservation facilities.

1.2.1.3 Information to New Customers

New customers, including new land owners, will be provided with public information materials on irrigation water conservation, emergency water demand management plan and adopted BMA rules and regulations on mandatory water conservation measures.

1.2.2 Water Supply Augmentation

1.2.2.1 Dependable Supply Approach

During a very dry water year, BMA will have to decide how much available supply to use and how much to carry over into the next year as insurance against consecutive drought years. Generally, agricultural systems, especially those with a sizable fraction of annual crops compared to permanent crops, will tend toward minimum carryover. However, BMA should be aware that irrigation needs tend to be greater during dry years, because lack of winter rainfall results in drier soils.

In assessing dependable supplies, BMA should start with the current amount of usable water stored in Lake Medina. Assuming that the next year will be equivalent to the worst year of record (such as that of 1950s, 1960s or 1980s), add the amount of additional supply that would be expected in such a year. This provides an estimate of total dependable supply for the two year period with 99 percent certainty. The amount considered to be necessary for carry-over into the next year would then be deducted from this total to yield the dependable supply for the current year. Allowance for evaporation and losses, should also be deducted, if these losses have not been accounted for in the worst-year estimate. This dependable supply would be the amount available without special action.

Use of this method to estimate dependable supply in Lake Medina has risks, since Lake Medina has significant recharge and leakage losses. An alternate method is to define a dependable supply as that which can be obtained in about 90 percent of the years. This is an easy approach, but it can lead to questionable estimates. A better approach is to make a simple assessment of the water supply situation periodically throughout the rainy season. A "rule curve" is a good method for this purpose.

1.2.2.2 Rule Curve Approach

A rule curve is a method whereby BMA can estimate a system's capability to deliver water as a function of runoff or accumulated reservoir storage level (Lake Medina). There are many kinds of such rule curves, but the simplest relates water-year runoff and expected remaining water-year runoff to system deliveries.

To arrive at the total amount deliverable, BMA would construct a single-stream reservoir rule curve by adding expected storable and divertible inflow to current starting storage, then subtracting the storage reserve needed at the end of the water year. The resulting annual supply available is plotted on a chart against runoff. This is done for several years to plot a curve (see Figure D-5). Periodic runoff forecasts are made as the season progresses, giving the BMA an immediate estimate of water supply.

One of the virtues of a rule curve is that it can show water customers, at a glance, where their supply system stands as a function of runoff. Water users can readily see how their supply of water relates to the wetness or dryness of the year, and it drives home the point that water availability depends on the weather and is not an assured quantity.

1.2.2.3 Supply Augmentation Measures

If it is necessary to augment available supplies, many possibilities can be considered. Several supply augmentation measures are described below. These are only suggestions. The actions taken by BMA will depend on local conditions.

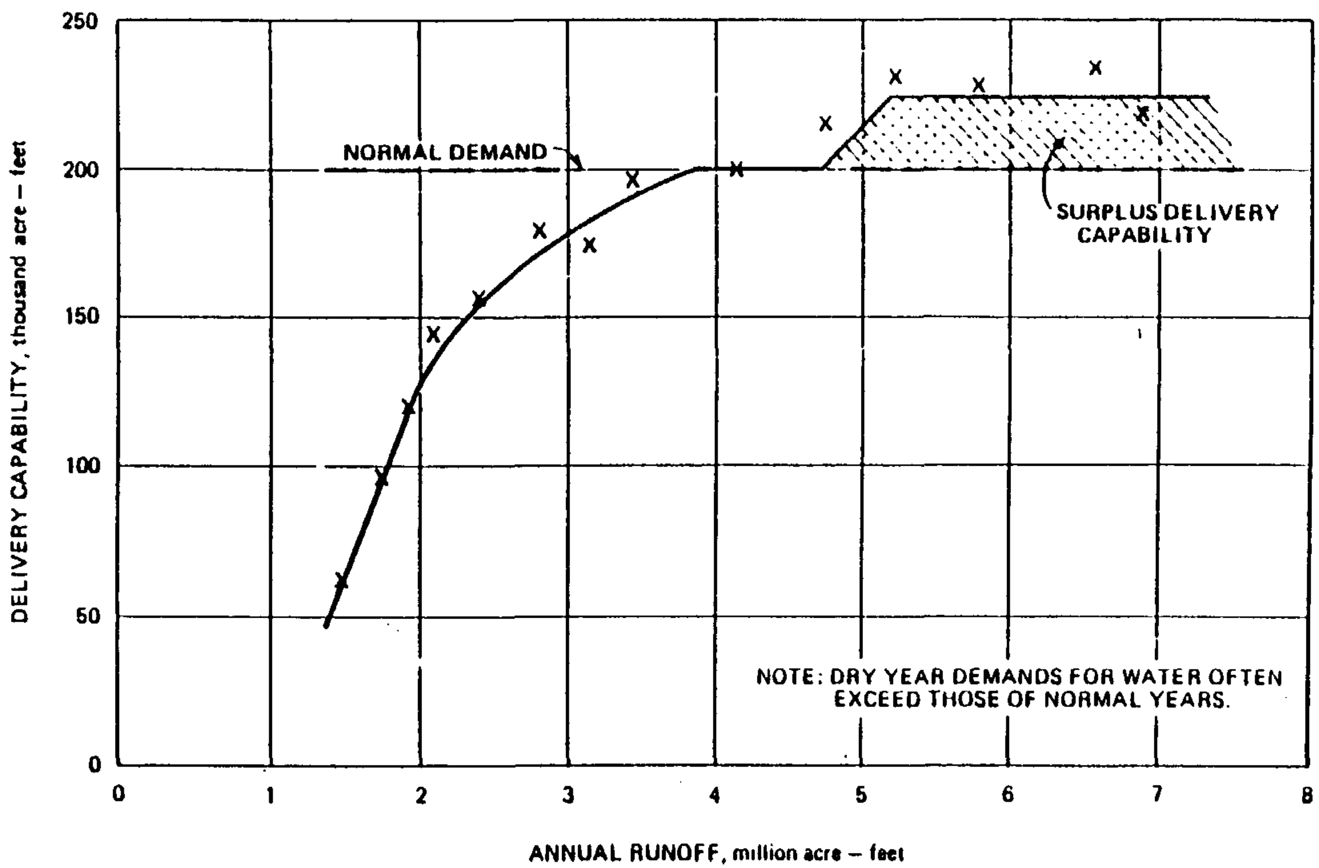
1.2.2.3.1 Prepare to Switch to Ground Water Where Possible

BMA may want to switch to ground water during a drought. There are several steps required to do this. The first step is to gather all the data available on ground water resources and its availability.

The second step is to ensure that all potentially usable wells are in good working order. Where it can be determined from a review of the data in the first step that ground water levels will decline to the point that a well would run dry, consider deepening the well prior to the months of high demand.

For wells not in use, inspect and prepare them for use. Such preparation might include surging and cleaning the wells and pumping to ensure the well is capable of producing water. Rehabilitation of large capacity wells can be very expensive. Thus, the BMA may wish to check what is needed and where

Figure D-5
Sample Rule Curve Showing Water Delivery Capability Versus River Runoff



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services can be obtained, but delay embarking on the most expensive projects until water supplies are known to be short.

The third step is to ensure that enough equipment is available and arrange for power hookups. If many abandoned wells are put back into service, there may not be enough pumps, pump motors, and electrical transformers available, and this may limit the amount of ground water available for use. An early assessment of the need for groundwater pumping equipment improves the chance of adequate water supply. Also, the power needs of the pump motor must be considered, including the time needed to provide power hookups.

During the drought of 1950s, 1960s and 1980s many new wells were constructed and old ones were rehabilitated. However, the demand for new and rebuilt wells exceeded available time, equipment and well drillers. Therefore, in order to avoid a similar situation in the future, pre-planning is essential.

1.2.2.3.2 Interconnections and Transfers

After examining prospects for local surface and groundwater supplies, the next option may be to develop an exchange with another purveyor who has available water or who may be willing to share his water for a price.

To the extent physical interconnections at water system crossings can be readied ahead of time, a wise move may be to work out agreements and begin construction of physical works for potential use in a future drought or emergency situation.

1.2.2.3.3. Retirement of Crop Land for Added Water Supply

BMA farmers may be willing to sell the water otherwise used for their crops. This would provide a transferable supply in surface water delivery areas where the reduction in use would add to surface water supply. Generally, the amount made available would be the evapotranspiration of the crop (the difference between diversion and return flow, including deep percolation).

1.2.2.3.4 Added Wastewater Use Potential

In the BMA area, there is potential for some additional use of reclaimed wastewater from the City of San Antonio, City of Pearson or the Living Water Catfish Farm. With the uncertainties of drought, examination of opportunities for new wastewater reclamation projects is always an important part of water conservation and drought contingency planning. Use of reclaimed water on certain irrigated crops is another possibility. Proper treatment is vital, as reclaimed water can constitute a danger to those who use that water unless steps are taken to ensure the absence of pathogens and dangerous chemical constituents.

1.2.2.3.5 Potential Use of Unstored Winter Runoff to Increase Soil Moisture

During drought years it is common for the irrigation season to start earlier and for agricultural irrigation requirements to be higher than in normal years. A reduction in winter rainfall results in a deficit in soil moisture that has to be made up by application of additional irrigation water.

The water-holding capacity of mineral soils normally ranges from 1 inch per foot in sandy soils to 2.5 inches for clay soils. A soil with 1.5 inches per foot of holding capacity and an effective rooting depth of 4 feet can retain 5 acre-feet of water per acre. If soil moisture is not replenished by winter rain, it must be augmented with applied water to meet crop water requirements. It is prudent, therefore, to use wet season rainfall and the ensuing storm drainage water as much as possible during drought years to ensure the soil moisture storage is filled.

Following are some elements to be considered in attempting to fill soil moisture storage when a drought is expected:

- Preparing land surfaces in the Fall to increase infiltration of rain water into the soils and maintain moist soil in the seed bed. The local Soil Conservation Service (SCS) should be contacted for advice when soil erosion is a potential problem.
- Preparing fields to prevent surface drainage of rain water by installing levees and basin contours, and/or damming furrows to encourage ponding of rain water.
- Improving the distribution of surface drainage water. Fields may have areas where drainage water tends to accumulate. Installation of simple structures, such as training dikes and ditches, can reroute excessive drainage to areas where needed.
- Diverting storm water from the adjacent fields, rivers, sloughs, creeks and other natural waterways to supply pre-irrigation needs. This must be prepared in compliance with the water rights. Anyone who intends to divert or take control of high flows or flood flows for a beneficial use must file an application with the Texas Water Commission for a water right permit to assure that any such proposed diversion is a lawful use of water.
- Investigating the feasibility of augmenting water supplies with storm drainage water to meet pre-irrigation needs. BMA could look into the possibility of capturing all sources of storm drainage water, including those from nearby cities.

1.2.2.3.6 Investigate Blending Poor-Quality Water With Good-Quality Water to Stretch Supplies

Although too saline for irrigation, brackish water may help stretch supplies in the BMA area. This water can be blended with high-quality water to expand the usable quantities. Sometimes poor quality drainage water can be recycled back to the field water supply ditch. Doing so would have minimal long-term consequences on once-through systems where return flow and deep percolation is lost from the fresh water system anyway. Where return flow is reused and where soil salinity is a problem, the use of partially brackish supply may not be advisable; the wrong chemical constituents can ruin soil permeability and future water uptake. The advice of local experts on the leaching requirements to maintain salt balance and salt tolerance of various crops should be sought before extensive applications of brackish water.

1.2.3 Demand Reduction

1.2.3.1 On-Farm Water Management Practices

The BMA could require on-farm water management and conservation practices for its water users. These practices will include the following elements:

1.2.3.1.1 Simple and Inexpensive Farm Management Techniques

There are four relatively simple and inexpensive farm management techniques that can help almost any irrigator use water more efficiently and maintain or boost crop productivity. However, the usefulness of the techniques and the results they produce depend on several factors, including specific soil type and land slope.

1.2.3.1.1.1 Soil Moisture Monitoring

Soil moisture monitoring is the simplest and least expensive technique for improving irrigation water management. Several monitoring methods and devices are available to measure soil moisture and help determine when crops need water. Many of the devices can be connected to computer-controlled irrigation systems that automatically apply water only when it is needed. The four principal monitoring measures include:

"Feel" While soils can show a wide range of moisture characteristics, the physical feel and appearance of soil samples taken at one-foot depth intervals can give a rough indication of soil moisture. Printed guides that discuss soil characteristics and explain how to evaluate soil moisture by feel and appearance are available from offices of the U.S. Department of Agriculture and many local soil and water conservation districts.

"Gypsum blocks" Gypsum blocks, which measure the flow of electricity through soil, can be used to indicate soil moisture levels. The blocks contain gypsum-encased stainless steel electrodes that are connected to a meter. A set of three gypsum blocks, buried at one-foot intervals to a depth of three feet, should be used for each 40 acres of land. Because gypsum blocks tend to give inaccurate readings in very wet soil, they work best when used with less water-sensitive crops, such as grains and grasses. Gypsum blocks are not recommended for crops that require saturated soil.

Since gypsum deteriorates, new blocks need to be installed each season. A resistance meter costs about $250, and each block costs about $3. The BMA could assist irrigators in the purchase and maintenance of meters and gypsum blocks.

"Tensiometer" Tensiometers measure soil moisture tension, which is the amount of water that can be removed by suction in the same way a plant draws water from the soil. The instrument is a water-filled tube with a porous tip and a vacuum gage. As the soil dries, water is pulled through the porous tip, and a negative pressure registers on the vacuum gauge.

The most commonly used tensiometers are 12, 24 and 36 inches in length and measure soil moisture at one-, two- and three-foot depths, respectively. Three tensiometer placed at these depths should be used for each 40 acres of land.

Tensiometers are most accurate in sandy soil when soil moisture is above 40 percent of field capacity. In clay soils they are most accurate when soil moisture is below 75 percent of field capacity. Field capacity, a characteristic that varies with soil texture, is the amount of water available to plants in the soil after free water has drained away.

Tensiometer are reusable, simple to install and read, and cost only about $50 each. The instruments, however, must be periodically refilled to replace the water that slowly moves into the surrounding soil. The BMA could assist irrigators in the purchase and maintenance of tensiometers.

"Neutron Probes" A neutron probe uses a radioactive source and an electronic counter system to determine soil moisture. The device measures the slowdown of neutrons as they strike water molecules in the soil. Neutron probes are more accurate than other monitoring methods because they are not affected by temperature and barometric pressure and are only slightly affected by other factors such as the chemical composition of the soil.

Because of the extreme caution required when using low-level radioactive source material and the high cost of the equipment, the device is seldom practical for individual irrigators. The Soil Conservation

Service and the BMA should have trained technicians who can, on request, install and operate neutron probes.

1.2.3.1.1.2 Irrigation System Evaluations

Grants from the Texas Water Development Board are available to help local water conservation districts, like the BMA, buy mobile water conservation laboratories and other evaluation equipment. With this equipment, and the help of technicians from the U.S. Department of Agriculture's Soil Conservation Service, free, on-farm evaluations are offered to individual farmers. These evaluations, which usually take less than a day, can help farmers improve overall irrigation efficiency from 10 - 20 percent, if equipment and management recommendations developed during an evaluation are followed. BMA could use this mechanism to show farmers how well their irrigation equipment works for each of the system's components.

1.2.3.1.1.3 Furrow Diking

Furrow diking, also known as basin tillage, conserves water by forming small earthen dams that trap irrigation water or rainwater that would otherwise run off. Water held between the dams can slowly infiltrate into the soil, thereby increasing soil moisture and reducing runoff. Increasing infiltration is particularly important in slowly permeable soils.

Furrow diking equipment attaches to a tractor's rear tool bar and usually can be used while performing another farming operation with the tractor. Most furrow dikers can be adjusted to change the distance between dams and thereby control the amount of water held in each basin. Depending on the desired moisture conditions, dikes are usually placed in every row or every other row.

Furrow dikes can benefit dryland farmers, sprinkler irrigators (particularly those using Low-Energy Precision Application systems), and furrow irrigators who water alternate rows.

1.2.3.1.1.4 Conservation Tillage

Conservation tillage helps retain soil moisture by leaving about 10 percent of the crop stubble on the soil surface. The plant stubble reduces wind and water erosion, and evaporation is reduced because the soil is not turned over and exposed to the air. Reduced cultivation costs are an added benefit from conservation tillage practices.

1.2.3.1.2 Capital Improvements for Additional Water Savings

Three capital intensive improvements - land leveling, underground drainage and conveyance system improvements - can substantially contribute to improved irrigation water management. Although each improvement requires significant capital investment, the resulting water savings often allow the cost to be repaid in a reasonable period of time. For assistance in calculating the costs and benefits of these improvements, BMA could establish a cooperative program with local agricultural extension agents and the USDA's Soil Conservation Service.

1.2.3.1.2.1 Land Leveling

Land leveling conserves water by reducing runoff. In flood irrigation systems, such as those used to grow grasses, land leveling allows basins to be quickly and evenly filled and drained. For effective land leveling, it is important to survey the existing slope and determine how the land surface must be reworked to provide the correct slope for the most efficient use of water.

While land leveling requires a high capital investment, it can significantly reduce water use and boost crop yield.

1.2.3.1.2.2 Proper Soil Drainage

Proper soil drainage ensures that plant growth will not be hurt by too much water, either on the surface or from an underground water table that is too high. Most crops do not grow well in soils that are saturated with water.

Crops can also be damaged by harmful dissolved salts that remain in saturated underground soil layers surrounding plant roots. Perforated pipes, set in graves, can be installed underground to collect and drain excess water away from the root zone. Drainage systems composed of clay tile, which were common in the past, are more expensive than new underground drainage systems using perforated plastic pipe.

1.2.3.1.2.3 Conveyance Systems

Conveyance systems should be designed so that they do not lose water. Studies indicate that about 30 percent of the water conveyed by BMA through earthen ditches is lost to seepage and evaporation before it reaches the fields. These losses can be reduced by lining ditches with concrete or by installing underground plastic pipe to convey water.

In addition, weeds and other phreatophytes should be eliminated from and adjacent to all canals. Water losses to these types of vegetation can be extensive.

1.2.3.1.3 Irrigation System Conversions

1.2.3.1.3.1 Conserving Water and Saving Money with Furrow Irrigation

With furrow irrigation, a stream of water is provided at the head (upstream slope) of the furrow and allowed to flow down the furrow to the tail. Deep percolation and tail-water runoff are the two main problems with furrow irrigation. Deep percolation involves water penetrating too deeply into the soil to be used by crops. Tail-water runoff results from too large an irrigation stream flowing through the furrow. On the other hand, a small stream can reduce runoff but often results in deep percolation. The objective, therefore, is to select a stream size that keeps both tail-water runoff and deep percolation to a minimum.

A relatively new technique to reduce tail-water runoff and deep percolation is Surge Irrigation, which can cut water losses in furrow irrigation systems by as much as 30 percent. Water is applied to the furrows in a series of pulses or surges rather than in a continuous stream. A valve controlled by a clock or by changing water pressure allows the water flow to be alternated between furrows.

The alternating wetting and "resting time" for each surge of water slows down the infiltration rate of the wet section of the furrow and produces a surface that is smoother and hydraulically-improved for water flow during subsequent surges. This allows the next surge to travel more rapidly down the wet part of the furrow, thereby reducing losses to deep percolation and ensuring more uniform water application.

Surge irrigation works best on light, loose soils. It is less effective on heavier soils or after soil has been compacted later in the growing season.

1.2.3.1.3.2 Conserving Water and Saving Money with Sprinkler Systems

Center pivot and lateral-move sprinklers can be easily converted to Low-Energy Precision Application (LEPA) systems. A LEPA system distributes water directly to the furrow from either above or below the crop canopy through drop tubes fitted with low-pressure (10 - 20 psi) nozzles.

In addition to water savings, a low-pressure LEPA system requires much less energy than conventional sprinkler systems, which distribute water at operating pressures of 30 - 90 psi.

Furrow diking is an important part of a LEPA system, particularly on less permeable soils. The micro-basins created by small dams across furrows reduce runoff and hold irrigation water and rainwater for infiltration and crop use.

Farmers irrigating with side-roll, permanent or moveable impact, and gun-type sprinkler systems should make sure that the systems apply water at the lowest possible angle to avoid water losses from wind drift and evaporation. The application rate should also be set to avoid deep percolation or excessive runoff.

LEPA system saves water in three ways:

- Water is emitted closer to the ground, reducing evaporation and losses to wind drift.
- Water is applied in large droplets rather than in a spray, which also cuts losses from evaporation and wind drift.
- Water is distributed in a pattern designed to prevent runoff, deep percolation and under watering.

1.2.3.1.3.3 Conserving Water and Saving Money with Drip Irrigation

Orchards, vegetable crops, vineyards and windbreaks can be more efficiently watered by Drip Irrigation, which applies water directly to individual plants through flexible tubing equipped with built-in or attached emitters.

Since water is applied drop by drop to the area around the plant roots, evaporation is greatly reduced, and runoff and deep percolation are reduced. Advantages of drip irrigation include:

- Water Savings: Water use can be cut as much as 60 percent with drip systems.
- Energy Savings: Because water is applied at much lower pressures than with other types of irrigation systems, less water is needed, and energy costs are reduces.
- Weed Control: Because a smaller area is irrigated, weed growth is inhibited, and the need for cultivation and herbicide application is reduced.
- Salt Control: Drip irrigation allows the use of water with a higher salinity level in some cases. Just as less water is applied, so is less salt. Proper system design, maintenance and management can also keep harmful salts away from plant roots.
- Use of Marginal Land: With a properly designed drip system, steep slopes and problem soils can be successfully irrigated.

1.2.3.1.4 Conserving Water and Saving Money With Computerized Irrigation Scheduling

Computerized irrigation scheduling allows irrigation to be automatically controlled so that soil moisture conditions are adjusted to those required for proper plant growth. A computerized system can adjust water application rates to match specific infiltration rates, taking into account different soil characteristics from furrow to furrow.

While a computerized irrigation system can help farmers make the most efficient use of irrigation water, such a system can be expensive. A simple system would include sensors to detect current climatic conditions and soil moisture levels, a radio receiver to gather information from the sensors, a microcomputer with software programs designed to control the system, and a flow-control valve for water outlet in the system.

Additional information about computer-controlled irrigation systems and software programs is available from the Texas Agricultural Extension Service and the Texas Agricultural Experiment Station.

1.2.4 Establishing A Drought Contingency Plan

BMA will establish a "Drought Contingency Plan." BMA should draft and circulate the proposed plan for review and comment by its water users. The plan should then be adopted so it is ready for implementation when a drought occurs. The plan should include:

- The conditions that will cause the plan to be implemented (including a discussion of the water supply situation)
- A description of the method to be used to allocate water during shortages.
- Special water pricing or standby charges that will be enacted.
- A list of rules and regulations specifying water use restrictions and procedures that will be followed.
- A list of specific enforcement procedures to be implemented.

1.2.4.1 Plan Implementation

BMA should consider announcing that potential drought conditions exist whenever it is anticipated that the district's water may be insufficient to meet the needs of its water users during the next water year. It is important to let agricultural water users know as early as possible that a water shortage may occur, even though there will be times when a warning is issued and a drought does not materialize. The water users can plan their cropping program with a potential water shortage in mind, rather than plan to have a full water supply and learn after the water year starts there will be reductions in the supply. It is also important for BMA to start planning for a drought as early as possible.

1.2.4.2 Water Shortage Allocations

In general, BMA will deliver the amount of water needed by its users when sufficient water is available to the district. In other words, only when there is an inadequate water supply will a shortage be imposed.

During times of shortage, water will be allocated according to some formula based on the historical use of each irrigator and/or an average amount of water/acre irrigated. The exact mechanism is currently being developed and will depend to some extent on the method used to measure water consumption.

1.2.4.3 Rules and Regulations

The rules and regulation for the allocation of water should specify:

- The authority to impose a water allocation shortage;
- The procedure to be followed in implementing the allocation;
- The procedure water users are to follow in applying for a water allocation;
- Where the allocation should be filed;
- The deadline for filing the application;
- Exceptions to the rules;
- Provisions for emergency allocations, acceptable water transfer procedure, payment requirements and penalties for nonpayment; and
- Penalties for violation of rules and regulations.

The responsibility of each user to properly manage water supplies must also be spelled out clearly. Waste of water should not be tolerated, and penalties for waste should be adopted and enforced.

1.2.4.4 Enforcement Procedures

All enforcement procedures should be clearly explained to the water users. In most cases, the ultimate penalty for noncompliance with BMA rules and regulations is the discontinuance of water service. However, before such action is taken, the water user must be in clear violation of a district rule on nonpayment of fees and penalties. The enforcement of district rules may require additional staff. Other examples of penalties that could be imposed for rule violations are:

- Reduction in flow or time allowed for water service;
- Locking the water user's turnout;
- Fines; and/or
- Increased water charges.

1.2.4.5 Water Pricing

Because BMA charges water users according to the area irrigated, it may realize the same amount of income during a drought as during a normal year. However, if a reduction in water allocations results in reduced crop acreages, the district will also have reduced revenues.

In that case, it is important to discuss possible budget problems early, and alert water users not only to the possibility of a water shortage, but also to any special or abnormal watering charges. Planning for these financial impacts is as important as planning for the drought water supply allocations.

1.2.4.6 BMA Drought Contingency Plan

The BMA's Drought Contingency Plan (DCP) will provide recommended standards for drought conditions, including stages of drought severity. Severity stages are defined by hydrologic and water level parameters in Lake Medina. The recommended actions and demand reduction measures discussed in the remaining sections of this report generally followed the procedures setforth above.

Upon declaration of a drought by the BMA, water users should be encouraged and, possibly, required to initiate demand reduction measures to reduce water usage. Minimum demand reduction measures are defined herein. Additional measures may be identified and implemented by the BMA, as needed, to ensure the fulfillment of the goals of this DCP.

1.2.4.6.1 Stages and Triggers

There are three defined stages of drought severity and associated triggers. The stages are:

- Mild Drought
- Moderate Drought
- Severe Drought

Implementation of demand reduction measures will always begin with the requirements of the Mild Drought Status. Each subsequent drought management stage will be declared by the BMA in progression. When management conditions are not prescribed with those outlined in this section, the BMA will exercise discretion in determining when to declare respective stages.

1.2.4.6.2 Mild Drought Status

The Mild Drought Status should commence when Lake Medina capacity reaches, on its falling stage, 180,000 ac-ft of storage (Figure D-6) for 14 consecutive days[3] (moving average).

During this stage, the BMA should provide biweekly (every two weeks) press releases to local newspapers and electronic media notifications to the public of the Mild Drought Status. The BMA may request voluntary irrigation curtailment. In addition, the BMA should commence daily water level monitoring of Lake Medina.

This trigger could be discontinued when lake water levels rise above 180,000 ac-ft of storage for more than 14 consecutive days or, in the judgement of the BMA, that this condition no longer exists.

1.2.4.6.3 Moderate Drought Status

The Moderate Drought Status should commence when Lake Medina capacity reaches, on its falling stage, 150,000 ac-ft of storage (see Figure D-6) for 14 consecutive days[4] (moving average).

In this stage, the BMA could provide weekly press releases to local newspaper and electronic media. BMA office staff and ditch riders should personally contact irrigators requesting water to notify them of possible non-mandatory/mandatory water curtailments.

In addition, the BMA should monitor Lake Medina on a daily basis. Mandatory curtailment of all unnecessary water use should be enforced. All major water users should be advised that mandatory curtailments in water usage are forthcoming if "system" water use is not reduced. Voluntary curtailment for users could be requested.

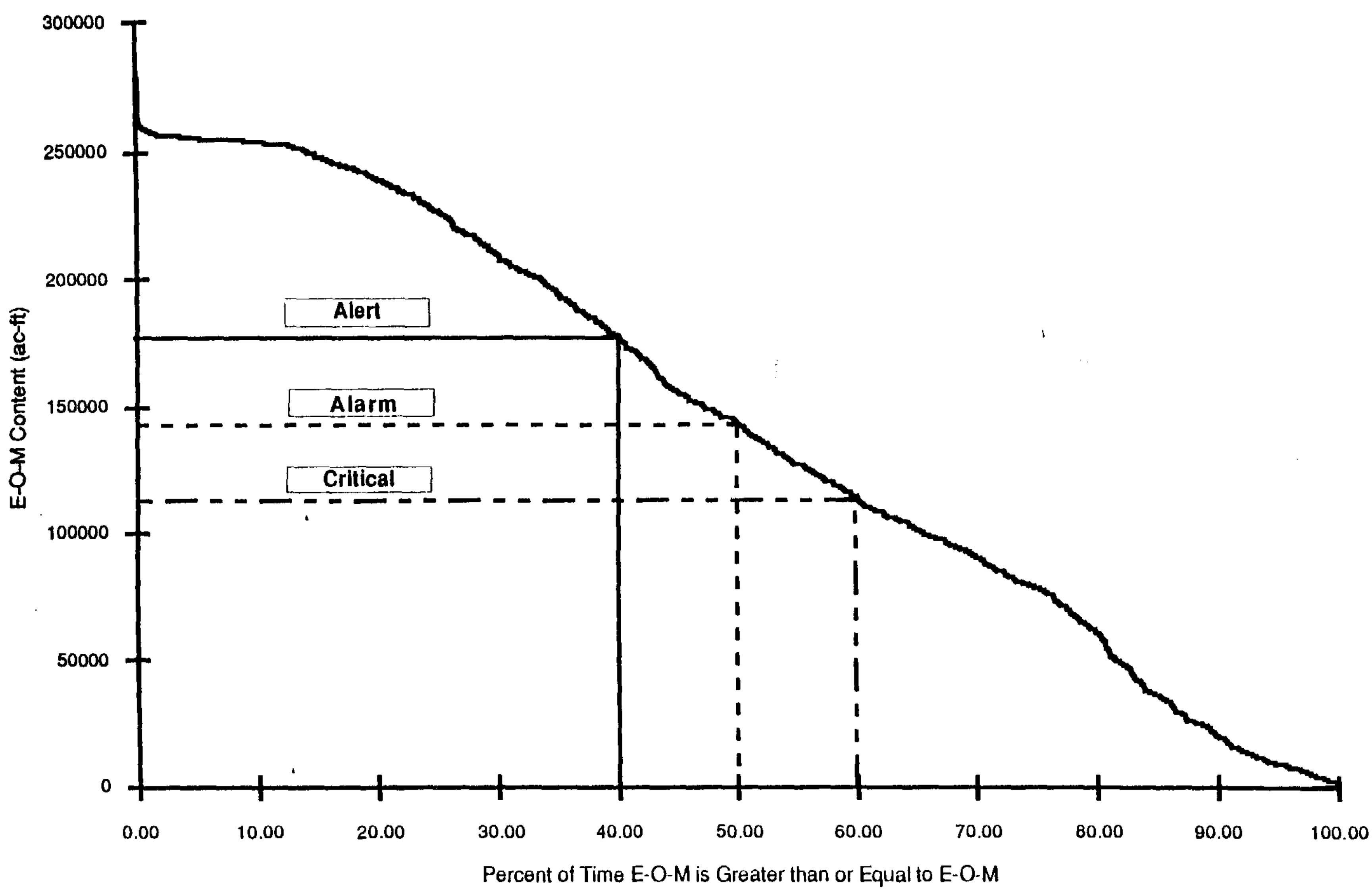
The Moderate Drought Status could be discontinued when lake water levels rise above 150,000 ac-ft of storage for more than 14 consecutive days or, in the judgement of the BMA, that this condition no longer exists.

1.2.4.6.4 Severe Drought Status

The Severe Drought Status should commence when Lake Medina capacity reaches, on its falling stage, 120,000 ac-ft of storage (see Figure D-6) for 14 consecutive days[5] (moving average).

[3] If hydrologic events unfold more rapidly than within 14 days, the BMA may respond as necessary.
[4] If hydrologic events unfold more rapidly than within 14 days, the BMA may respond as necessary.
[5] If hydrologic events unfold more rapidly than within 14 days, the BMA may respond as necessary.

Figure D-6
Medina Lake End of Month Content Frequency Curve



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Bexar-Medina-Atascosa Water Control and Improvement District

Michael Sullivan and Assoc., Inc.
Engineering and Environmental Consultants
Austin, Texas

MSA 91023

In this stage, the BMA should send mailers to all water users notifying them of drought severity and possible curtailment of irrigation deliveries. The BMA should perform biweekly hydrological analyses on Lake Medina and the irrigation delivery system to project immediate future water supply scenarios. The BMA should commence implementation of supply augmentation plans and enforce all adopted water conservation/drought contingency plans/activities.

The Severe Drought Status could be discontinued when lake water levels rise above 120,000 ac-ft of storage for more than 14 consecutive days or, in the judgement of the BMA, that this condition no longer exists.

1.2.4.6.5 Water User's Responses

Upon declaration of each drought management stage, water users should be expected to reduce their water use. To this end, two mechanisms should be used. The first mechanism is to achieve recommended water use reduction goals established for each stage. The goals define percentage reductions in base usage. The second recommended mechanism is to require each user to implement specific minimum demand reduction measures. Users could develop individual User Drought Contingency Plans (UDCP) that describe how each of these two mechanisms could be implemented within their respective service areas or operations.

1.2.4.6.6 Reduction Goals

Agricultural use reduction goals of 20%, 30% and 50% should be established for each drought management stage, respectively. Each irrigator should be required to achieve these reduction, or at a minimum these reduction should be achieved on a district area-wide basis.

1.2.4.6.7 Target Volume

The reduction goal percentage should be applied to the volume irrigated by each user based on a fixed three year average usage. The target volume should be the total amount that can be used during any successive 12-month period, unless either a more restrictive or a less restrictive drought management stage is declared. The target volume may be prorated over the coming year by the user in accordance with the user's requirements. A monthly water budget may be established by BMA for each user in each drought stage. Use in excess of the water budget could be subject to a "punitive" water rate or other penalty. Excess revenues derived from any punitive water rate should be dedicated to water conservation programs.

If no water volume data are available for an irrigator, the user could calculate the average annual use for similar irrigators in the area. The target volume should be this average, minus the reduction goal for the applicable stage.

1.2.4.6.8 User Drought Contingency Plans

BMA's DCP could require the development of User Drought Contingency Plans (UDCP). Each user could be required to prepare, adopt and implement UDCPs consistent with this DCP.

Upon receiving notification from BMA that drought response measures are needed, irrigators could be required to initiate action according to their approved UDCPs. They could also be required to enforce use restrictions in their respective service areas.

1.2.4.6.8.1 Required UDCP Content

UDCPs developed by BMA users could, at a minimum, include the following:

- Those demand reductions measures specified above;
- Additional demand reduction measures developed by the user which, when combined with the required measures achieve the reduction goals of this plan;
- Financial measures that encourage compliance with the DCP and maintain financial stability of the user during a drought;
- Provision for the regulations or contractual requirements necessary for the user to enforce the DCP and the UDCP; and
- Provision for reporting water used.

1.2.4.6.8.2 UDCP Implementation

For Mild Drought Status, the reduction goal of 20% could be met to voluntary compliance with restrictions achieved through increase public awareness. If a 20% reduction goal is not achieved, BMA may implement non-voluntary reduction measures. Water waste would be prohibited. Waste is defined as any use water to run-off into a ditch or drain, or a failure to repair a controllable leak.

Beginning with Moderate Drought Status, mandatory compliance could be required to achieve the reduction goals of 30%. BMA could consider technical assistance programs, which encourage alternative and/or supplemental water supply sources.

During the Severe Drought Status stage, a 50% reduction in water use could be required. BMA may need to establish allocations for irrigators, enact penalties for exceeding the allocations and place restrictions on irrigators who repeatedly exceed their allocation.

1.2.4.6.8.3 Reporting

Irrigators should report volumes use for irrigation during both drought and non-drought conditions. The frequency of reporting should increase upon declaration of Mild Drought Status, and continue at the increased frequency until drought conditions cease to exist. Larger users should report more frequently than smaller users.

Recommended reporting frequency requirements should be as follows:

Irrigated Acreage	Non-Drought Conditions	Mild Drought Conditions	Moderate Drought Conditions	Severe Drought Conditions
< 25 acres	Annual	Quarterly	Monthly	Monthly
> 25 acres	Annual	Quarterly	Monthly	Monthly

1.2.4.6.8.4 Recommended BMA Actions

BMA could adopt rules to implement this recommended DCP. BMA could also review and approve variances from the requirements of this plan. It could monitor the hydrologic parameters used as trigger conditions, notify news media and users of water resources conditions and appropriate drought management responses, enforce the DCP, and review and revise the plan as necessary.

BMA should continually monitor and forecast lake levels and water irrigation demand. If drought conditions or changes in stages are projected, BMA should notify all users by mail at least 20 days in advance, whenever possible. Notification should include a description of pending drought or non-drought conditions (stages) and expected user response.

BMA could assist water users by providing concise descriptions of BMA's rules and regulations concerning water rates and emergency rationing programs. BMA could make available educational materials on rate structure and related rate changes that may be necessary to successfully implement this recommended DCP and UDCPs. BMA could submit this DCP and associated rules, if developed, to the TWDB for review and comment.

1.2.4.6.9 Rules

BMA should begin the procedure to adopt rules for implementing the DCP. BMA should conduct public hearings to receive comments on the proposed rules.

1.2.4.6.10 Variances

BMA could institute a mechanism whereby variances to this plan of adopted rules can be obtained. Any user seeking a variance could file the appropriate request or include the variance request in its UDCP, in accordance with procedures established by BMA. The user should be required to identify the requirement(s) for which the variance(s) is sought, to justify the variance and to identify the demand reduction measures that may be implemented. A variance request should be justified by a unique economic or financial hardship that is not experienced by other similar users. The user could also provide BMA with information and data supporting the request.

BMA should evaluate each variance request on the merits described in the application. In evaluating a request, BMA should consider factors such as the user's water use efficiency and economic/financial considerations. BMA may conduct a public hearing in variance requests, and it could approve or disapprove each request in accordance with established procedures. The approval should specify the period of time that the variance will be in effect. The user should receive written notification of BMA's action.