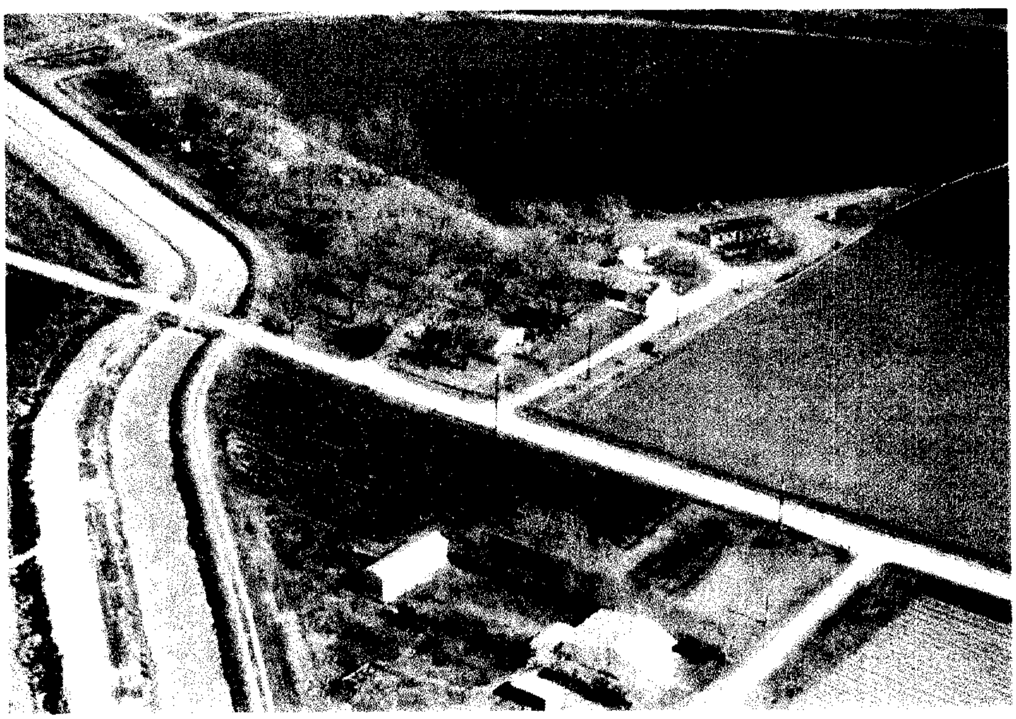
BEXAR - MEDINA - ATASCOSA COUNTIES WATER CONTROL AND IMPROVEMENT DISTRICT NUMBER 1



NATURAL RESOURCE PLAN - CONVEYANCE SYSTEM EFFICIENCY, WATER QUALITY, AND MUNICIPAL WATER DEMAND

ADOPTED BY
BEXAR - MEDINA - ATASCOSA COUNTIES WCID #1
APRIL 10, 1995

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NATURAL RESOURCE PLAN -

CONVEYANCE SYSTEM EFFICIENCY, WATER QUALITY, AND MUNICIPAL WATER DEMAND

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INTRODUCTION

The Bexar - Medina - Atascosa Counties Water Control and Improvement District Number 1 (BMA or District) and the Medina County Soil and Water Conservation District (SWCD) have cosponsored the development of a Natural Resources Plan for water conservation within the BMA service area. Assistance in the preparation of this plan was provided by the Natural Resources Conservation Service (formerly Soil Conservation Service, SCS).

Presented in this report are viable alternatives for conveyance system optimization and a review of water quality issues for inclusion in the Natural Resources Plan. The conveyance system improvements included in this study are recommended in order to increase water availablity for agricultural, municipal, and industrial uses. With competition for water increasing in the region, it is imperative that agricultural users increase efficiency in conveyance, application and distribution of water. The report also presents the results of water quality testing of the canal system and a review of potential sources of impact on water quality.

BMA's service area is located in south central Texas in Bexar, Medina and Atascosa Counties, 24 miles west of San Antonio. The District is predominantly rural with only seven communities: Devine (pop. 3,928); Castroville (pop. 2,159); Lytle (pop. 2,255); Natalia; La Coste; Pearson and Rio Medina.

The District owns and operates four dams and more thant 250 miles of irrigation canals. Since the beginning of system construction in 1911, benefits to the Medina River Valley from the District include a strong agricultural base, contribution to the groundwater supply resulting from recharge of the Edwards Aquifer from the lakes, reduction of flash flooding risks as a result of the dampening effects of the two major dams, and by providing a more stable base river flow. The system is unique in that it uses no pumping. Water is released from Medina Lake into Diversion Lake where it is diverted into the canal system. The vast network of earthen canals works solely on gravity flow. The system uses siphons to cross obstacles, chutes and drops to maintain proper grade, and checks to regulate flow. Due to its age, the system is in need of renovation to minimize water losses.

According to BMA's audited annual financial statements for the years 1980 through 1990, the District included over 34,336 acres of taxable land. Of this, only about 16,000 acres receives water for irrigation at least once per year. The subdivision of large farms has led to an increase in the number of tracts served by the District and a resulting increase in the cost of service. This change in circumstances requires construction and maintenance of an increasing number of laterals for diminishing water sales. Historically, the District delivered water to the high point of a tract and the landowner was responsible for distribution throughout the tract. However, once water is delivered, waste can be high if part-time farmers of small tracts do not manage water use efficiently. Even some farmers of large tracts have historically practiced poor irrigation techniques. The cause of such practices is simply that the current flat rate structure for purchasing water does not encourage conservation.

Increasing urbanization within the District is rapidly shifting the demand for water from agricultural to municipal uses. Until recently, the entire region depended on the Edwards Aquifer to meet municipal, industrial, and a large portion of agricultural water demands. The Edwards Aquifer is one of the largest sole source aquifers in the United States and the first to be so designated by the Environmental Protection Agency. Rapid growth in San Antonio region has increased demand on this limited resource which has led to intervention by the Federal Courts. With increasing demands for water, inefficient use and conveyance wastes this limited resource.

The loss of water along the route of delivery determines the conveyance efficiency. Losses can be determined by measuring the flow at the point of diversion, and again at the field. Whenever the loss exceeds 1/2 to 2 percent per mile, steps should be taken to determine the cause and implement corrective action. Causes of water loss may include excessive growth of trees along or in the canal, or seepage which can be corrected by lining or sealing.

The District has been more aggressive recently in improving water conservation and delivery efficiency. These efforts have included: 1) increased maintenance and clearing of canals, 2) replacement of failing canal structures (Natalia Canal Diversion Structure), 3) terminating service to farms that waste water, 4) deleting small tracts from service area which cannot be served efficiently, 5) cooperative efforts with the Natural Resources Conservation Service to implement improved methods of irrigation, and 6) purchased and installed meters in the main canal with the assistance of the TWDB to identify segments with high losses.

BMA has made considerable progress in improving its conveyance system efficiency. Another concern being addressed by BMA is water quality. Potential sources of water quality degradation include agricultural and municipal stormwater runoff, partially treated wastewater discharges and other nonpoint sources. All of these sources are outside of the direct control of BMA. However, these point and nonpoint sources can contribute sediment, chemical, and biological loadings of BMA's waterways. Potential pollutants from agricultural land uses include sediment, dissolved solids ("salinity"), nutrients (phosphates and nitrates), herbicides, and pesticides.

Nitrogen and phosphorus loading from fertilizers can increase the cost of canal maintenance, while reducing the ability of a canal or stream to transport water by promoting growth of vegetation, and increase the growth of oxygen depleting algae in lakes. Another potential water quality problem may exist where the main canal flows near an area where the City of Castroville irrigates with sewage effluent at an elevation higher than the canal. In order to ensure confidence in the quality of water in the system, a monitoring program is recommended.

BEXAR — MEDINA — ATASCOSA
W.C. & I.D. #1

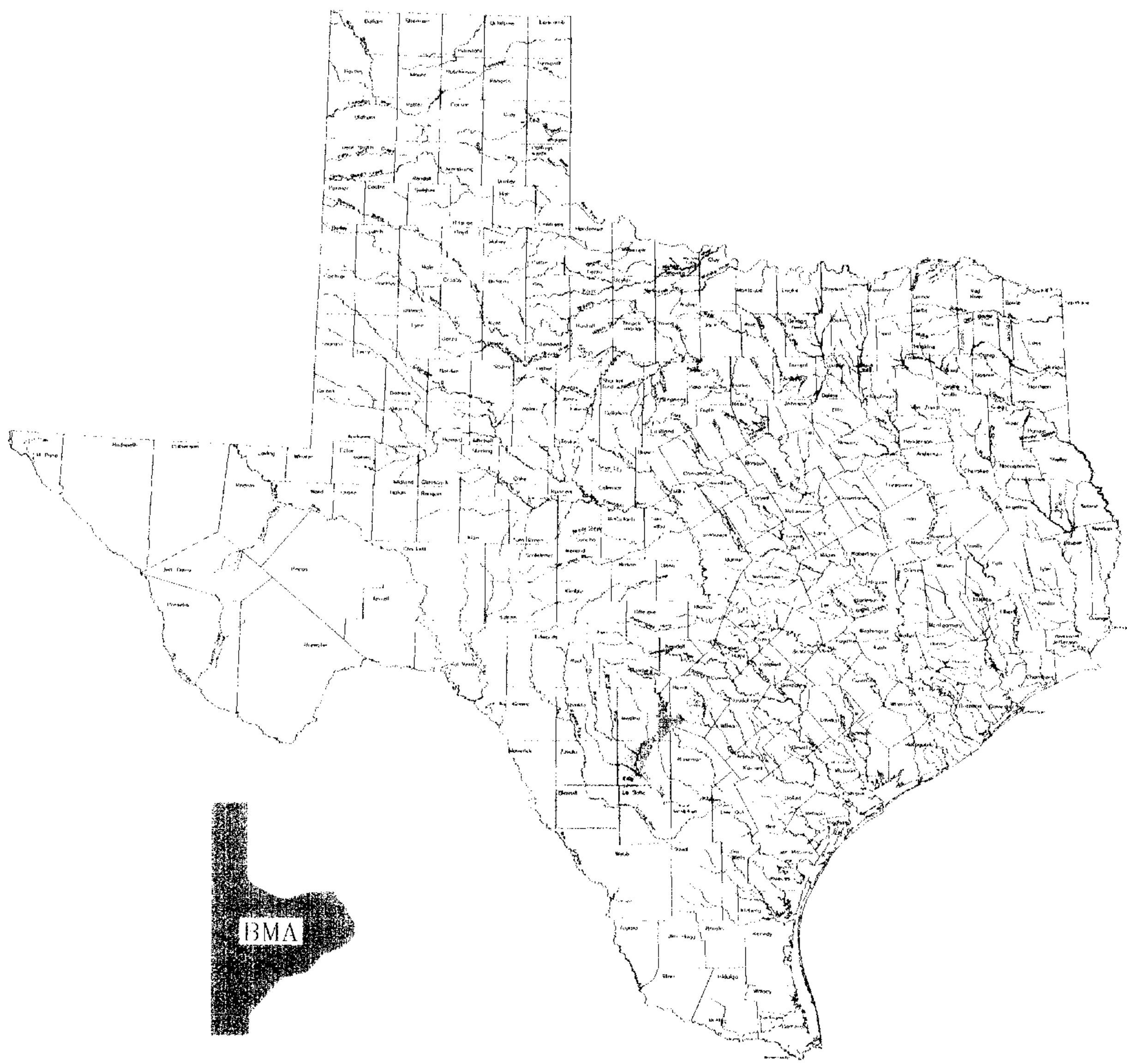


Figure 1

BEXAR – MEDINA – ATASCOSA WATER IMPROVEMENT DISTRICT #1

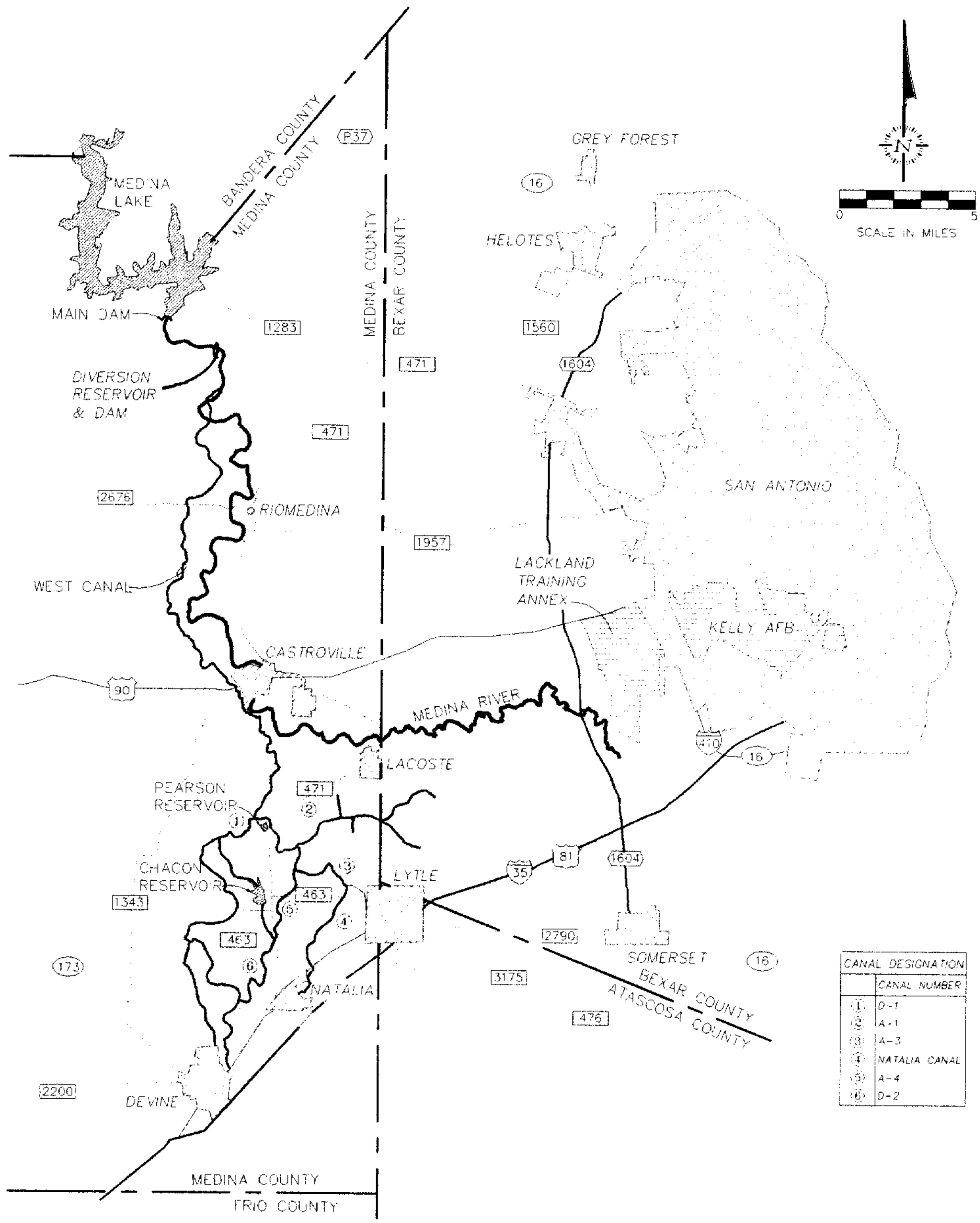


Figure 2

PREVIOUS STUDIES

Over the past thirty years, several studies have been produced that evaluate BMA facilities, including the canal system. These previous studies include:

1964 The SCS examined the feasibility of a PL-566 project to provide assistance to BMA and the SWCD. This project included renovating the delivery system, installing floodwater retarding structures, and providing on-farm assistance to cooperators with irrigation water management practices. The recommendations of the study were not implemented by the BMA directors due to their concerns about the assocated costs and federal government intervention into the operation of the District that threatened local control.

1969 The United States Geological Survey (USGS) conducted a gain / loss survey of BMA's Main Canal. The study identified a four cubic-feet-per second (cfs) loss in a 24 mile reach between the diversion point and a measuring site at the first lateral near Pearson. During the study, a constant flow in the main canal was achieved and maintained while the USGS personnel took current-meter measurements at specific locations. Documented losses were previously attributed to evapotranspiration. The findings of this study are summarized in Table 1.

TABLE 1

USGS GAIN/LOSS SURVEY ON BMA MAIN CANAL

Site No.	Date	Stream	Location	Canal Mileage	Discharge (cfs)
1	8/15/69	Main Canal	Stream gaging station	0.4	106
2	8/15/69	Main Canal	Medina Dam Rd., 1.6 mi. nw of Rio Medina	4.8	106
3	8/15/69	Main Canal	Quihi Rd., 2.4 mi. west of Rio Medina	6.3	103
4	8/15/69	Main Canal	US Highway 90, 0.2 mi. west of Castroville	16.3	104
5	8/15/69	Main Canal	Private road, 1.1 mi. northwest of Pearson	24.0	102

1978 The Bureau of Reclamation prepared *The Special Report on the San Antonio-Guadalupe River Basins Study,* which reviewed multiple needs and demands for water use in the Lake Medina, Diversion Dam, and Medina Main Canal areas.

1986 The City of San Antonio and the Edwards Underground Water District

(EUWD) hired CH2M-Hill to prepare a regional water resource study, including BMA's facilities.

1987 EUWD hired W.E. Simpson, Inc. to evaluate the Medina and Diversion Lake dams as part of a due diligence review prior to tendering an offer to purchase the water resources.

1987 PRODEK Inc. evaluated Medina and Diversion dams as part of a Federal Energy Regulatory Commission (FERC) permit application for a hydroelectric power plant on the main dam.

1990 BMA, Bexar Metropolitan Water District and the Bexar County Technical Water Planning Committee reviewed potential water uses from Lake Medina and BMA's system.

1991 The Texas Water Development Board (TWDB) conducted a gain / loss study on a 24 mile section of the main canal previously analyzed by USGS in 1969, an 18.3 mile section of the D-1 canal, and Diversion Lake. The study found a 48 percent loss in Diversion Lake and a net loss of 20 percent in the main canal. Although the TWDB could not reliably determine the losses in the D-1 canal due to storage behind the many check structures, a 33 percent loss was estimated. TWDB and BMA personnel speculated that most of the loss in D-1 occurs in the lower canal segment due to sandy soil conditions. The results of this investigation are summarized in Table 2.

1992 A Bureau of Reclamation report assessed the resources of BMA's service area and the operation and maintenance of its facilities. Reclamation recommended that BMA define its service area in order to eliminate the expense of maintaining unnecessary facilities. Reclamation also recommended more detailed seepage studies of the reservoirs and canal system. A water quality study was also recommended for the entire system. A study involving wetlands and other environmental considerations was also suggested in order to satisfy both federal and state concerns for cultural and wetland resources. Other recommendations involved BMA's facilities operation and maintenance. BMA, in cooperation with Reclamation, requested assistance from SCS for some of these recommended studies.

1993 Blackwell Environmental Inc. conducted a detailed stability analysis of the Medina and Diversion Lake dams. A siltation study was conducted in conjunction with the analysis.

1994 Blackwell, Lackey, & Associates, USGS, and Mike Sullivan and Associates began work on a detailed water balance study of Medina Lake.

TABLE 2 TWDB GAIN/LOSS STUDY ON BMA MAIN CANAL						
Location	Date	Station	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	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	26.23	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

PHYSICAL CHARACTERISTICS OF THE DISTRICT

The District is located west of San Antonio in Atascosa, Bexar, and Medina Counties with Medina Lake located in Medina and Bandera Counties. Watershed topography is generally undulating to steep rocky soils with SCS classifications of C and D. The District's service area is generally flat to rolling alluvial plains with fertile sandy loam and sandy clay soils. Elevations in the area range from 600 feet around Devine to 1,500 feet above Medina Lake.

SOILS WITHIN THE DISTRICT

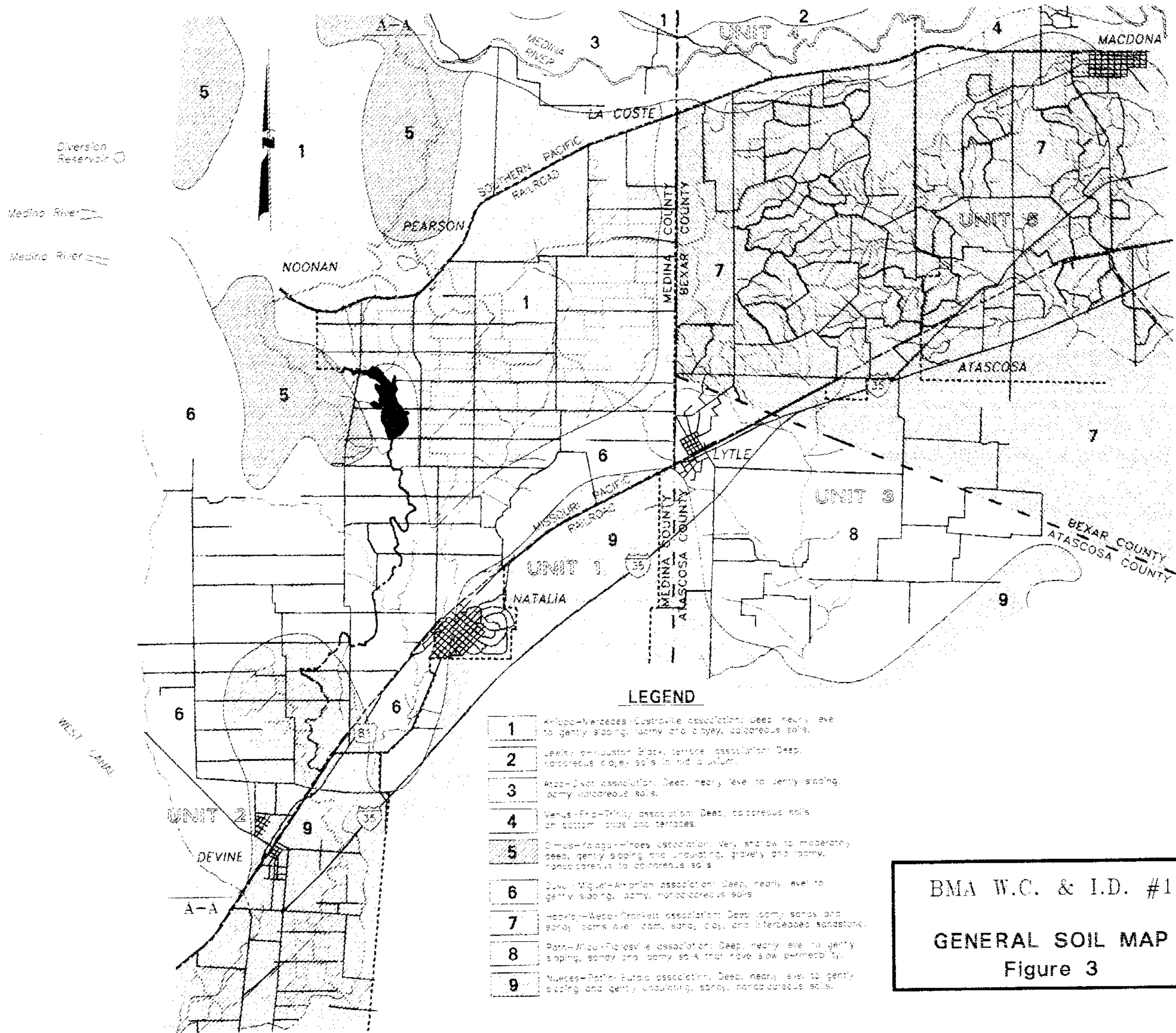
According to the SCS Soil Surveys prepared for Bexar (1962), Medina (1977), and Atascosa (1980) Counties there are approximately nine soil groupings within the District service area. The following is a listing of these groups and a brief description of each:

1) **Knippa-Mercedes-Castroville Associaton:** Deep, nearly level to gently sloping, loamy and clayey, calcareous soils.
2) **Lewisville-Houston Black, terrace Association:** Deep, calcareous clayey soils in old alluvium.
3) **Atco-Divot Association:** Deep, nearly level to gently sloping loamy calcareous.
4) **Venus-Frio-Trinity Association:** Deep, calcareous soils on bottom lands and terraces.
5) **Olmos-Yologo-Hindes Association:** Very shallow to moderately deep, gently sloping and undulating, gravelly and loamy, noncalcareous soils.
6) **Duval-Miguel-Amphion Association:** Deep, nearly level to gently sloping, loamy, noncalcareous soils.
7) **Hockley-Webb-Crockett Association:** Deep, loamy sands and sandy loams over loam, sandy clay, and interbedded sandstone.
8) **Poth-Wilco-Floresvelle:** Deep, nearly level to gently sloping, sandy and loamy soils that have slow permeability.
9) **Nueces-Patilo-Eufala Association:** Deep, nearly level to gently sloping and gently undulating, sandy, noncalcareous soils.

A map illustrating the distribution of these soils within the district is presented in Figure 3.

CLIMATE

The climate is considered to be subtropical subhumid, which is typified by hot summers, cool



BMA W.C. & I.D. #1

GENERAL SOIL MAP

Figure 3

winters, and low rainfall. Prevailing winds are out of the southeast during the majority of the year switching to the north during the winter months. Table 3 summarizes the data on the District according to the Texas Climactic Atlas.

TABLE 3

ATASCOSA, BANDERA, BEXAR, AND MEDINA COUNTIES CLIMACTIC INFORMATION

DESCRIPTION	HIGH (monthly)	LOW (monthly)	ANNUAL (cumulative)
PRECIPITATION (inches)	4	1½	28
TEMPERATURE (°F)	95	37	68
EVAPORATION (inches)	9½	2½	65

SYSTEM DESCRIPTION

The system of dams and canals that are presently owned and operated by BMA were originally designed, financed, and built by the Medina Valley Irrigation Company in the early 1900's for the primary purpose of capturing and storing waters of the Medina River for irrigation. The company fell into bankruptcy after its founder and principal manager, Dr. Pearson, died in the sinking of the Lusitania. Ownership of the dam and other facilities were transferred in 1925 to the newly formed Bexar-Medina-Atascosa Counties Water Control and Improvement District No. 1.

MAIN DAM AND MEDINA LAKE

The watershed for Medina Lake is comprised of approximately 653 square miles of rugged, rocky land on the Edwards Plateau. Vegetation consists mainly of grasses, cedars, and scrub oaks. Beginning in moderately steep to rolling plains, the headwaters of the Medina River are approximately 45 miles upstream from the lake. The river flows in a southeasterly direction about 36 miles to the city of Bandera, then flows southward approximately nine miles to enter Medina Lake. While the average rainfall in the area is only 28 inches, thin, rocky soils on steep slopes produce high runoff rates.

The Main Dam was completed in 1912 after 53 weeks of construction at a cost of $1.5 million in private capital. The dam is a concrete gravity-type structure with an overall crest length of 1,580 feet and contains 298,000 cubic yards of concrete. At its largest cross-section the dam is 164 feet tall, 136 feet wide at the base, and 23 feet wide at the top.

Resting on massive Glen Rose Limestone, the base is anchored by 10 - 12 feet deep keys on both the upstream and downstream toes. A grout cut-off wall was constructed along the entire length of the face to minimize water flow under the dam. Construction of this wall consisted of drilling 1¼-inch holes on six foot centers to a depth of 20 feet and injecting alternate holes with neat cement under high pressure. The intermediate holes were grouted to complete the seal. To reduce uplift pressure on the dam, 122 relief wells were installed on centers of five feet to a depth of 30 feet below the foundation. These wells extend 13 feet above the foundation to the drainage/inspection gallery. These wells allow water to exit the downstream side of the structure. The gallery is four feet wide by six feet tall, 557 feet in length. The gallery is located 23 feet from the upstream face, with two access tunnels exiting from the downstream face.

An interesting feature of the Main Dam is the spillway, which was constructed by cutting the ridge between the Medina River and the Mexican Draw canyons to an elevation twelve feet below the crest of the dam. The 880 feet long spillway has a three feet wide concrete cut-off wall along the crest to prevent erosion from cutting through the ridge. Flows that exceed the storage capacity of the main reservoir spill into Mexican Draw and return to the river several hundred feet below the Main Dam into the Diversion Reservoir.

Maximum pool level is elevation 1072' Medina Lake Datum (Medina Lake Datum = Mean Sea Level + 7.5 feet) which is also the crest elevation of the uncontrolled spillway. By owning or controlling by inundation easement all land upstream of Medina Dam to elevation 1084', BMA has provided twelve feet of protection from flooding above maximum pool elevation. Numerous residential, recreational, and commercial developments have been built around the perimeter of the lake above the 1084' elevation. The surface area of the reservoir at that level is approximately 5,575 acres with a total capacity of about 254,000 acre-feet of conservation storage. Dead storage below the invert of irrigation outlets at elevation 975.3 is about 4,780 acre-feet.

Measured at the USGS Pipe Creek gauge located on Medina River near the upper end of the lake, the average annual inflow to Medina Lake is about 94,500 acre-feet. The USGS established a stream flow measurement station (Mico station) at a location about 2,000 feet downstream from Medina Dam and measured daily flows in calendar year 1930. Below the Mico station, the Medina River flows across a small reach of rapids before entering Diversion Reservoir, a 3.5 mile long impoundment created by Diversion Dam. A stream flow measurement station (USGS Gage 08180500 Medina River near Rio Medina) operated between 1922-1934 and from 1953-1983. This station historically provided a record of mean daily flows downstream from Diversion Dam. Records of diversions to the main canal were maintained by the USGS and reported as Gage 08180000 Medina Canal near Rio Medina until 1994 when a BMA gauge was installed. Annual diversions to the main canal have averaged 30,280 acre-feet between 1957 and 1994.

DIVERSION DAM AND RESERVOIR

Diversion Dam and Reservoir are located approximately four miles downstream from Medina Lake. The dam was built in 1913, using 30,000 cubic yards of concrete at a cost of $250,000. The structure was built to avoid four miles of canal and tunnel work down the river canyon. The outlet structure of the dam is at an elevation that permits gravity flow through the BMA canals. The dam is a concrete, gravity/ arch-type structure, which is 50 feet tall and 50 feet wide at its base. The design and construction of this dam is generally the same as was used for the Main Dam. The crest is 440 feet along an arch with a 700 foot radius. The overflow spillway consists of the middle 355 feet of the crest and is ogee-shaped for protection of the structure. The foundation of the dam rests on limestone with the heel extended approximately ten feet into rock and the toe extended five feet into rock. The headworks and control gates for the main canal are located at the western end of the dam.

PEARSON DAM AND RESERVOIR

The Pearson Reservoir is located immediately south of the point where the D-1 canal splits from the Main Canal (See Figure 2). This provides off-system storage for conservation of water remaining in the canal system at the end of the irrigation season and other times during the year when irrigation water is not needed due to rainfall. Water is diverted to the reservoir when flow in the main canal ceases and is stored until needed. This water management practice conserves water that would otherwise be lost. It is used to fill small orders for water without filling the entire canal system. (See PHOTO 7)

The dam consists of an earthen or embankment type structure with a gated outlet. Water is diverted into the reservoir by lowering the gate into a concrete-lined chute and is raised until it overflows into the 23 acre impoundment. The embankment dam is approximately 30 feet tall, ten feet wide at the top, 90 feet wide at the bottom, and 1,700 feet along the crest. Side slopes of the structure are 1.5 (horizontal) to 1(vertical).

CHACON DAM AND LAKE

Chacon Lake is formed by an earthen dam across Chacon Creek (See Figure 2). Like Pearson Reservoir, the 130 acre Chacon Lake is used as a holding facility for excess water in the system. However, unlike the Pearson, Chacon Lake also receives runoff from the 17 square mile Chacon Creek watershed. The dam is approximately 15 feet tall, 10 feet wide at the crest, 60 feet wide at the base, and 800 feet along the crest. The structure includes a spillway to allow surplus water to continue down Chacon Creek and a gated outlet works for releasing water into the lower canal system. (See PHOTO 8)

JUNGMAN, KIRBY, DUBOSE, AND BALL LAKES

These lakes were originally designed and built as off-system storage. Jungman Lake, though relatively small, is still being operated in this manner. Kirby Lake, which is located near the very end of the BMA system, is of little operational value to the District since pumps would be required to transfer the water back up to the system. Ball and Dubose lakes both need extensive repairs before they can be returned to service. (See PHOTO 9 - 12)

TRANSMISSION SYSTEM

The BMA irrigation canal system was designed in 1910 with a capacity of 600 cubic feet per second (cfs). Its alignment generally follows the west side of the Medina River past Castroville to a point north of the Southern Pacific Railroad near Pearson. The canal then branches, providing irrigation to the area bounded roughly by Devine to the west, Macdonna to the east, the Southern Pacific Railroad to the north, and the Missouri Pacific Railroad to the south. The main or West Canal is approximately 24 miles in length and was designed with an average slope of two feet per mile.

At Pearson, the canal drops 140 feet in less than a mile passing through a concrete lined chute and a series of drop structures. Native clay soils were used as a liner for all sections of the canal except for the previously described Pearson chute and the first segment near Diversion Dam. The rugged topography in the vicinity of Diversion Dam, with its steep side slopes, required a narrow concrete lined cross-section. Two reinforced concrete inverted siphons were constructed to permit two crossings of the Medina River. This alignment avoided the steep canyons at a bend in the river. The first siphon consists of two - eight foot diameter pipes 1,150 feet in length, while the second was constructed as two - seven foot diameter pipes, each 1,310 feet in length. Eleven flumes were constructed in lengths varying from 122 feet to 1,520 feet with a maximum height of 95 feet in order to cross creeks and low areas without changing the canal grade. These flumes consisted of a pair of semi-circular, galvanized steel flume channels supported by creosoted timber trestles. By 1938, most of the flumes had deteriorated to the extent that they were in danger of collapse. Over the next several years, the worst were by-passed by a canal constructed around the head of the canyon, installation of a drainage pipe and filling across a canyon, or by building siphons. Upon completion of the replacement structures, the flumes were demolished with the exception of one located approximately three miles north of Castroville which remains standing adjacent to the relocated canal.

According to the District Engineer's report in 1938, the replacement siphons reduced the capacity of the main canal to 382 cfs at the site of Flume 11 based on anticipated losses in the canal system. The canals were originally built with 2:1 side slope inside the channel, 1½:1 side slopes on the outside of the channel, and on a grade to maintain a velocity of 2.5 feet per second (fps). Over time, maintenance efforts have drastically altered the original trapezoidal cross-section such that the side slopes on most segments are approximately one to one and the bottom is irregular. Check, drop, control, and turnout structures currently in use in the system include both original ones of constructed of redwood and newer ones constructed of concrete.

For the purposes of this study, the canal system has been divided into five categories based upon the relative size and capacity. Pictures of each type have been included in the Appendix for reference. Table 4 provides a summary of these categories and an inventory of the system broken down by length, size, and soil type. (See PHOTO 1 - 6)

TABLE 4 BMA CANAL TYPES					
Type	Description	Top Width (ft)	Bottom Width (ft)	Average Depth (ft)	Estimated Capacity * (cfs)
A	Main Canal	25	10	6	229
B	Minor Canal	12 - 16	6 - 10	4	90
C	Major Lateral	8 - 12	4 - 6	3	36
D	Minor Lateral	3 - 8	1.5 - 4	3	22
E	Field or Pull Ditch	1 - 3	1	1	1.3

* The estimated canal capacity is based upon Manning's Equation for a trapezoidal channel with an n = 0.029, a one to one side slope, and a slope of two feet per mile (0.0004 ft/ft).

In addition to the canal footage shown in Table 5 below, the District has installed approximately 1,000 linear feet of 36 inch diameter plastic pipe in the D-2 canal immediately south of US-81 and 2,000 linear feet of ten inch diameter plastic pipe in canal 35-E.

TABLE 5 BMA CANAL INVENTORY						
Soil Association	Type A	Type B	Type C	Type D	Type E	Total Footage
Knippa-Mercedes-Castroville	20,400	84,000	44,400	–	214,800	363,600
Lewisville-Houston Black, terrace	–	–	–	–	–	0
Atco-Divot	45,600	–	–	–	–	45,600
Venus-Frio-Trinity	–	–	–	9,600	–	9,600
Olmos-Yologo-Hindes	62,400	1,800	–	26,400	7,800	98,400
Duval-Miguel-Amphion	–	16,680	60,600	117,120	164,760	359,160
Hockley-Webb-Crockett	–	45,000	–	433,800	–	478,800
Poth-Wilco-Floresvelle	–	–	–	3,000	–	3,000
Nueces-Patilo-Eufala	–	–	33,240	52,200	64,800	150,240
Total Canal Footage	128,400	147,480	138,240	642,120	452,160	1,508,400

IRRIGATION AND RIVER BASIN HYDROLOGY

There are certain fundamental principles for water diverted for agricultural irrigation which must be considered to ensure efficient use. Figure 4 illustrates the relationship between irrigation diversions, water use, and river basin hydrology.

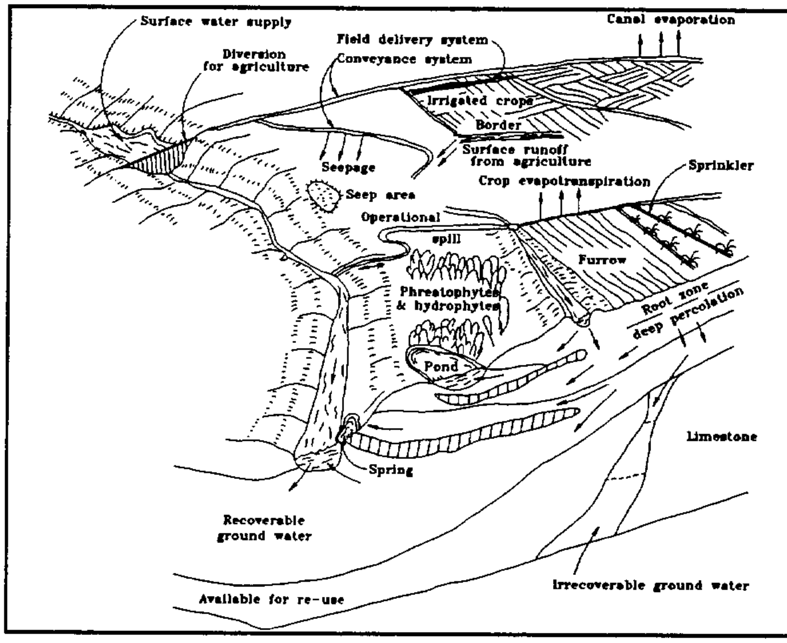


Figure 4

The volume of water diverted for irrigation must be greater than the volume needed by an irrigated crop in order to compensate for losses in the delivery system. While the diverted irrigation water may include return flow from other areas, losses from the conveyance system will include crop evapotranspiration, seepage, operational spills, deep percolation, tailwater runoff, evaporation, and phreatophyte and hydrophyte consumption. Phreatophyte and hydrophyte consumption is non-crop vegetative transpiration of water that may occur adjacent to streams and channels, or in areas of shallow water tables. The existence of such vegetation may provide or enhance wildlife habitat.

Seepage varies according to canal and on-farm ditch condition. Piped or lined conveyance systems have lower seepage rates than unlined channels. Seepage and deep percolation (movement of water below the root zone) can return to natural stream channels either directly via drains, or indirectly through groundwater aquifers. Return flows reaching open canals or natural streams are available for instream use or downstream diversion. Return-flow water quality, however, may be affected. Seepage from the conveyance system may also contribute to aquifer recharge and maintain groundwater levels in the area.

A small quantity of deep percolation, known as the leaching requirement, is necessary to remove chloride and sulfate salts that could otherwise accumulate within the root zone, hampering and eventually inhibiting plant growth. The volume of water required for leaching depends on soil type, crop type, climate, and water quality. Depending on geologic conditions, deep percolating water may slowly enter deep aquifers or streams through natural or manmade drainage systems.

In a graded irrigation system, filling the root zone results in tailwater runoff at the lower end of a field. The amount of runoff depends on soil conditions, irrigation system design, and water application methods. Some tailwater runoff is unavoidable when a graded surface irrigation system is operated to achieve adequate infiltration and water application uniformity. Tailwater may evaporate, percolate, be consumed by phreatophytes, or reach stream channels as surface or groundwater return flow. Runoff can be collected on-farm and pumped back into the delivery system for reuse, or may be intercepted by other users as a supplemental or primary water source.

Irrigation water that recharges a ground-water aquifer through seepage or deep percolation adds to the water supply available to ground-water users in the area. Some farms and small communities depend on these replenished supplies. In a few instances aquifers are used to store and distribute excess surface water.

Return flows to natural stream channels resulting from tailwater runoff, drainage flows, operational spills, or ground-water discharge can provide all or a portion of a downstream user's water demand. Return flows from irrigation sources often sustain flow in smaller streams to support aquatic habitat. Sources of return flows include surface runoff during irrigation, drainage from canal seepage, leakage at canal structures, waste water discharge during conveyance, discharge at the lower end of the canal, and drainage from excess percolation during irrigation. The amount of return flow depends on the amount and timing of water diverted, conveyance and irrigation efficiency, subsurface soil formations, surface soil texture, and drainage facilities.

Operational spills result when demand for water is reduced due to rainfall after the irrigation water has entered the conveyance system. These spills return to the natural stream channels via wasteways and become available for instream or downstream use.

WATER SUPPLY

Precipitation in this region is unreliable for crop production. The three classifications of water supply within the region are surface water, ground water, and miscellaneous sources that include municipal water and treated wastewater. Application methodology and irrigation system design depend on the type of supply and its rate of delivery. Surface water impounded in Medina Lake is the primary source of irrigation water within the District. Secondary supply sources used by some farms, such as groundwater, may provide practical alternatives for the District in the future.

SURFACE WATER

Surface water supplies typically include water held in reservoirs and water diverted or pumped from streams and rivers. Excess irrigation water that reaches streams through surface drainage, flow through drainage ditches, or percolating return flow from irrigated land and available for rediversion is generally considered a surface supply.

As previously discussed, return flow from an irrigated area can be available for instream use or downstream diversion. It is sometimes possible to impound out-of-season return flows in reservoirs for use during the next irrigation season.

High efficiency in graded-border or furrow irrigation produces some surface runoff at the lower end of a field. In areas of shallow soils or steep grades, level fields are not always practical. Limited water supplies often make it economically feasible to recover excess water before it becomes return flow and to pump back into the delivery system for reuse. This requires a pickup ditch that directs water to a sump or storage basin and a pump with piping to deliver water back to the conveyance system. The capacity of pickup ditches should be sufficient for both irrigation water and rainfall runoff. Sumps and pumps should have adequate capacity to insure efficient use of the pump-back stream in the irrigation system. If the capacity of the sump or storage pit is low in relation to the volume of runoff that can be expected, automatic controls on the pump are recommended.

Tail-water recovery facilities should not be installed as a substitute for good irrigation practices. Instead they should serve as a supplement to increase irrigation efficiency. Efficient use of furrow irrigation requires that a tail-water recovery system be used to eliminate the labor required for cutback streams while maintaining high efficiency.

GROUND-WATER

Three ways of obtaining ground-water include: pumping from porous or cavernous water-bearing formations; free flowing artesian wells, such as the widely-reported catfish farm east of the District; and from collecting the flow from large natural springs or seepage areas. Groundwater has the advantage of being free of weed seeds and debris, which is particularly important when using sprinkler irrigation. Groundwater supplies are usually developed and operated by individual farmers or by a few landowners working together. The Medina County Underground Water District and the Edwards Underground Water District, along with local well drillers are the best sources of information about ground water availability.

A properly constructed and developed well will be limited only by the yield capacity of the water-bearing formation. In areas where ground water is plentiful, wells are typically located near the center of the irrigated area for convenience and economy of pumping. The requirements for an irrigation well are:

- ❑ The lift should be as small as possible,
- ❑ The well should have a long life, and
- ❑ The water pumped must be reasonably free of sand.

The dominant water-bearing formations in the District are the Edwards Limestone formation and unconsolidated sand and gravel formations, such as the Carrizo-Wilcox. In limestone formations, wells are drilled through the limestone into a highly permeable zone and a casing is set and grouted in place. In unconsolidated sands or gravel, wells are drilled through the water-bearing formation, and casing is set. The lower end of the casing consists of either a perforated section or a well-screen that permits water to pass from the water-bearing sands or gravel into the well. Well casings are used to prevent contamination from surface or perched waters.

While a group of wells drilled in one of these formations has certain characteristics, each well must be individually analyzed, designed, and constructed. No two water-bearing formations are exactly alike and wells should not be drilled and developed exactly like a nearby well without first determining the best development procedures.

Drilled wells are put down by percussion drills, rotary drills or some modification of these tools. They can be drilled to diameters up to about thirty-six (36) inches through almost any material, and to any practical depth. For these reasons drilled wells are the most common irrigation wells. A casing is installed in the drilled hole down to the water bearing strata and a well screen is attached to the bottom of the casing. If the aquifer is predominantly sand, a perforated casing with a graded gravel pack is generally used instead of a well screen.

Water from flowing artesian wells or pumped from artesian aquifers can produce substantial amounts of water at relatively high pressures. In order to avoid depletion of artesian pressure, annual withdrawals should not exceed annual recharge. Excessive withdrawal will cause flowing wells to cease, making pumping or artesian wells necessary.

MISCELLANEOUS SOURCES

Miscellaneous sources of water include municipal water systems, effluent from wastewater treatment plants, and wastewater from industrial plants. The quantity of water available from these sources is usually sufficient only for irrigation of small areas.

Municipal potable water supplies are usually too expensive and inaccessible for agricultural use, except for suburban gardening. However, effluent from municipal wastewater treatment plants can be used for irrigation under specific conditions. Wastewater effluent is return flow from domestic and industrial uses. Since it often amounts to two-thirds or more of the water delivered to consumers, effluent can be an important source of water for irrigation in the future. In considering the use of wastewater effluent for irrigation, the potential for crop contamination and groundwater pollution must be considered. To minimize the potential effects, state regulations govern the use of effluent for irrigation. Sewage effluent is generally more suitable for use on coarse-textured sandy soils than on fine-textured silt and clay soils since the nutrient content of effluent may improve the sandy soils.

CONVEYANCE SYSTEMS

Current District policy requires that irrigation water be made available to the farm at a rate and elevation that permits proper operation of furrow irrigation systems. The District continually strives to convey irrigation water as economically, efficiently, and safely as possible. Due to the capacity limitations of the canal system, water is delivered to individual farms on a turn basis to ensure that irrigation can be completed within a reasonable time. Once finished, the next farmer that has placed an order is allowed to irrigate. BMA's conveyance system of surface canals includes the necessary grade-stabilization (drop structures) and water control structures necessary for open channel gravity delivery.

Low construction costs make open ditches more widely used for irrigation water conveyance than any other type of conduit. Ditches that carry irrigation water from the source of supply to one or more farms are known as canals or laterals and are generally large, permanent installations. Field or pull ditches are smaller, semi-permanent facilities that convey water from the farm source of supply to a field or fields within a limited area.

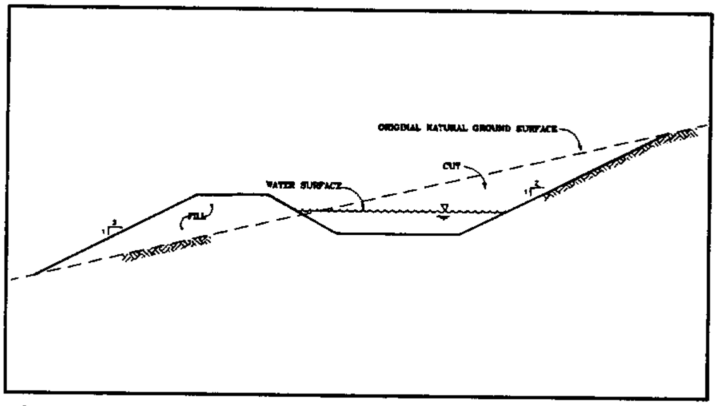


Figure 5

Ditches work best in clay or loam soils since seepage is usually less and ditch banks are more stable than those in sands or sandy loam. Open ditches can carry large volumes of water, are easy to build, and have the advantage of low cost per volume of water carried. The disadvantages of open channels include, high losses from seepage and evaporation, increased maintenance costs due to vegetation and erosion control, require large land areas, and can hinder farm operations.

OPEN CHANNEL DESIGN

Open channels are designed to transport water at atmospheric pressure and may be constructed in a wide variety of shapes. The use of an open channel is dictated by topographic conditions suitable to permit gravity flow with minimal excavation or fill. With uniform flow conditions, the slope of the water surface is parallel to the bottom. The parameters affecting the design of open channels include the cross-sectional shape, slope, and roughness coefficients (Manning's "n"). Design of a channel begins by determining the cross-sectional area necessary to transport a specified flow rate.

Determining the depth of flow and velocity are important for selection of an appropriate liner material. High velocities require special liners which are not affected by erosion such as concrete. Canal liners are discussed in greater detail later in this section. The Manning's equation is the most widely accepted channel design calculation.

$$Q = \frac{1.486\ A\ R^{0.67}\ S^{0.5}}{n}$$

Where: Q = Discharge, cubic feet per second (cfs)
A = Cross-sectional area of flow, square feet
R = Hydraulic Radius, ft = A/W_p where W_p is the wetted perimeter of flow.
S = Slope of water surface, usually assumed to be parallel to stream bed slope (ft/ft). Note that often, slopes are represented as percentages. The designer should assure that the units are feet per feet before using S in calculations.
n = Manning's Roughness Coefficient

The roughness coefficient is determined by the type of material used for the liner, vegetation, and any obstructions. Presented in Table 6 are typical ranges for Manning's coefficients.

CHANNEL LINING

Channel lining is an effective way to control seepage and erosion to the channel bottom and banks. Lining permits channels to transport more flow than larger unlined channels because of reduced roughness. This efficiency means that less land is needed for channel construction. Lining also provides some protection against damage by rodents, protects adjacent land against waterlogging and salinity, reduces maintenance costs, and minimizes interruptions in water delivery.

Water loss through evaporation in a canal system is usually only a small percentage of the water volume. However, losses through the bottom and sides of the canal can be quite significant. Exfiltration loss varies according to soil permeability, soil thickness, depth of flow in the canal, and soil saturation.

The two main reasons for constructing a liner in a water supply canal are to reduce water

TABLE 6
MANNING'S ROUGHNESS COEFFICIENTS

Minor Streams	Min.	Max.
A. Fairly regular section		
1. Some grass, weeds; little or no brush	0.030	0.035
2. Dense growth; flow depth greater than weed height	0.035	0.050
3. Some weeds, heavy bank brush	0.050	0.070
4. Some weeds, dense bank willows	0.060	0.080
5. For submerged branches, increase all values by	0.010	0.020
B. Irregular section w/ meanders - increase above by	0.010	0.020
C. Rocky, steep channels, little vegetation		
1. Small rocks	0.040	0.050
2. Large rocks	0.050	0.070
Flood Plain		
A. Pasture, no brush		
1. Short grass	0.030	0.035
2. Tall grass	0.035	0.050
B. Cultivated areas		
1. No crops	0.030	0.040
2. Mature row crops	0.035	0.045
3. Mature field crops	0.040	0.050
C. Heavy weeds, scattered brush	0.050	0.070
D. Wooded - Coefficients vary with type and density.	0.075	0.200
Major Streams		
Coefficients less than for minor streams of similar description.		
Lined Channels		
1. Concrete lined	0.012	0.018
2. Concrete rubble	0.017	0.030
Unlined Channels		
1. Earth, straight and uniform	0.017	0.025
2. Winding and sluggish	0.022	0.030
3. Rocky beds, rubble sides	0.025	0.040

losses caused by exfiltration and to reduce maintenance costs associated with slope instability caused by erosional or seepage forces related to leakage of water from the canal. The first type of problem is usually a global one that involves assessment of the entire length of canal and a generalized solution for the entire system. The second problem is usually a localized problem requiring a specific solution for each area of instability.

Selection of a lining material depends on several factors including material availability, ease of installation, ditch size, climatic and foundation conditions, whether the irrigation stream is continuous or intermittent, potential for damage due to freeze damage, potential for damage from livestock, fluctuation of the water table, and vegetation. There are a number of materials currently in use as liners. These include native soils, concrete, bituminous materials, butyl rubber, vinyl, and various synthetic fabrics. Of these, native soils are the most common due to economics. The reduction of exfiltration of water by the construction of a liner is often not as simple as it would appear. Analysis of the problem begins by asking:

1) Is the leakage generally uniformly distributed along the length of the canal or is it concentrated along certain reaches of the canal?

2) Does the entire wetted perimeter of the canal leak or are the leaks limited to a specific area of the cross-section such as the side-walls or bottom?

3) What is the minimum thickness and permeability that will reduce the exfiltration to a satisfactory level?

The second type of problem arises when a leaking canal bottom or side-wall causes the soil in the vicinity of the canal to become unstable. This instability can result in failure of the sidewall, bottom or entire canal cross section. These problems are the result of excess velocity through the system or soil instability. The purpose of channel lining is both to save water and to maintain the integrity of the canal and, thus its ability to convey water.

The design, construction, and maintenance of a canal for the purpose of transporting irrigation water is one of the most difficult to analyze types of engineering problems. By its very nature, flow in an irrigation canal is seasonal and variable. Canals are usually constructed using natural materials that are susceptible to erosion and leakage. In addition, soil stability is widely variable through the course of the canal. Some canal properties change with respect to age, such as resistance to erosion and permeability. The water transported in the canal can erode, transport and deposit sediments.

Oversimplification of variables in an engineering analysis can result in approximations that lack significance. The solution is to rely heavily on empirical data and observations. The appropriate slope, cross section, velocity, and soils stability can be easily observed in the existing canal system where they have either been proven successful or not.

LINER MATERIALS

Earth - A canal that is constructed in natural soils must be stable and resist erosion while remaining relatively impermeable so as to minimize water losses due to exfiltration. Soils typically are divided into two categories based on the size of the grain particles: fine (clays and silts) and coarse (sands and gravel).

Gravel can provide a canal with greater resistance to erosion owing to the weight of the material. However, gravel is also an extremely permeable material that would require fairly flat side slopes for stability.

Clay soil (CL or CH), with its low permeability, makes an excellent liner except for its lack of resistance to erosion. Clay soil will also tend to crack when dried and swell when saturated. Clay is particularly well suited for liners in canals that are in constant use. Alternating wet and dry cycles can reduce the resistance of clay to erosion, reduce the density, and decrease the shear strength thereby increasing permeability. A compacted clay with a permeability of $1x10^{-9}$ cm/sec and a void ratio of 0.40 may withstand the scour induced by water velocity in excess of four feet per second (fps) immediately after it is constructed. However, after several alternate periods of wetting and drying, the void ratio can rise to approximately 1.0 with the permeability increasing to more than $1x10^{-7}$ cm/sec. These changes can reduce the scour velocity to less than two fps.

Occasionally the alternate wetting and drying is not a significant problem due to the canal becoming "armored" with coarse sand or gravel from the sediment transported with the water. After a few days of operation the swelling of the clay seals all of the cracks and leakage ceases to be a serious problem. These events are difficult to predict during design, but are simple to verify in the field.

While armoring is an unpredictable occurrence, a similar effect can be designed into channel construction through material selection. One of the best liner materials for a canal is generally what is called dirty gravel. This is a gravel soil that has a significant clay constituent (GC). The gravel gives it a high resistance to erosion and the clay lends impermeability.

Materials with similar characteristics to dirty gravel are dirty sand or sandy soil with a significant clay constituent (SC) and a low plasticity clay (CL) with a significant amount of sand or gravel. Mixtures of gravel, sand and silt that are classified as dirty gravel (GM) have been successfully used as constructed liners for canals. These soil mixtures are typically natural occurring rather than man-made mixtures. A notable exception has been liners constructed of scarified natural soils with bentonite and water mixed in the upper few inches and followed by recompaction of the mixture. The permeability of soils range from highly permeable (clean coarse uniform grain sized sand) to practically impermeable (well compacted saturated clay). The common classifications of permeability ranges are:

Degree of Permeability	K, cm/sec
High	> 1×10^{-1}
Medium	1×10^{-1} - 1×10^{-3}
Low	1×10^{-3} - 1×10^{-5}
Very Low	1×10^{-5} - 1×10^{-7}
Practically impermeable	< 1×10^{-7}

A change in magnitude of canal soil permeability in a long canal from medium to high can be significant and reduce exfiltration losses to an acceptable level. However, the costs of decreasing permeability by two to five orders of magnitude (10^{-5} to 10^{-7}) can be economically prohibitive, assuming a constant liner thickness and hydraulic gradient.

An alternative to reconstruction would be design of a maintenance program to bring about a gradual change of soil thickness, soil type, and permeability through routine restorative efforts. Unfortunately, these changes can also bring about an unsatisfactory change in hydraulic gradient in the liner. Since water transported by an irrigation canal has a very low market value, only a relatively small expenditure per acre-foot of water is warranted.

Constructing a soil liner for a canal with a permeability in the very low to low range is much easier, and less costly than similar construction in the practically impermeable range. Due to the installation techniques required, there is little or no cost differential between the very low to low range liners and those liners in the medium to high range of permeability. A liner constructed of clay with a permeability of 1×10^{-7} cm/sec may cost twice as much as a sand/silt/clay mixture of soil with a permeability of 1×10^{-5} cm/sec. Depending on the installation, a liner constructed of a sand/silt/clay mixture with a permeability of 1×10^{-5} cm/sec may cost the same as another constructed of the same material with a permeability of 1×10^{-2} cm/sec. Cost differences are the result of differences in the type of equipment and effort required to construct liners with different materials. Lower permeability requires more compactive effort.

Liners constructed with dirty sands, dirty gravel, and mixtures of sand/silt/clay are easier to construct than clay liners due to the difference in workability of the materials. Clays have a workability factor that is classified as poor, while dirty sands, dirty gravel and mixtures of sand/silt/clay have workability factors classified as good to excellent. Light rubber tired compactors with vibrations work well on these soils while clays require heavy sheep's foot rollers and much higher moisture contents during compaction. Clay used for liners also has a tendency to form clods that are very difficult to break up. This means that clay soils used for liner construction cannot be easily stockpiled unless it is heavily disked or pulverized before use.

Dirty sand, dirty gravel, and mixtures of sand/silt/clay do not tend to form clods. The difficulties caused by poor workability and clod formation are two major cost factors that are amplified by the fact that much of the liner is constructed on a slope. While it is difficult to operate heavy compactors on a slope, the high moisture contents required for the proper compaction of clays makes the work even more demanding.

In addition to the difference in construction costs, there is also a difference in the amount of engineering inspection and supervision required. Higher acceptable permeability requires less engineering and supervision. The "Law of Diminishing Returns" is another factor which affects the cost of liner construction. This is best explained by use of an example:

> A canal is built through two types of soil. One soil which covers 70 percent of the length of the canal has a permeability of 1×10^{-5} cm/sec has proven to be satisfactory. The other 30 percent of the canal length is constructed with a soil with a permeability of 1×10^{-3} cm/sec which has proven to be unsatisfactory. A computation of the weighted (average) permeability of this canal results in a permeability of 3.07×10^{-4} over its entire length. A program to construct a liner on part or all of the unsatisfactory portion of the canal is investigated. Alternative ONE involves using a clay liner with a permeability of 1×10^{-7} cm/sec. Alternative TWO involves using a mixture of sand/silt/clay with a permeability of 1×10^{-5} cm/sec. The cost of Alternative ONE on a unit area basis is significantly higher than the cost of Alternative TWO.
>
> Alternative ONE involves lining only a portion of the unsatisfactory area of the canal with a clay liner with a permeability of 1×10^{-7} cm/sec. The amount to be lined will result in an average permeability of the entire canal of 1×10^{-5} cm/sec. It turns out that 28.7% (all of the unsatisfactory portion of the canal except for 1.3%) of the canal must be lined to get an average permeability of 1×10^{-5}.
>
> Alternative TWO involves lining all the unsatisfactory portion of the canal with a liner with a permeability of 1×10^{-5} cm/sec so that the average permeability will be 1×10^{-5} cm/sec. It turns out that the liner will cover all of the 30 percent of the unsatisfactory canal.
>
> Alternative ONE requires the construction of practically the same amount of liner as Alternative TWO, but the cost is significantly higher.

The point to be illustrated by the example is that if a liner is to be constructed, there are two options to be considered. The first option is to line the entire canal, which is usually done if almost all of the canal has an unsatisfactory permeability. If this is done, the average permeability for the canal is equal to the permeability of the constructed liner. The other option is to line only that portion of the canal this is unsatisfactory. If that is done, there is little or no advantage in making the new constructed liner any less permeable than that portion of the canal that is satisfactory. Another point to remember is that the seepage should be controlled to an acceptable level at a cost that does not exceed the value of the water saved.

It is very important to determine a satisfactory liner permeability before a liner is designed. If a satisfactory liner permeability is in the range of 1×10^{-4} to 1×10^{-5}, a significant cost saving can be made compared with using a liner with a permeability of less than 1×10^{-7} cm/sec primarily because soils with a lower clay content can be used.

Concrete Lining - Portland cement concrete is one of the most widely used materials. If site conditions are favorable, a well-constructed concrete lining gives long service with minimum repair and maintenance costs. Nonreinforced or lightly reinforced concrete is generally used. Thickness ranges from 1-1/2 to 3 inches, depending on climate and the expected water velocity in the ditch.

Concrete linings can withstand high stream velocities and are, therefore, particularly suitable for erosion control as well as seepage prevention. They are superior to most other linings in resistance to mechanical damage. They are limited to nonexpansive soils where it is possible to get good internal drainage. If concrete linings are to be installed on poorly drained sites, in areas subject to severe frost heaving, or in soils having a high sulfate-salt concentration, they must be specially designed and protected.

High quality, locally available concrete can make slip-form-placed Portland cement concrete an economical lining. In this method concrete is placed by a specially designed machine. The slip form rides on, and is guided by, the channel subgrade as it is pulled forward by a tractor or winch. Freshly mixed concrete is poured through a hopper so that the slip form distributes concrete to the sides and bottom of the ditch. The rear section of the slip form is a strike-off or screening mechanism. The thickness of the concrete lining is controlled by the difference in height between the bottom of the rear section and the bottom of the front section. Ready-mixed concrete is preferable because its quality is easy to control and sufficient volume is available to provide continuous operation.

For smaller ditches, panel-formed lining has certain advantages. After digging the ditch to grade, guideform panels are set about ten feet long and pours concrete in every other panel, skipping a ten foot section. When the concrete is set, the guides are moved and the skipped panels are poured. The bottom in each section is poured first, and then the fresh concrete is screeded up the slope.

Pneumatically applied mortar, known as shotcrete or gunnite, is sometimes used to line and resurface old concrete. Special machines are required and the concrete mix must be carefully controlled. While it is possible to get a strong durable lining, it is more costly than slip-form concrete due to the difficulty in controlling the thickness.

Asphalt Lining - Asphalt can be used as a seepage control lining, either as asphaltic concrete or in sheets, planks, or membranes. Asphaltic concrete consists of sand and gravel bound together with asphaltic cement. It is similar to portland cement in many respects but will not last as long or withstand higher velocities. Asphaltic concrete is not as hard as portland cement and is therefore more susceptible to mechanical damage. In many places the subgrade must be stabilized to prevent vegetation from growing through the lining and causing deterioration. Placement of hot-mix asphaltic concrete also requires special equipment for blending and placement. Placement is either by a slip form or heated screed moved slowly along the ditch by winch or tractor.

Flexible-Membrane Lining - Strips of specially formulated film in sheet form, usually rubber or plastic can be joined using a heat fusion process and used as a ditch lining. The channel subgrade must be firm, smooth, and free of vegetation. All sticks, clods, and debris should be removed to protect the lining against punctures.

In permanent ditches the membrane is buried to lengthen its usable life. The ditch is overexcavated, the lining is placed and followed by a protective soil cover. The covering material must be carefully selected and placed on the membrane to avoid damage during construction. Flexible membranes can be used only in ditches in which the stream velocity does not exceed three feet per second. A six to nine inches thick earth covering serves to hold the liner in place when the channel is empty and to minimize mechanical damage. Since weeds may pierce a plastic lining, a sterilizing agent is used on the subgrade before the membrane is placed. Butyl rubber resists deterioration due to exposure, biological activity, and root penetration. Maintenance work must be done very carefully to keep membrane linings from being damaged.

Chemical Sealants- Chemical sealants can be used to make ditch subgrades nearly impermeable to seepage. These are effective if the channel perimeter is moist most of the year but are less effective if the ditch dries out. Cracking of the soil breaks the membranes formed by the sealant and provides channels for seepage. Chemical sealants can be used on any soil, but are not especially suited to sandy soils. Some are unsatisfactory owing to a short life, high cost, and toxicity to animals and crops. These sealants are waterborne and therefore must be put in the channel water, usually at a point of disturbance such as a drop structure to facilitate mixing the sealant with the water. Some supplemental mixing may be required.

One application method is to put the sealant into a flowing ditch with the water checked at a ditch structure to reduce the velocity of flow. This allows more time for the sealant to act on the subgrade in a given reach than is possible under normal flow. Ponding is another application method. Treated water is allowed to stand in successive ponds formed in a ditch by temporarily sealing ditch structures or by placing temporary dams between structures. The water is allowed to remain in each pond long enough for the sealant to act on the soil. Although this method may be more costly, the sealing effect is somewhat better than that of the flowing-water method.

Bentonite - Bentonite is a low-cost material similar in appearance to ordinary ground clay. The material swells 12 to 15 times its dry size when wet and fills the voids through which water seeps. The three general methods of using bentonite for sealing ditches are by membrane lining, soil-mix lining, and sedimenting.

In the first method, bentonite is spread as a membrane one to two inches thick over the canal subgrade and then covered with 6 to 12 inches of a protective blanket of stable earth or gravel. When properly placed, the membrane lining controls seepage for many years.

The soil-mix method uses bentonite spread evenly over the perimeter of a ditch and then mixed with the upper 3 to 6 inches of soil by disk, spiked-tooth harrow, or rake. The treated soil is then rolled or tamped until a good soil density is obtained. In some instances, a protective cover of stable earth or gravel is applied.

In the sedimenting method bentonite is applied in one of three ways, either scattered over the surface of the water, dumped into the ditch at intervals before the water is turned in, or put into the ditch water as slurry. As the bentonite swells, the resultant gel fills the voids along the sides and bottom of the ditch. Since it does not penetrate the soil to any depth it forms a thin coating on the wetted perimeter of the ditch which reduces seepage. Bentonite shrinks on drying allowing it to be eroded by flowing water.

Table 7 presents a cost comparison the various lining materials.

TABLE 7 COST COMPARISON OF LINING MATERIALS	
Liner Material	**Unit Cost ($ per Sq. Ft.)**
Earth	$2.25
Concrete	$2.00
3" Steel- Fiber Reinforced Gunite	$2.59
Asphalt	$3.37
30-mil Flexible Membrane w/ Gunite	$2.14
Chemical Sealants	Not Available
Bentonite	$2.50

SLOPE STABILITY

For all natural and man-made slopes there is a maximum slope angle at which the friction between the soil grains can resist the weight of the soil and prevent a slope failure. If an embankment is on the verge of sliding, these forces are equal. Cohesive soils (clays) generally have the highest amount of internal friction and is stable at a steeper angle (angle of repose) due to the very small size of the individual soil grains. This is why slopes in clay areas can be steeper than those where granular (sandy) soils are predominant. Presented in Table 8 are the typical angle of repose and unit weight for various types of soils.

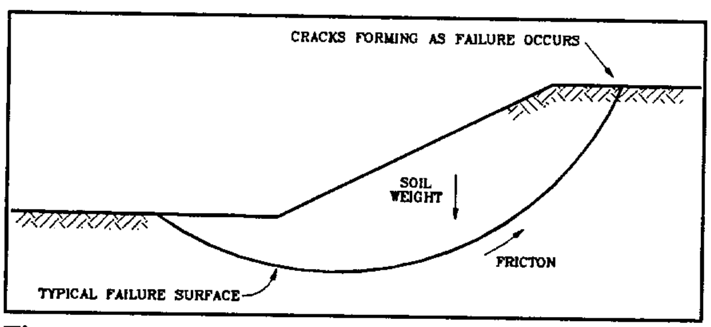


Figure 6

High water content in a soil due to rain or exfiltration from a source such as the irrigation canal can dramatically alter the stability of a slope by adding weight and acting as a lubricant. Lateral tension cracks forming in a slope is the most obvious sign that failure has begun. (See PHOTO 13) The following are the typical methods employed for slope stabilization:

- Reduce the slope angle by filling;
- Reduce the slope angle by installing a retaining wall;
- Increase the friction of the soil with a Geogrid; and
- Increase the friction of the soil with an additive.

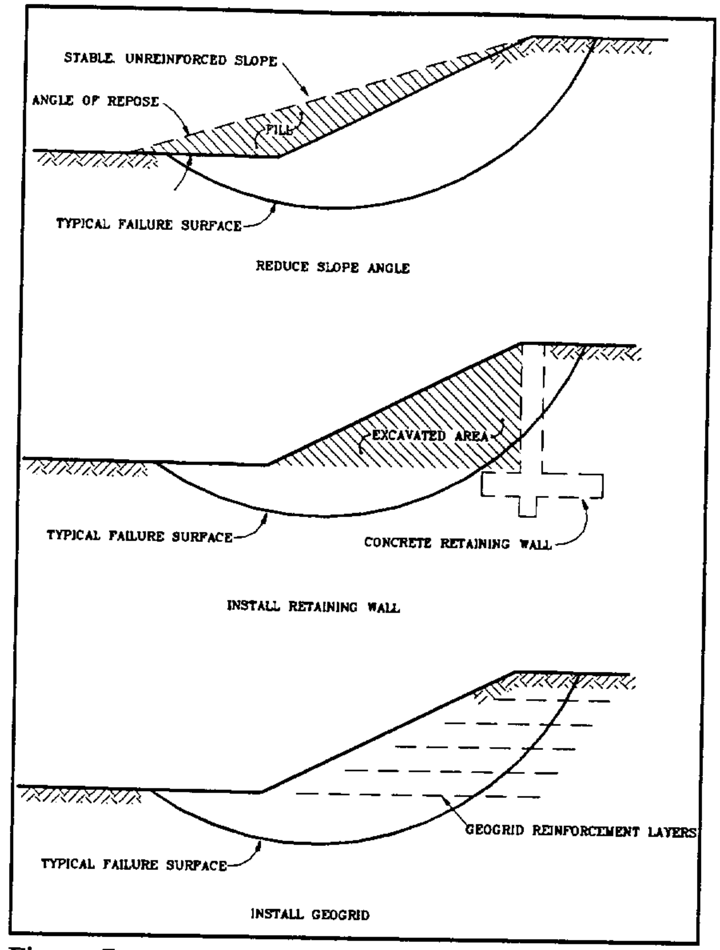


Figure 7

TABLE 8 SLOPE STABILITY CHARACTERISTICS			
SOIL	ANGLE OF REPOSE (DRY)	ANGLE OF REPOSE (SUBMERGED)	UNIT WEIGHT (PCF)
Sand, clean, dry	1:1.5	1:2	90
Sand & Clay	1:1.33	1:3	95
Clay	1:3	1:3.5	100
Gravel, clean	1:1.33	1:2	100
Gravel & Clay, dry	1:1.33	1:3	100
Gravel, Sand, & Clay, dry	1:1.5	1:3	100
Soft Weathered Rock	1:1	1:1	100
Hard Weathered Rock	1:1	-	100

SLURRY CUT-OFF WALLS

Soil-Bentonite slurry walls are subsurface, nonstructural barriers to the lateral flow of groundwater. The cut-off walls are constructed using a slurry trench technique and are composed of a mixture of soil and bentonite. The principal advantages of this type of cut-off wall is their low permeability (10^{-6} - 10^{-9} cm/sec), their general suitability for both new and remedial applications, and their construction can proceed without disturbing the function or operation of existing facilities. The soil-bentonite slurry trench technique has been in use in the United States since the 1940's. The early applications of soil-bentonite walls were for dewatering large excavations and as hydraulic barriers in dams and dikes. Recently, there has been a growing number of applications of slurry walls for

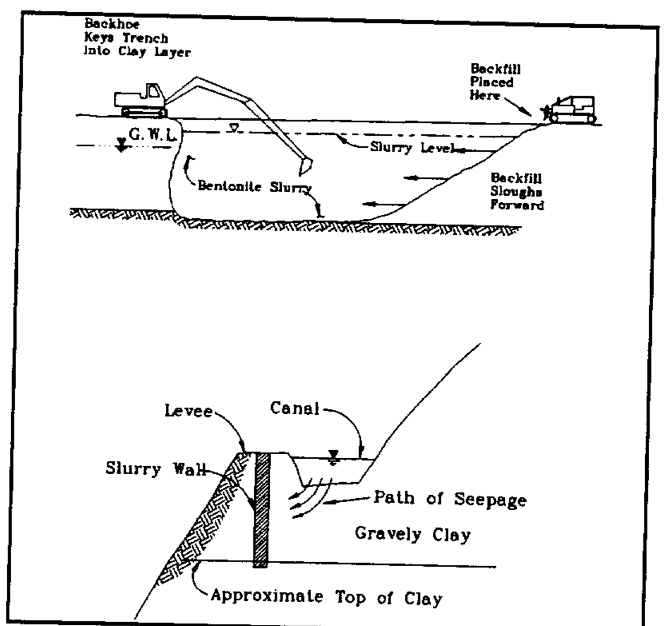


Figure 8

pollution control, particularly on projects where a positive leachate cutoff is required. Recent advances in the capability of excavating equipment and refinements in technique have brought the cost of slurry walls down. Slurry walls are now economically competitive on projects where compacted clay cutoffs, sheeting, or well points would have previously been used.

The major characteristic of slurry cutoff wall construction is the use of bentonite-water slurry which allows excavation without the use of other lateral support. Slurry cutoff walls are built by excavating a narrow trench (2-4 ft. wide) while pumping in the slurry and maintaining its level at or near the top of the trench during the excavation process. Usually, the trench is keyed into an underlying layer of relatively impermeable soil which forms the bottom and the slurry wall the sides of the containment. This narrow trench is then backfilled with impervious materials to form a permanent cutoff. When the backfill consists of a mixture of soil and bentonite, the construction work is called a soil-bentonite slurry cutoff wall. After the trench has been excavated under a bentonite slurry, more slurry is mixed with the soil adjacent to the trench. A bulldozer is used to work the material to a consistency similar to wet concrete. It is then pushed back into the trench so that the backfill slope displaces the bentonite slurry forward. Excavation and backfilling are phased to make the operation continuous with relatively small quantities of new slurry required to keep the trench full and to mix backfill. Average costs for slurry cut-off wall installation is approximately $2.00 per vertical square foot.

PIPELINES

Irrigation pipelines are a means of conveying water through closed conduits. Since pipelines are costly, careful planning is necessary for location, sizing, material selection, and installation method.

Pipelines can be place above or below ground. Portable surface pipe has an advantage over underground pipe in that it can be moved and used in more than one location, but it has a disadvantage in the labor required to move it. Underground lines are made of concrete, reinforced concrete, corrugated metal, steel, aluminum, or plastic. Surface pipe is made of aluminum, steel, rubber, plastic or canvas. The choice of material depends on the conditions under which the pipe is to be used, cost, and personal preference.

Pipe conduits can be used in most places but are particularly suited to areas where seepage losses are high. Advantages of pipe over channel construction include its use in areas of poor soils and steep slopes, weed control and farming operations are easier, and less tillable land is taken up. Maintenance work in general is less than that for open ditches, and water control is easier. Generally, cost is the main limiting factor in irrigation practices. While construction costs are higher than for comparable open channel systems, the overall annual operating costs are often less.

Irrigation piping systems are either low or high pressure. Low-pressure pipelines are open to the atmosphere and are usually used with operating heads of less than 20 psi. High-pressure pipelines are closed to the atmosphere and are used where operating heads exceed 40 psi. Valves are used in lieu of open vents and stands. High-pressure pipelines generally are used to convey water for sprinkler irrigation systems and require pumping from a surface supply or well. In the BMA system, this type of pipeline would presently be typically limited to individual farms.

Low-pressure pipelines are used primarily with surface irrigation methods. They can be permanent, semi-portable, or portable. Permanent systems usually consist of buried supply and distribution lines. In semi-portable systems on farms, buried pipe is used for field supply lines with a quick-coupling metal pipe or flexible pipe placed on the ground to distribute the water. A fully portable system uses metal or flexible surface pipe for both field supply and distribution. Concrete is typically used for low-pressure buried lines, but steel, aluminum, and plastic pipe can be used. Concrete pipe is made with tongue and grooved joints, which are sealed with rubber gaskets or filled with cement mortar.

It is very important that a pipeline be large enough to convey the flow needed in various areas under present and future conditions. It must be large enough to supply the water required during the period of peak crop use even though this full capacity may be needed in only a small part of the total irrigating season.

Specialized structures are needed on pipelines to control water and to protect them against damage. Pipelines on sloping land may develop excessive pressure heads that must be controlled by standpipes or regulating valves. Lines fed directly from pumps also must have structures for controlling the maximum pressure automatically.

CONVEYANCE STRUCTURES

Elevated ditches, inverted siphons, protective structures, drops, checks, road crossing structures, and flumes are used to carry water across swales, draws, and roads and along steep hillsides. These structures are necessary to transport irrigation water efficiently.

<u>Elevated Ditches</u> - Elevated ditches are open channels built on compacted earth fill to convey water across shallow depressions or to deliver water by open ditch to a high part of a field. The fill material must compact readily but not crack when dry. Elevated ditches generally are used for carrying large flows or in places where they are less costly than flumes, siphons, or pipelines.

Major problems include seepage loss, dry-weather cracks through the ditch bank, difficulty of controlling weeds and rodents, and difficulty of maintenance. For these reasons it is usually best to use pipe conduits if the ditch must be elevated more than two or three feet. Careful and timely maintenance is necessary because a break in the bank can result in serious washouts that will damage the structure and the surrounding area. The higher the fill, the greater the potential damage from breaks or holes made by burrowing animals. The ditches can be lined to lessen this hazard and to reduce seepage. If an elevated ditch crosses a drainageway, a culvert is needed.

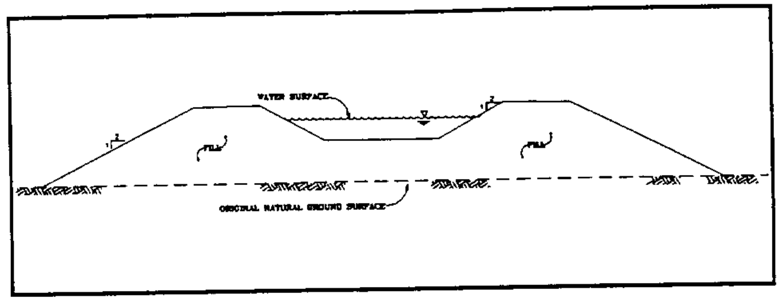


Figure 9

Inverted Siphon - An inverted siphon, or sag pipe, is a closed conduit with each end raised, forming a U-shaped structure. This structure is used to transport water under obstructions such as streams, canyons, or roadways and to regain as much elevation as possible after the obstruction has been passed. Siphons differ from culverts in that the top of the pipe drops below the hydraulic gradient causing it to operate under pressure.

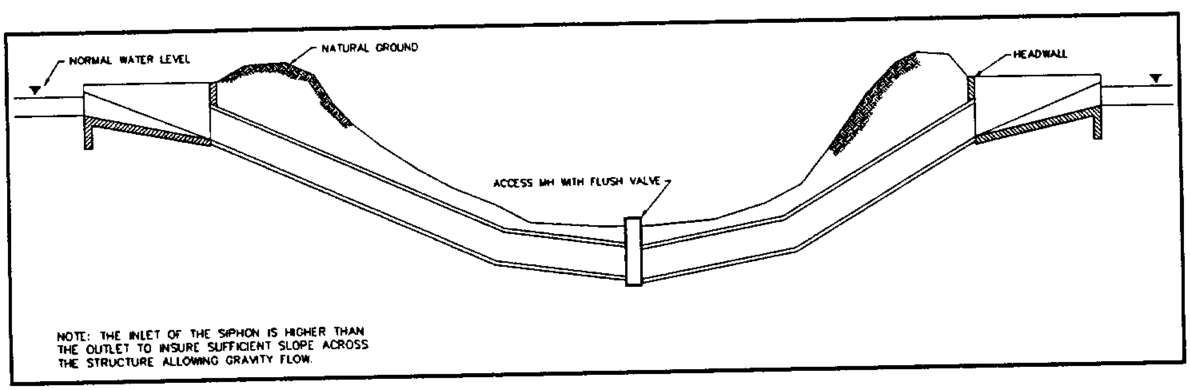


Figure 10

Two considerations which govern the profile of a siphon are provision for hydraulic losses (friction) and ease of cleaning. The friction loss through the barrel will be determined by the design velocity and the roughness of the pipe material used. Normally, the water surface elevation at the entrance is maintained at a level sufficiently above that of the exit to overcome the head loss of the structure. Siphons are generally designed with a velocity of two to three feet per second to provide sufficient scouring to be self-cleaning under minimum flow conditions. They are usually made of corrugated or smooth metal pipe, concrete pipe, or reinforced concrete poured in place. The amount of water they can carry depends on the size and kind of conduit and on the difference in elevation between the water surface at the inlet and at the outlet. Trash racks are needed to keep the siphon open. Properly installed inverted siphons require little maintenance. Since they are underground, they are well protected, especially against flood damage.

Protective Structures - Protective structures are installed on a canal system to protect both the system and the adjacent property owners from uncontrolled releases. These releases can be caused by either restrictions or excessive storm water runoff flows in the canal. Restrictions in the canal can be due to a number of sources including landslides, excessive aquatic plant growth, and blockages on structures or safety racks. Excessive or uncontrolled stormwater flows entering a canal system can cause problems by exceeding the capacity of the canal or by reducing its capacity by filling in the canal with silt. In order to safeguard the integrity of the system from stormwater, the flows must either have a controlled entrance or be provided with a means to cross under/ over the canal. Energy dissipators and erosion control measures such as concrete lining at locations where runoff is allowed to enter a canal.

Excessive flows in a canal must be controlled to minimize the potential damage caused from overtopping. Protection can be incorporated into a system through the construction of drains and spillways. Drains allow a canal to be manually drained for normal maintenance or emergencies. A disadvantage to a manual drain is that if an emergency arises at a time that personnel are not in the area, the canal bank could be overtopped and breached. Spillways constructed at strategic locations in the system, such as immediately upstream of structures with safety racks, provide an automatic release of excess water in a controlled manner. The major components of a canal spillway include an inlet weir set at an elevation above the normal operating water level and the lowest elevation of the canal bank, a pipe or channel to direct the water to a drainageway without causing property damage, and energy dissipation to minimize erosion.

Drops - The purpose of drop structures is to transport water from a higher elevation to a lower one in a short distance while dissipating excess energy resulting from the drop. These structures are placed in areas where topography would require that a canal have an excessively steep slope or grade where velocities would cause erosion if unlined.

The common types of drops are: vertical, where the water spills over a vertical wall several feet tall to the next section of canal which has been protected from erosion by lining or rock rip rap; inclined (chute), where the water is routed down a steeply sloping concrete lined channel with energy dissipation at the lower end; and pipe, which is identical to the inclined drop (chute) except that a pipe is utilized in lieu of a lined channel. Inclined drops are generally used when large flows are being dropped from heights exceeding fifteen feet over long distances. Drops should not be spaced so closely together that uniform flow is not maintained between two structures. Large open drops are usually built of reinforced concrete.

Reinforced concrete, concrete block, rock masonry, or rot-resistant lumber, such as redwood, cedar, fir, or creosoted pine, can be used for smaller structures.

Checks - Check structures are used in a canal system to raise and maintain the upstream water level at an elevation high enough to make water deliveries from a given reach of the system. The water surface is controlled by installing stoplogs or raising gates until the desired level is backed up by the structure. Once the water reaches the desired level, it overflows the check and continues down the canal.

Road-Crossing Structures - Culverts, inverted siphons, or bridges are used to carry water across roads. Culverts are used most often under farm roads because they are generally the least expensive. Corrugated metal, smooth metal, and concrete are used most commonly for culverts in farm ditches. The culverts should be long enough to maintain a roadway of adequate width and must have enough covering to protect the pipe from concentrated loads. Inverted siphons are particularly suited to crossings at which the water surface in the ditch is higher-than the road. Bridges can be used for road crossings over canals regardless of the elevation of the water in the ditch and can be built so there is little or no loss of head through the structure.

Distribution-Control Structures - Distribution-control structures are required for easy and accurate distribution of irrigation water to the various fields on a farm. Good control practices permit efficient distribution and application and reduces labor requirements. Selecting the correct kind of water control structure and locating it properly is an important part of planning a farm irrigation system.

1) Headgate - Farm headgates are used to divert the required amount of irrigation water from the farm source of supply to the farm field ditches. Headgates may include a weir measuring device that determines flow into a field ditch. They may be culvert-type diversion structures equipped with a measuring well or submerged orifices with measuring gages.

2) Division Box - Division boxes are used to divide or direct the flow of water between two or more ditches. Water enters the box through an opening on one side and flows out through openings on the other sides equipped with gates of a size to furnish the necessary flow to the field ditches. Division boxes are also used at pumps to control the flow of water from the pump outlet into one of two or more field ditches. Concrete or concrete block are the materials generally used for division boxes. Prefabricated metal panels that can be bolted together to form a box quickly and easily are also available.

3) Checks - Checks are structures placed in ditches to form adjustable dams that control the elevation of the water surface upstream to divert flow from upstream.

Checks can be permanent or portable. A permanent check consists of a headwall with a weir opening equipped with grooves for flash boards or with metal slide gates for adjusting the upstream elevation of the water surface. Boards can be used as stops. By changing the number or height of the boards, the upstream elevation can be controlled as well as the rate of overpour. If slide gates are used, the upstream elevation is controlled by raising the gate so that the excess water flows under the gate. Permanent checks used in the more nearly permanent ditches generally are made of concrete, wood, or steel. Checks can also be combined with drops. Permanent overfall checks in unlined ditches should have an apron for the overflow to prevent scouring that might wash out the check.

Portable checks can be removed after they have served their purpose for irrigating a given area and reset downstream for irrigating another area. They are generally made of canvas, plastic, rubber, or metal. Metal checks are forced into the sides and bottom of a ditch, the others are dug in and then backfilled so that they do not wash out. Portable checks can also be used in concrete-lined ditches. Portable metal checks usually are laid on a slant in lined ditches and are held in place by the weight of the water.

4) Turnouts - Turnouts are boxes or orifice-type structures in the bank of a head ditch that provide and control the flow of water from the head ditch into border strips, contour levees, and contour ditches. These usually include a simple slide gate to regulate the flow. Wooden boxes and concrete or metal pipe are generally used for turnouts.

Concrete or metal pipe turnouts must be long enough to extend through the ditch bank and should be equipped with an antiseep collar and slide gate. In lined ditches, turnouts should be located carefully and be installed at the time the ditch is lined.

UNACCOUNTED FOR WATER IN CONVEYANCE SYSTEMS

In order to determine the efficiency of a canal, it is important to understand the factors that can cause changes water volume within the system. These include:

- ❑ Seepage
- ❑ Evaporation
- ❑ Transpiration
- ❑ Groundwater Inflow
- ❑ Precipitation
- ❑ Authorized / Unauthorized Withdrawal
- ❑ Water Discharged During System Shut-down
- ❑ Overland Inflow

Of these, the greatest influences on unaccounted for water in the BMA canal system are seepage, evaporation, transpiration, groundwater inflow, and authorized/unauthorized withdrawals.

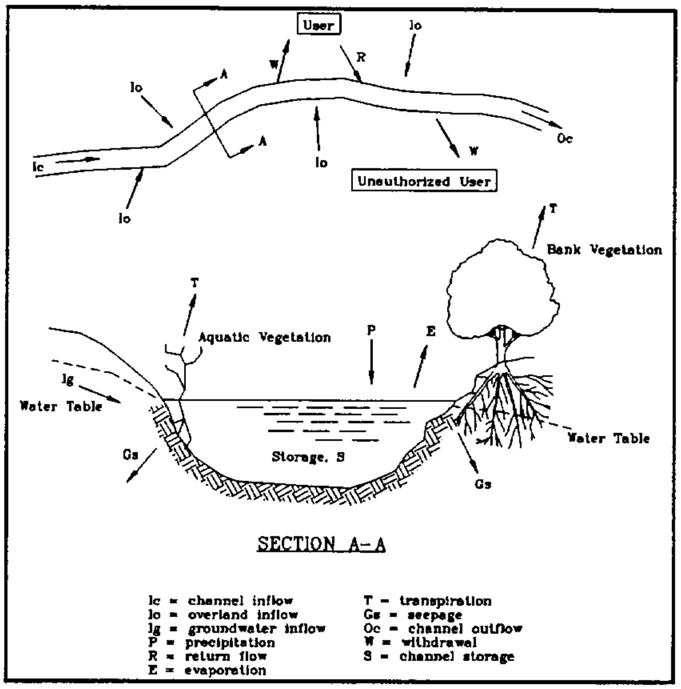


Figure 11

SEEPAGE

Seepage is generally defined as the movement of water into or out of irrigation channels through the bed material. The amount of seepage may be measured in cubic feet per square foot of water surface or wetted surface, per 24 hour period; in cfs per mile; or in percentage of total flow per mile. Of these terms cfs per mile is believed to be most generally useful. (See PHOTO 14)

Seepage is a complex hydrologic phenomenon and, because of the many variables involved, no general rules for computing the rate of seepage have been developed. In a canal, the water in contact with the bottom and the banks of the channel immediately starts to move into the spaces between the particles making up the lining of the channel. This movement is a combination of capillary flow and percolation. The capillary flow is caused by the capillary attraction of the fine passages between the particles of the bed material, whereas percolation is caused by the action of gravity forcing water through the pores of the bed material. The action of gravity is always downward, but capillary attraction operates in all directions and may cause water to rise many feet above the level of the water in the channel. Capillary movement is extremely slow and is ordinarily small in comparison with percolation.

The canal banks and bottom in contact with the water are always saturated, but as the water seeping from the canal leaves this zone this condition may or may not exist. If the water table in the area is in contact with the bottom of the canal or has risen above it, all soil in the immediate vicinity of the canal below this level is saturated. Seepage then travels by percolation.

If the water table is above the level of water in the canal, then the direction of flow will be toward the canal and a gain in water will occur. If, however, the water table is below the level of the bottom of the canal, the region immediately below the canal will not be saturated except in special cases, such as when the underlying material is less pervious than the bed of the channel. Where this occurs a pressure zone is built up around the wetted portion of the channel and the flow occurs as percolation. However, when the water table is below the bottom of the canal, the water seeping from the canal flows downward by gravity as a film of water surrounding the particles of the soil. Under these circumstances, water lost from the canal flows downward in a zone directly beneath the canal with little, if any, lateral spreading.

Whether the material forming the lining of a canal is natural soil or an artificial lining, the permeability of the material forming the lining is the most important factor in determining the rate of seepage. Permeability is influenced by the size of the pores and the percentage of pore space or porosity of the material. Since permeability increases with porosity, low porosity materials such as clay are relatively impermeable. Permeability varies approximately as the square of the diameter of the pore spaces, and since in clay the pore spaces are very small, the permeability is also small. The presence of gravel in most materials increases the permeability because it increases porosity. Gravel alone, if made up of particles of uniform size, has a high permeability because the interstices between the particles are not filled with finer material and consequently the pore spaces are relatively large. Soils consisting of gravel mixed with clay are practically impervious to water and are quite stable.

The most widely accepted rule governing the flow of water through soil is Darcy's Law.

$$V = k\, i\, A$$

where, V = rate of flow (cm^3/s)
k = coefficient of permeability for saturated soils
i = slope of the hydraulic gradient (cm/cm)
A = cross sectional area of the soil conveying flow (cm^2)

According to Darcy's Law, the velocity of flow through water-bearing sands is directly proportional to the head consumed. This law is generally assumed to apply to all saturated water-bearing materials in which the pores are of capillary size and the flow is uniform. Experiments have shown that samples of coarse gravel may transmit water at a rate 450 million times that of clayey silt. For a head of one foot per foot of gravel, the discharge was 90,000 gallons per square foot of cross-sectional area per 24 hour period. Under similar conditions the discharge through the clayey silt was only 0.002 gallon per 24 hour period. The actual losses from canals, however, are far less than the maximum because the bed materials of canals are partially sealed by silt and clay carried in the water. Furthermore, although the depth of water in canals may be as great five feet or more, field studies have shown that seepage is only loosely correlated with the depth. Studies have also indicated that the seepage rate decreases materially when the water table reached the level of the water-spreading ground. However, the depth to ground water had no effect so long as the water table was below the surface of the ground. Maximum seepage rates occurred during the period that the water table was dropping after it had risen to the ground-level has dropped several feet. The combination of these factors, together with others the influence of which is not recognized at the present time, makes it difficult to evaluate the influence of depth of water on seepage.

While permeability may be determined by direct measurement of the velocity of flow by means of dyes or chemicals, or by computation from the data for drawdown or discharge from pumped wells, the values would only be valid for the general area from which the observations were made. Difficulties are also encountered in determining the effective head causing the seepage from canals because of the great variations in conditions. The depth in the canal is only one of the factors. According to Darcy's Law, the pressure of both ends of the column through which seepage is occurring affects the rate of seepage, and their magnitude must be known before the effective head can be determined. Measurement of the area through which seepage is taking place presents no difficulty. Most canals are of fairly uniform section and a few profiles across a canal will give a reasonably close approximation of the area. Where the canal is irregular, sufficient accuracy can be obtained by taking more profiles.

Because of the difficulty in measuring the parameters, Darcy's formula $V = k\, i\, A$ cannot be used in determining the actual seepage from a canal, but is quite useful in demonstrating the relationship between seepage and various factors. Even though the value of k or i may be unknown, and that A is highly variable, it is apparent from the formula that the seepage is proportional to each of these factors and any changes in them will affect the seepage in similar fashion. The method commonly utilized to determine the average loss for an existing section of canal is to determine the flow entering and leaving the area being studied and calculating the difference. If the flow is held constant during the study period, the difference can be attributed to seepage.

Regardless of the lining, the quantitative determination of seepage from an existing channel and the location of probable areas in a proposed canal or lateral through which seepage will occur are of major importance to the planner and designer in selecting the reaches of canal to be lined. Factors affecting seepage loss from canals in natural earth materials are:

- Type of material forming the liner, its permeability, and the wetted perimeter;
- Type and permeability of soil surrounding the canal;
- Type of vegetation adjacent to the canal (trees, bushes and other vegetation);
- Canal usage (intermittent use increases losses due to the saturation cycle);
- Canal system age (seepage may reduce with age due to natural sealing by fine silt);
- Weather conditions (temperature, rainfall, humidity);
- Sediment carried in water (quantity, grading);
- Depth of water flow in the canal; and
- Depth to ground water in the vicinity of the canal.

Other factors that affect seepage losses in canals to varying degrees are the percentage of entrained air in the soil, capillary tension in the soil, barometric pressure, soil and water chemistry, relative proximity of drainage channels to irrigation canals, and location of canals within the radius of influence of wells.

EVAPORATION AND TRANSPIRATION

These are processes by which moisture is released into the atmosphere. Evaporation is defined as the change of water from a liquid to gaseous state. While evaporation may occur from the surface of water bodies, plants, or ground, most occurs from water surfaces. Evaporation rates are a direct function of wind speed and temperature, but is inverse function of barometric pressure, humidity, and dissolved solids content.

Transpiration is the process in which plants give off water vapor through the pores of their leaves during synthesis of plant tissue. The moisture is absorbed from the soil by the root system and transferred to the leaves by capillary action. In the presence of an unlimited source of water, the rates of transpiration for plants will be about the same rate as evaporation from a water surface. In areas where there is an abundant amount of rainfall, all vegetation will transpire at the same rate.

However, where precipitation is limited or is seasonal, root depth becomes an important factor. Grasses with shallow roots die off as the soil surface dries while trees and brush with deeper roots flourish by drawing water from the lower soil strata. Therefore, over the course of a year, vegetation with deep root systems will transpire greater amounts of water than grasses.

While the rate of evaporation from soil is limited by available water, the rate of transpiration is not reduced significantly by a decrease in soil moisture until the wilting point of the soil is reached. In addition to the factors previously listed, sunlight increases photosynthesis in plants thereby increasing the rate of transpiration. The dripline of a tree, as depicted in Figure 12, is often used to estimate the limits of the root zone. In reality, the roots extend two to three times this distance from the trunk. This is especially true in the vicinity of water supplies.

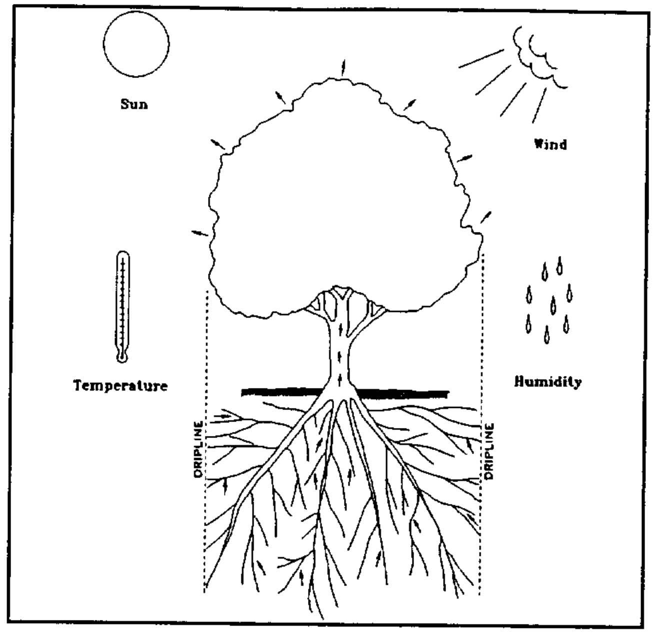


Figure 12

The Natural Resources Conservation Service recently reported the following findings of the Seco Creek Water Quality Demonstration Project being conducted in the northeastern portion of Uvalde County:

- ❑ Evapotranspiration accounts for about sixty (60) percent of precipitation.
- ❑ Evapotranspiration was ten (10) to twenty (20) percent less from an area without juniper than an area with it.
- ❑ About seventy (70) percent of the evapotranspiration was from juniper, but when juniper was removed, other plants and soil compensated.
- ❑ It was projected that elimination of all juniper in one study area could result in a thirty-three (33) percent increase in aquifer recharge.

Evapotranspiration, commonly termed consumptive use, refers to the total evaporation from all sources such as water surfaces, ground, and plant-leaf surfaces. The impact of larger, deep-rooted vegetation in close proximity to surface water (lakes, ponds, canals, etc.) is that the gross area available to transfer water to the atmosphere expanded. (See PHOTO 15 - 16)

Evaporation from free-water surfaces is usually measured with an evaporation pan. This pan is a standard size and is located on the ground near the body of water whose evaporation is to be determined. The depth of water in this pan is checked periodically and corrections made for factors other than evaporation that may have raised or lowered the water surface. A pan coefficient ranging from 0.6 to 0.8 is applied to the measured pan evaporation to obtain the reservoir evaporation. The standard evaporation pan of the U.S. Weather Bureau, called a Class A Level Pan, is four feet in diameter, ten inches deep and is positioned six inches above the ground.

AUTHORIZED AND UNAUTHORIZED WITHDRAWALS

Since its inception, the District has used a flat-rate structure for charging for water delivery. Water for irrigation is provided to farmers within the District on a "call" basis. Each farmer goes into the BMA office, places an order for water to be delivered to a specific tract, and pays the flat rate based upon number of surface acres to be watered. Once notified of the order, the ditchrider is responsible to adjust the various control structures in the canal system to ensure that adequate flow is diverted into the laterals serving the farm and to open the turn-out. Once irrigation of the field has been completed, the farmer notifies the ditchrider who adjusts the control structures on the canal system and turns the water off. The only time that the water is turned off prior to notification by the farmer is when water is observed flowing from the field on to a roadway or adjacent property. At the present time, neither the District nor the farmers know how much water has been diverted when an order has been filled.

The purpose of water measurement in irrigated areas is to determine if excessive losses are occurring in the conveyance system, insure an adequate supply for the desired crops, and prevent unnecessary, wasteful diversions through volume based billing. One problem that has become apparent in addressing this situation is that the there is currently no way to determine the quantity of water diverted in an accurate and equitable manner. With no flow measurement devices in place, the responsibility and the authority to determine volume actually used rests exclusively in the hands of the District. An accurate, acceptable manner to determine flows is needed prior to any changes in the method of billing.

The volume of water flow is computed simply by multiplying the cross-sectional area of a given flow by its average velocity. However, this is the ideal and is difficult to achieve in actual practice. The process of flow measurement in laterals and ditches by stream profiling (see Gain / Loss Study), is very time consuming and is not practical for determination of flow to individual farms. In order to accurately measure flow in these small laterals, weirs have become the most widely accepted method. Weirs are obstructions installed across an open channel which force the water to flow over a notch or through an opening of known size. The rate of flow is determined by measuring the head (height of water at the weir) on the weir.

There are two general forms of weirs, suppressed and unsuppressed. A standard suppressed or contracted weir consists of a weir box with a thin plate forming the crest far removed from the bottom of the weir box or approach channel to minimize frictional effects. The height of the crest above the bottom and the distance between the sides of the weir and ditch bank should be a minimum of twice the maximum flow depth over the crest. Weirs can be further broken down into four specific types: rectangular, Cipolletti, vee notch, and orifice. Each must be used in a ditch with a good slope so that the water will fall free over the crest. The rectangular and Cipolletti weirs can be used for large flows with equal accuracy. The vee notch weir is designed for small flows and should be used whenever the flow over a minimum width rectangular or Cipolletti weir is less than 2 inches. Other requirements which must be met include:

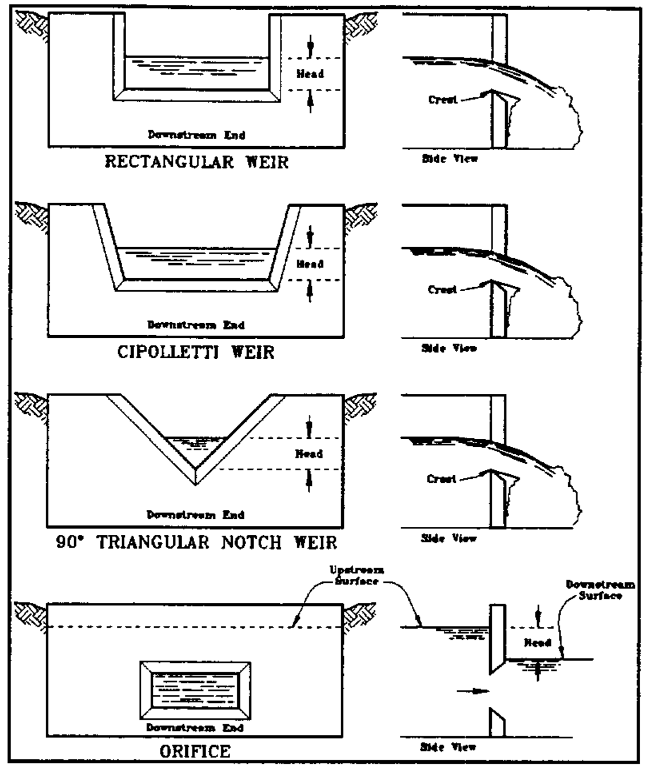


Figure 13

- ❑ The weir should be set at the lower end of a long pool sufficiently wide and deep to permit an even, smooth current with a velocity of approach of not over 0.5 foot per second, which means practically still water;
- ❑ The center line of the weir box should be parallel with the direction of the flow;
- ❑ The face of the weir should be perpendicular to the bottom, i.e., leaning neither upstream nor downstream;
- ❑ The crest of the weir should be level, so water passing over it will be of the same depth at all points along the crest, and sharp so that the over-falling water touches the crest at only one point;
- ❑ The distance of the crest above the bottom of the pool should be about three times the maximum depth of water flowing over the weir crest; the sides of the pool should be at a distance from the ends of the crest not less than twice the depth of the water passing over the crest;
- ❑ The gage or weir scale may be placed on the upstream face of the weir structure and far enough to one side to insure that it will be in comparatively still water. It may be placed at any point in the weir pond or box, so long as it is a sufficient distance from the weir notch as to be beyond the downward curve of the water as it flows over the weir crest. The zero of the weir scale or gage should be placed level with the weir crest. This may be done with an ordinary carpenter's level or, where greater refinement is desired, with an engineer's level;

- The crest should be placed high enough so water will fall freely below the weir, leaving an air space under the over-falling sheet of water. If the water below the weir rises above the crest this free fall is not possible, and the weir is then said to be submerged. Unless complicated corrections are made, measurements on submerged weirs are inaccurate;
- For accurate measurements the depth over the crest should be no more than one-third the length of the crest;
- The depth of water over the crest should be no less than 2 inches, as it is difficult with smaller depths to get sufficiently accurate gage readings to give close results; and
- To prevent washing by the falling water the ditch downstream from the weir should be protected by rip rap (concrete, loose rock, or by other material).

During the late 1980's, the Lower Colorado River Authority (LCRA) converted to a volume based billing system for their Gulf Coast Irrigation District and needed to develop an economical method of flow measurement. In 1990, LCRA requested that the Bureau of Reclamation perform a calibration study on two types of existing water boxes (small check structures on laterals). The results of this calibration effort are included in Appendix 2. The 4 and 6 foot wide water boxes were tested to determine if they could provide reasonable accurate flow measurements with only minor modifications. Due to the flat gradients within LCRA's irrigations districts, two types of modifications were evaluated to provide a standardized measurement and regulation, the submerged adjustable orifice (undershot) and weir (overshot).

These devices were volumetrically rated in a testing tank and a family of curves were developed to cover the wide number of variables. Since the structures are relatively accurate and economical to construct, they have become an "acceptable" measuring device. Both types performed substantially better when the wood-edge weir plate or orifice opening was replaced with a metal edge. Another major advantage to the use of these existing structures is that the ditchrider or a farmer can measure the distance down to the water on each side of the planks and compute the head, measure the opening (on an orifice), and quickly determine the discharge.

The Bureau of Reclamation also recommended that LCRA use existing pipes as flow measuring devices. By measuring the diameter of the pipe, water depth, silt depth, and velocity, field personnel can quickly determine the rate of flow. The current meter selected for this use by LCRA was the Flow Probe manufactured by Global Water Instrumentation. This meter is relatively inexpensive, rugged, and easy to use.

The ultimate purpose of water measurement is to encourage and enable the user to conserve water for the highest and most beneficial use. Irrigation systems based on adequate, volume-based billing forces conservation on only the most wasteful by providing an incentive to use only the amount of water that is necessary. Additionally, water conservation practices are not limited to crop requirements but include economic factors to be considered for conserving to use on the most profitable land.

Two examples of precise measuring systems are the watt meter and the water meter conveniently located at the dwelling. However they are not useful to most users since the devices do not supply the information in a way that encourages application by the user. The devices require recording and subtracting of the previous reading to determine quantities. This procedure is satisfactory for the technician because he is paid to do so but is beyond the efforts that most users will expend. The addition of an accumulating total dial to be reset for each selected period of time whenever restrictive allotments are made would allow the user to identify a goal and the progress towards achieving that goal.

The measuring needs for agricultural irrigation are similar to those for municipal water. The use made of the measuring information depends on the simplicity, completeness, and availability of the data. Consequently the challenge is to design a recording system to apply to the existing measuring devices that will either by design or because of demand be economically available for all agricultural uses. In some respects, it appears that the design efforts of metering have been unduly sophisticated, whereas the need for the majority of irrigation systems is to be as simple and inexpensive as possible.

Irrigation water must be measured if it is to be used efficiently. The principal objective of measuring irrigation water is to permit efficient distribution and application. By measuring water, a farmer knows how much water is applied during each irrigation. Diversion quantities based on the fifteen minutes observation severely limits the possibilities of water conservation by supplying the information after the opportunity to manage has passed.

During the process of initiating a flow measurement program as part of volume based billing, consideration should be given to the following:

- If well-maintained tongue and groove planks are not utilized, water boxes can permit excessive amount of unaccounted for water due to leakage.

- In any delivery system, fluctuations occur in canal depth and flow. Measurement of head on a weir may or may not be taken at the most equitable time. In several Districts located in western states which use water measurement devices that are influenced by fluctuations, the practice has developed whereby the farmer "pegs" the stream (placed a notched stick in the ditch to mark the water level). Any time the water level dropped the farmer would promptly notify the ditchrider to either measure the drop or make proper allowances. Some ditchriders, after taking the reading, make an allowance and adjust the charge in order to account for the fluctuating nature of the streams. The result is that with measurements based on a one-time daily check, some water is used for public relation purposes. Whether or not equity is maintained is debatable. It is apparent that when the normal procedure is to take a once daily reading on which to base a charge there is not a true measurement. As a result, many charges are negotiated between District personnel and the user.

- A program must be implemented to use the best device for any given location. Once the device has been selected, its operation should be explained to the farmers so as to encourage general acceptance of the measuring system. Farmers will participate only marginally if the measuring process requires them to use complicated, time consuming formulas or tables to determine flow.

- Lining canals may necessitate changes in measuring structures because the design and construction may alter velocities and flow characteristics resulting in measuring devices having to be replaced.

- Weirs should be inspected and repaired on a regular basis. Weeds or obstructions must be removed prior to and during times of use. In earthen channels, the upstream section eventually fills in with silt, sand, or gravel being deposited in the immediate vicinity of the gauge.

- It is important to plan for enough measuring devices. If all the irrigation water is to be delivered to a field through a single headgate, then a measuring device placed at this location may be the only one needed. However, if the supply is divided between two or more ditches, measuring devices will be required at each ditch.

In addition to the authorized water diversions as described above, there has been several occasions where District personnel have discovered individuals taking water. These individuals are generally caught either by accident or by District personnel investigating complaints of inadequate flow received from legitimate diverters. While the District has attempted to make every reasonable effort to prevent the unauthorized diversion of water, the practice has continued.

GAIN / LOSS SURVEY

GENERAL

In order to track water being conveyed in a system, it is necessary to know the flow or discharge at specific points along a canal. By comparing these flows at a given time, the system operator can determine if water is being gained or lost in a particular segment and its approximate quantity. While the most accurate method of determining discharge is by utilizing weir structures, reasonable results can be achieved by performing what is know as a stream profile. Stream profiling involves measuring the cross-sectional area and average speed (velocity) of the water passing the location on several different occasions when the depth of flow has changed. Discharge can be computed using the following formula:

$$Q = V \times A$$

Where: Q = discharge or flow in cubic feet per second
V = average velocity in feet per second
A = cross sectional area in square feet

The velocity within a channel varies greatly across the area of flow. Typically, velocity is greatest near the center of flow and lowest near the bottom or sides due to friction. In order to determine the flow at a given location, a measuring tape is stretched across the channel to determine the width and distance from the bank. The cross-section is divided into subsections 2 to 3 feet in width as shown in Figure 14. At the center of each subsection, the average velocity is measured with a current meter held at a specific depth for approximately 40 seconds.

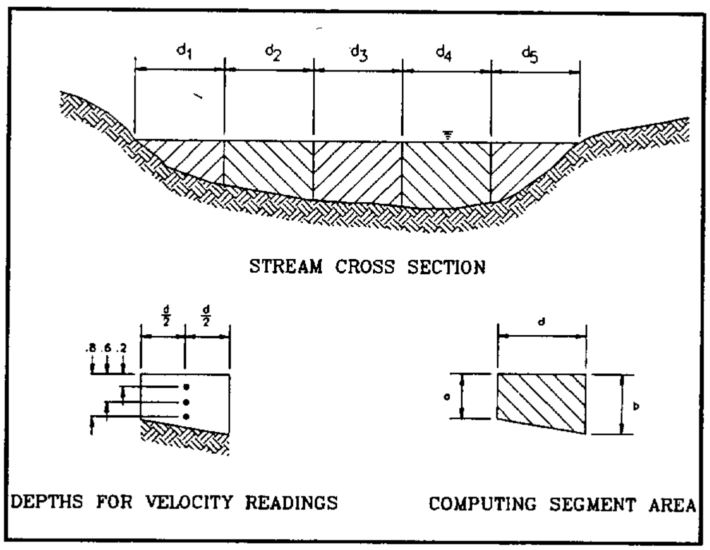


Figure 14

If the depth is less than 3 feet, the single-point method is used where the velocity is measured at a distance of 0.6 of the depth from the surface. In channels with a depth greater than 5 feet, the two-point method is utilized where the velocity is measured at 0.2 and 0.8 depths and averaged for each subsection.

Either method may be used in depths between 3 and 5 feet. The three most common types of current meters are the Marsh-McBirney Model 2000, Global Water Flow Probe, and the Price-type meter which is manufactured by several companies. The area for each subsection is computed by utilizing the following equation:

$$\text{area} = d \times \left[\frac{(a+b)}{2} \right]$$

The flow or discharge for each subsection is then computed by multiplying the area by its respective average velocity. Totaling the flows for each subsection results in the discharge for the cross-section at that depth of flow.

If continuous monitoring is needed, a stage-discharge rating curve can be developed for a given location in the system curve is developed by determining the discharge at several depths of flow and plotting them on a graph to create a curve for that site. Personnel may then determine flow by measuring the water depth at the site and comparing it to the curve. Data loggers can automatically measure the depth at predetermined time intervals and stored until an operator is ready to take the readings.

Sites to be used for flow monitoring should have the following characteristics:

- ❑ The canal should have a relatively straight run for a distance of approximately two canal widths upstream and one canal width downstream.

- ❑ The canal should be relatively free of disturbances such as sudden changes in width or depth, obstructions, contributing or outgoing sidestreams, and close proximity to sharp bends.

- ❑ The flow should be free of swirls, eddies, vortices, backward flow, or dead zones.

- ❑ Areas immediately downstream from sluice gates or where the canal empties into a body of stationary water should be avoided.

1994 GAIN / LOSS STUDY

During this study, approximately 48.2 miles of canal were surveyed in an effort to determine not only losses in the specific canal segments identified in Figure 15, but also to develop an estimate of water loss per mile of canal. To achieve the best possible result, a constant discharge was maintained for three days prior to the survey in the main canal and approximately two days for the smaller channels. Surveys for each of the canal segments were completed on the day they were initiated. The results are summarized in the following tables.

TABLE 9 GAIN/LOSS SURVEY ON MAIN CANAL (A)					
Site No.	Date	Location	Canal Mileage	Discharge (cfs)	Gain/Loss (cfs)
1	7/94	Main Meter @ Diversion	0.00	142	-
2	7/94	Rio Medina Meter, 2000' N. of Quihi Rd.	5.68	114	-28 (20%)
3	7/94	Castroville Meter, 3000' S. of US 90	16.10	110	-4 (3.5%)
4	7/94	Flume 11 Meter (upstream), 1.7 mi. S. of US 90	19.32	111	+1 (0.9%)
5	7/74	Flume 11 Meter (downstream), 3.12 mi. S. of US 90	20.74	109	-2 (2%)
6	7/94	Main Canal @ D - 1	23.86	65	-3 (3%)
7	7/94	D - 1 @ Main Canal	--	41	

TABLE 10 GAIN/LOSS SURVEY ON D - 1 (B)					
Site No.	Date	Location	Canal Mileage	Discharge (cfs)	Gain/Loss (cfs)
1	7/94	300' W. of Main Canal	0.00	22.3	-
2	7/94	100' E. of Noonan Siphon	1.89	21.0	-1.3 (6%)
3	7/94	54" under Noonan Rd. @ D - 1	2.75	20.6	-0.4 (2%)
4	7/94	48" Road Crossing 300' above Jungman Lake	4.73	20.2	-0.4 (2%)

TABLE 11 GAIN/LOSS SURVEY ON A - 1 (C)					
Site No.	Date	Location	Canal Mileage	Discharge (cfs)	Gain/Loss (cfs)
1	7/94	Check, W. of Ward Farm	0.00	73.8	-
2	7/94	Check, E. of Natalia Canal	0.76	69.7	-4.1 (6%)
3	7/94	Check, 1,500' W. of Bexar Co. line	3.41	48.3	-21.5 (31%)
4	7/94	Check, 300' E. of Bexar Co. line	4.17	42.6	-5.7 (12%)

TABLE 12
GAIN/LOSS SURVEY ON A-3, NATALIA, COAL MINE (D)

Site No.	Date	Location	Canal Mileage	Discharge (cfs)	Gain/Loss (cfs)
1	7/94	A - 3 @ Coleman Rd.	0.00	7.2	--
2	7/94	A - 3, 0.57 mi. SE of Coleman Rd.	0.57	6.9	-0.4 (6%)
3	7/94	Coal Mine Canal @ FM 463	1.37	0.3	-1.1 (16%)
4	7/94	Natalia Canal @ FM 463	1.42	5.5	
5	7/74	Natalia Canal, 2 mi. S. of FM 463	3.69	4.7	-1.1 (19%)
6	7/94	Natalia Canal, 0.23 mi. N. of Draper Jones Rd.	4.54	3.1	-1.6 (34%)
7	7/94	Field Ditch, W. off Natalia Canal, @ Site 6	0.00	1.0	--
8	7/94	Field Ditch	300'	0.8	-0.2 (20%)

TABLE 13
GAIN/LOSS SURVEY ON S CANAL (E)

Site No.	Date	Location	Canal Mileage	Discharge (cfs)	Gain/Loss (cfs)
1	7/94	S canal @ A - 1	0.00	3.4	--
2	7/94	S canal @ B - 4	0.66	3.0	-0.4 (12%)
3	7/94	S canal @ Jarrat Rd.	1.42	2.8	-0.2 (7%)
4	7/94	S canal @ Ess Rd. crossing	1.99	2.3	-0.5 (14%)
5	7/74	S canal, SE of Trawalter Rd.	3.03	0.99	-1.4 (57%)

TABLE 14
GAIN/LOSS SURVEY ON D-2 (F)

Site No.	Date	Location	Canal Mileage	Discharge (cfs)	Gain/Loss (cfs)
1	7/94	48" Culvert on Williams Property Near Devine	0.00	10.8	--
2	7/94	Outlet of 36", S. of US 81	1.04	3.6	-7.2 (67%)
3	7/94	Outlet of Pipe Under IH-35	2.46	1.7	-1.9 (53%)

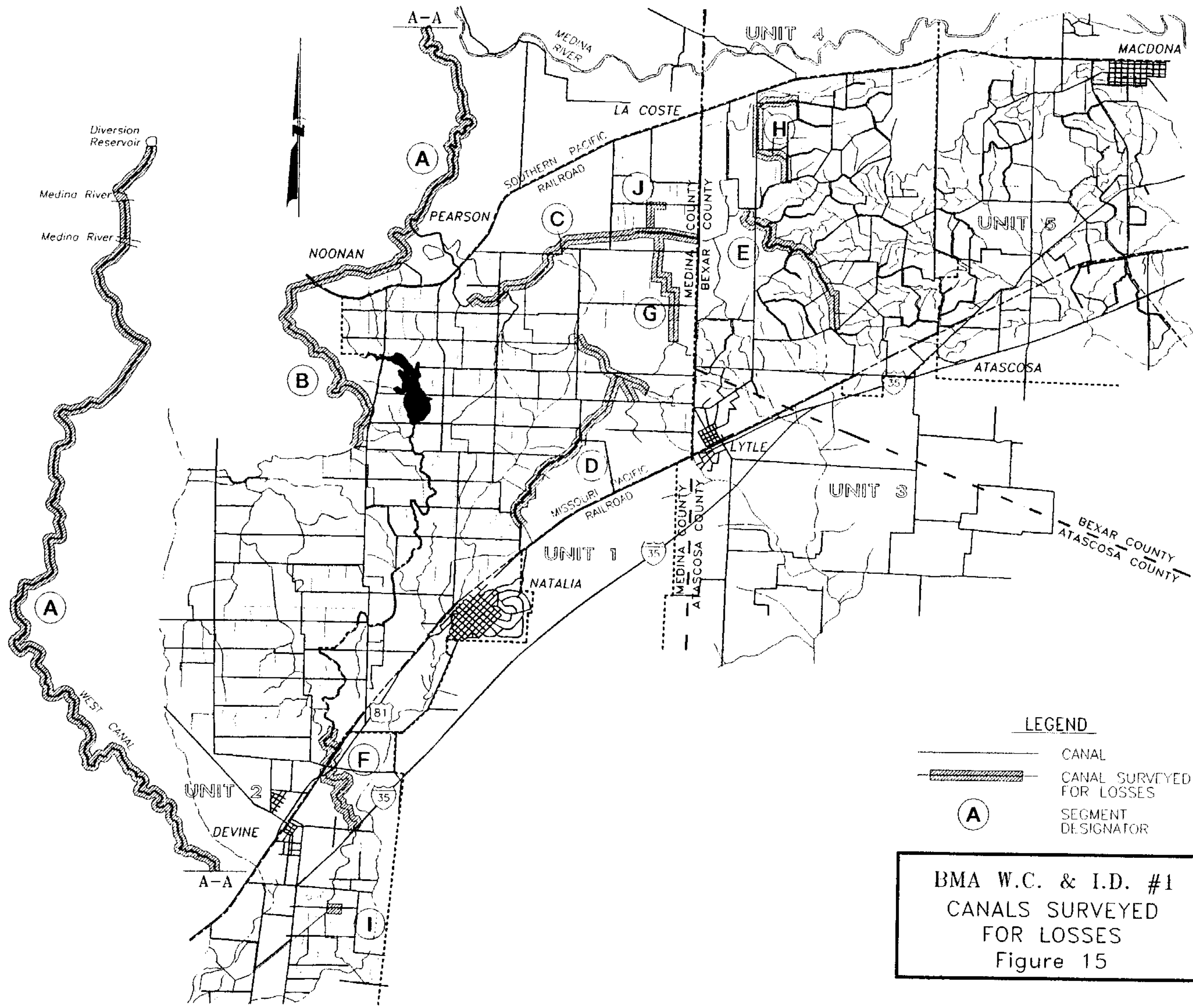
TABLE 15 GAIN/LOSS SURVEY ON SERVICE LATERAL (G)					
Site No.	**Date**	**Location**	**Canal Mileage**	**Discharge (cfs)**	**Gain/Loss (cfs)**
1	7/94	Service Lateral @ Main Canal	0.00	2.1	–
2	7/94	Check @ 90° Bend	0.70	1.8	-0.3 (14%)
3	7/94	Check	1.80	1.7	-0.1 (6%)
4	7/94	Lytle Canal	2.00	1.3	-0.4 (24%)

TABLE 16 GAIN/LOSS SURVEY ON B - 12 (H)					
Site No.	**Date**	**Location**	**Canal Mileage**	**Discharge (cfs)**	**Gain/Loss (cfs)**
1	7/94	Check, 300' N. of canal B	0.00	8.7	–
2	7/94	36", Corner of Wisdom Rd. & Sherwood Rd.	1.70	6.7	-2.0 (23%)
3	7/94	36", Corner of Miles Rd. & Sherwood Rd.	2.27	5.7	-1.0 (15%)

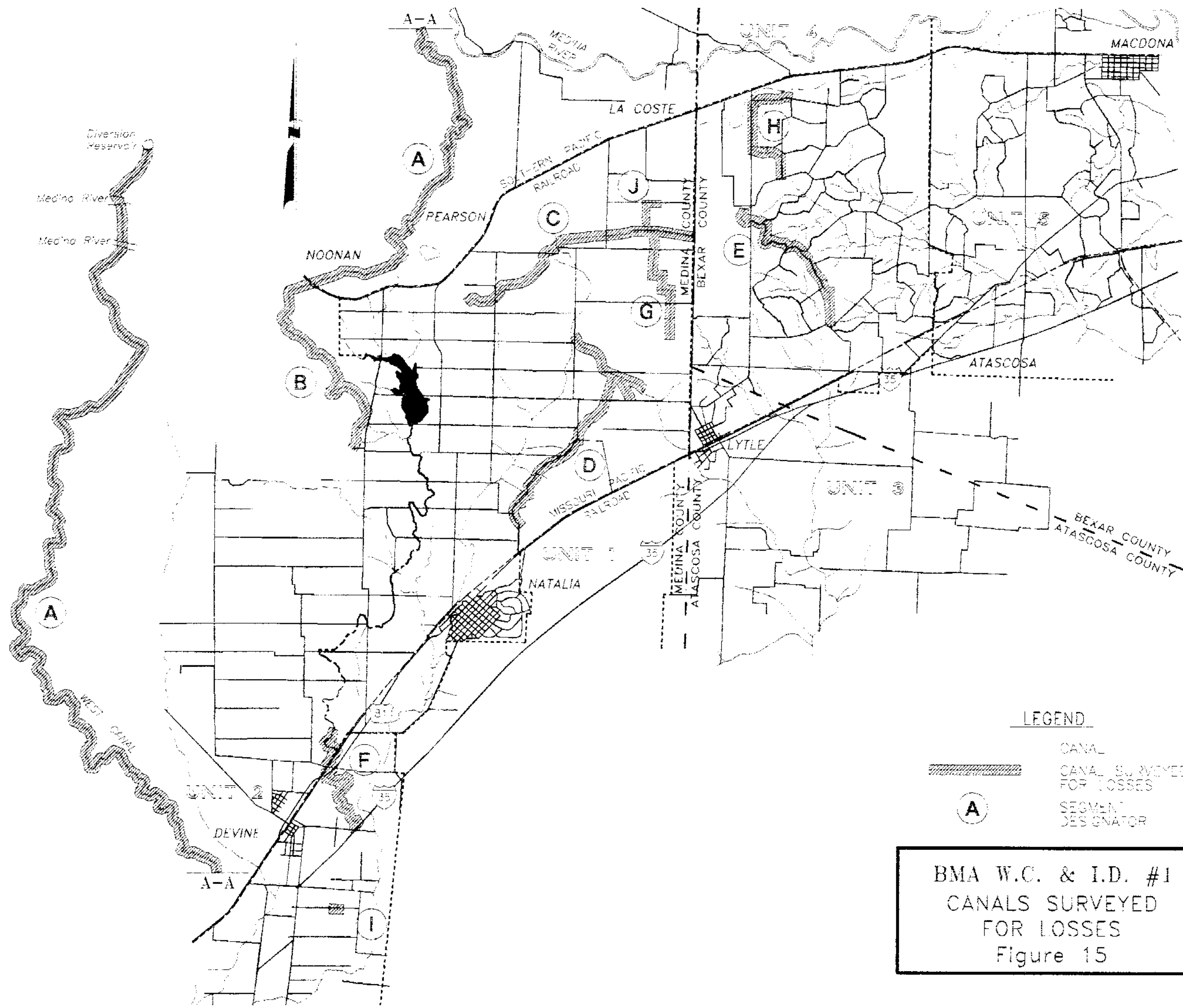
TABLE 17 GAIN/LOSS SURVEY ON FIELD DITCH E. OF DUBOSE LAKE (I)					
Site No.	**Date**	**Location**	**Canal Mileage**	**Discharge (cfs)**	**Gain/Loss (cfs)**
1	7/94	15" culvert, Block 32, 50' S. of D - 2	0.00	2.8	–
2	7/94	15" culvert	0.20	2.0	-0.8 (29%)

TABLE 18 GAIN/LOSS SURVEY ON McGRATH LATERAL (J)					
Site No.	Date	Location	Canal Mileage	Discharge (cfs)	Gain/Loss (cfs)
1	7/94	15" Culvert, McGrath Farm, Block 12, @ A - 1	0.00	1.9	-
2	7/94	15" Culvert	0.25	1.7	-0.2 (11%)
3	7/94	24" Culvert	0.50	1.57	-0.13 (8%)
4	7/94	15" Culvert	0.90	1.36	-0.21 (15%)

TABLE 19 SUMMARY			
Canal	Total Length (mi.)	Total Loss (cfs)	Loss / Mile (cfs/mi)
Main Canal, Diversion to D-1	23.86	36	1.5
D-1 Canal, Main Canal to Jungman Lake	4.73	2.1	0.4
A-1 Canal, 2000' W. of Mann Rd. to 300' E. of Bexar County Line	4.17	31.3	7.5
A-3, Natalia Canal, Coal Mine Canal	4.54	4.2	0.9
S Canal, A-1 to Trawalter	3.03	2.5	0.8
D-2, Williams Property to IH-35	2.46	9.1	3.7
Service Lateral, Main Canal to Lytle Canal	2.00	0.8	0.4
B-12 Canal, Check 300' N. of B Canal to Miles Rd. at Sherwood Rd.	2.27	3.0	1.3
Field Ditch E. of Dubose Lake, D-2 to 0.2 mi.	0.20	0.8	4
McGrath Lateral, A-1 to culvert 0.9 mi. N.	0.90	0.5	0.6



BMA W.C. & I.D. #1
CANALS SURVEYED FOR LOSSES
Figure 15



BMA W.C. & I.D. #1
CANALS SURVEYED
FOR LOSSES
Figure 15

CONVEYANCE SYSTEM EFFICIENCY

Loss of water from a ditch or canal along the delivery route to the field determines conveyance efficiency. This can be calculated by measuring the flow at the point of diversion or source, and again at the field. Whenever the loss exceeds 1/2 to 2 percent per mile, steps should be taken to determine the cause and corrective action implemented. As stated previously, the causes may be excessive growth of trees along or in the canal, seepage, or unauthorized diversion. The following is a generalized equation for conveyance efficiency:

$$E_c = 100 \frac{W_f + R}{W_r}$$

where: E_c = efficiency of conveyance
R = all water that can be recovered for reuse
W_f = water delivered to the field
W_r = water diverted from a river, stream, storage facility, or other source

Figure 16 illustrates the relationship between the water diverted into the BMA system over an extended period of time, the orders placed by the farmers, and the annual precipitation recorded at the station near Rio Medina. Based on this information, the efficiency of the system varies between 49% and 82% annually with the average for the ten year period being 62%. There appears to be a strong relationship between the amount of rainfall received in the area, timing of the rainfall, orders, time for water in the main canal, system design, and canal efficiency.

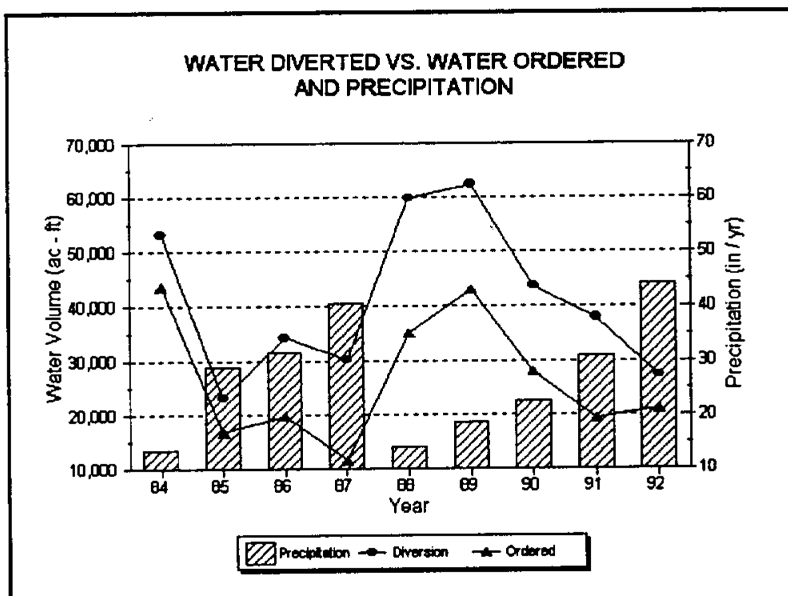


Figure 16

Water diverted into the main canal at Diversion Lake takes approximately three days to travel the 24 miles to the irrigated areas of the District. The occurrence of significant rainfall during the irrigation season results in cancellation of orders. With the system running full and no orders to fill, District personnel must divert excess water from the canal to receiving streams through the many wasteways after topping off the limited off-system storage facilities (Chacon, Jungman, and Pearson). Even minor storm events can lead to large amounts of water being lost. Approximately 2,500 acre-feet of water is lost annually due to these events. The annual loss due to evaporation from the open canal system is estimated to be 600 acre-feet.

WATER QUALITY

INTRODUCTION

Water quality in the canal system of the Bexar-Medina-Atascosa Counties Water Control and Improvement District Number 1 has been the subject of previous studies by the Natural Resources Conservation Service and the Bureau of Reclamation. Lacking sufficient water quality information for the canal system, a survey of baseline conditions was conducted by field investigation. A literature search of previous testing of the Medina River was supplemented by river samples taken concurrent with sampling of the canal system.

Within the BMA District, the standards for water quality are established for three primary uses - agricultural, municipal and industrial, and recreational. The water quality element of this study was designed to identify existing water quality problems that could adversely affect any of the primary uses of water from the canal system or the Medina River.

The overall project objectives were to assemble detailed data on the location and extent of existing and projected activities which might adversely affect the primary uses of water within the District. Activities which might contribute nonpoint source pollution or point source loads on the Medina River and the canal system were considered as they relate to the proposed uses of water and any resulting expenses to the users.

Presented in Figure 17 is an overall map of the study area that identifies the locations for water quality sampling during this study.

WATER QUALITY REGULATIONS

Clean Water Act - The legislative roots of the Clean Water Act of 1987 can be traced as far back as the Rivers and Harbors Act of 1899. Federal statutes of the 1950's and 1960's contained most of the basic concepts of today's legislation but the far-reaching nature of the law came with the Federal Water Pollution Control Act of 1972. Enacted on October 18, 1972, Public Law 92-500 was intended by Congress to address almost every type of water pollution control problem conceivable at the time.

The Clean Water Act of 1972 established four basic precepts that have affected almost every federal, state and local water quality control issue since enactment. These precepts are:

1. No one has a right to pollute the navigable waters of the U.S. In order to discharge pollutants, one must first obtain a permit.

2. Permits shall limit the composition of a discharge and the concentrations of pollutants. Violators of the conditions of a permit are subject to fines and imprisonment.

3. Some permit conditions require the best controls that technology can provide, regardless of the receiving water's natural purification ability. As such, Congress decreed that certain levels of control are worth their cost.

4. Any limits or control higher than the minimum federal requirements must be based on receiving water quality. In order to impose standards higher than those required by PL 92-500, it must be demonstrated that continued protection of the receiving water demanded more stringent limits.

Amended 12 times between 1972 and 1987, the Clean Water Act was reauthorized in 1987 through 1994. Failing efforts to reauthorize the Act during 1994 with significant changes to certain provisions of the law, the Act as reauthorized in 1987 remains in effect until acted upon by Congress in 1995.

Nonpoint Source Pollution - More so than in its 1972 version, the Clean Water Act of 1987 emphasizes state responsibility for implementation of certain programs. One of the 1987 amendments, Section 319, attempts to address some fifteen years of interest in the subject of nonpoint sources and their control. States are required to inventory waters within their jurisdiction that fail to meet water quality standards because of nonpoint source pollution.

An important highlight of Section 319 of the Act is that it forms the foundation of the EPA's emphasis on a watershed approach to water quality management by requiring that states, wherever possible, develop nonpoint source pollution control programs on a watershed by watershed basis. Indications are that EPA's watershed approach to water quality control will play an even greater role in permitting in the future.

The sources of nonpoint source pollution are diffuse and cover substantial areas and are generated and transported as part of the hydrologic cycle. These sources include agricultural, municipal, silvicultural, and mining. Even without human activity, there are certain background levels of nonpoint source pollution such as erosion and wildlife. Surface runoff from agricultural and municipal land uses have certain similarities in that they both can contain sediment, chemical and bacteriological constituents that may affect the water quality of receiving waters.

The random, intermittent rainfall events that drive nonpoint sources, combined with their diffuse nature, make traditional treatment technologies impractical and prohibitively expensive. The content of urban runoff include many of the same constituents as municipal wastewater discharge including solids, bacteria, heavy metals, oxygen-demanding substances, nutrients, and oils and grease. With the application of pesticides and fertilizer common practice among homeowners, urban runoff can contain some of the same constituents as agricultural runoff. Runoff from agricultural land can contain solids, pesticides, and nutrients, as well as bacteria.

Municipal Wastewater Discharge - The Clean Water Act of 1977 mandated an enforcement mechanism to ensure wastewater discharges meet the effluent limitations for particular stream segments. This mechanism is the National Pollutant Discharge Elimination System (NPDES). NPDES permits are issued to all municipal and industrial wastewater treatment plants to ensure that water quality standards are met.

The NPDES permit contains the technology-based treatment requirements for municipal treatment facilities and for phased improvements in technology to allow higher levels of treatment. Technology-based limits prescribe minimum standards of pollution control for municipal and industrial dischargers without regard for the quality of the receiving waters. Water quality-based standards, on the other hand, identify an intended use for the receiving waters and prescribe the biological and chemical conditions that must be met to sustain that intended use.

Through the TNRCC, the State of Texas issues a discharge permit in addition to the NPDES permit. The Castroville wastewater treatment plant operates under Permit No. WQ0010952-001 issued by the Texas Natural Resource Conservation Commission (TNRCC). This plant consists of a carousel aeration basin with a clarifier, an oxidation ditch, and two oxidation ponds. A copy of the most recent inspection of the facility has been included in Appendix 3.

The plant is permitted to treat a maximum flow of 0.35 million gallons per day of municipal wastewater to a level of 65 mg/l BOD and 65 mg/l TSS. Effluent from the plant is used to irrigate pasture land adjacent to the Medina Canal.

Sandy soils throughout the District allow for a high volume of percolation both from and into the canal system. There is reason to believe that treated effluent disposal in the vicinity of the Medina Canal is seeping directly into the canal. For agricultural uses, the elevated levels of BOD and nutrients contained in the wastewater are probably not of major concern. Municipal, industrial, and recreational uses of the water, however, are potentially adversely affected.

Municipal wastewater discharge permits in Texas typically have minimum parameters of 20 mg/l for BOD and TSS for discharge into surface waters. The permit level of 65 mg/l for the Castroville plant is reflective of a no discharge permit. However, there may be reasons to infer from recent interpretations of the Clean Water Act by the U.S. Environmental Protection Agency that this situation may require the City of Castroville to upgrade its effluent quality.

Recent EPA interpretations have stated that all discharges which reach surface waters either directly or indirectly through groundwater that is hydrologically connected to surface waters violate the Clean Water Act. In this case, it can be demonstrated that municipal effluent used to irrigate pastureland adjacent to the Medina Canal does, in fact, reach the surface waters of the canal.

With proposed recreational and municipal uses just three to four miles downstream of the indirect discharge point from the Castroville plant, there is a high potential for reuse of the Castroville effluent. This would indicate that the City of Castroville will probably face a requirement to upgrade its level of treatment in order to continue irrigation of the same pasture lands. (See PHOTO 17 - 18)

<u>Safe Drinking Water Act</u> - The Safe Drinking Water Act (SDWA) establishes national standards to ensure that the public receives safe water throughout the United States. Interim standards adopted in 1975, defined contaminant as any physical, chemical, biological, or radiological substance or matter in water. Maximum contaminant level (MCL) was defined as the maximum permissible level of contamination in water at the point of use in a public water system. The Act delineates between health-related quality contaminants and aesthetic-related contaminants by classifying the former as primary and the latter as secondary contaminants.

Primary Drinking Water Standards under the SDWA list the tests as well as the MCLs required by federal law. The establishment of each of the MCLs was predicated on protecting consumers from detrimental effects over long term exposure to the water supply. For inorganic chemicals such as arsenic, chromium, mercury and lead, the MCLs were based upon possible health effects that might occur after a lifetime of exposure of approximately 2 liters of water per day.

The MCLs for pesticides were derived from available data on the effects of acute and chronic exposure to both organochlorine and chlorophenoxy pesticides. Limits for constituents such as these are determined with a factor of safety to minimize the amount of toxicant contributed by the water supply when other sources, such as food and air, are known to represent additional sources of exposure to humans. Therefore, MCLs should not be regarded as the definition of safe or dangerous concentrations.

While each of the tests mandated by the SDWA are performed to ensure compliance at the point of delivery to the customer, many of the Priority Pollutants are chemical compounds that are not significantly affected by the typical treatment processes. For this reason, it is important that raw surface water supplies are analyzed and monitored to ensure that violations of the SDWA do not occur.

Several of the substances listed in Table 19 are not commonly found in nature and often result from nonpoint source pollution. These criteria are most appropriate for evaluating the quality of a raw water supply source.

WATER QUALITY STANDARDS FOR USAGES WITHIN THE DISTRICT

Applying the various federal and state water quality standards to the waters within the District requires an examination of the historical and projected uses of water. Irrigation of cropland and pastures, as well as watering livestock, is expected to continue to as the primary consumer of water in the District. With available supplies of water and the projected retention of existing supplies resulting from reduction of water losses within the canal system, it is forecast that more water will be available for municipal and industrial uses in the coming years.

One of the basic objectives of the Clean Water Act was to provide water quality that would protect fish and wildlife and provide for recreation. The State of Texas has established specific numerical criteria to prevent contamination of drinking water supplies and to ensure that fish are safe for human consumption. The numerical criteria for specific toxic materials are shown in Table 19. The first column lists the specific compound, the second column the criteria for drinking water and fish, and the third column the concentration for fish when waters are not used for drinking water supplies.

TABLE 20 CRITERIA IN WATER FOR SPECIFIC TOXIC MATERIALS		
Substance	Drinking Water and Fish (µ/l)	Fish Only (µ/l)
Aldrin	0.0312	0.0327
Alpha-hexachoro-cyclohexane	0.645	0.997
Arsenic (d)	50 (a)	–
Barium (d)	1,000 (a)	–
Benzene	5	312
Benzide (d)	0.11	0.0035
Beta-hexachloro-cyclohexane	2.26	3.49
Bis(chloromethyl)ether	0.207	1.59
Cadmium (d)	10 (a)	–
Carbon Tetrachloride	5 (a)	182
Chloradane (c)	0.0210	0.0213
Chlorobenzene	1,305	4,947
Chloroform	100 (a)	12,130
Chromium (d)	50 (a)	–
Cresols	4,049	46,667
DDD	0.297	0.299
DDE	0.0544	0.0545
DDT	0.0527	0.0528
2,4-D	100 (a)	–
Danitol	0.709	0.721
Dibromochloromethane	1590	15354
1,2-Dibromoethane	0.0518	1.15
Dieldrin (b)	0.0012	0.0012
1,4-Dichlorobenzene	75 (a)	–

TABLE 20 (cont.) CRITERIA IN WATER FOR SPECIFIC TOXIC MATERIALS		
Substance	**Drinking Water and Fish (µ/l)**	**Fish Only (µ/l)**
1,2-Dichloroethane	5(a)	1794
1,1-Dichloroethylene	7 (a)	87.4
Dicofol	0.215	0.217
Dioxins/Furans (TCDD) Equivalents (b) Compound Equivalency Factors 2,3,7,8-TCDD 1 2,3,7,8-PeCDD 0.5 2,3,7,8-HxCDD 0.1 2,3,7,8-TCDF 0.1 1,2,3,7,8-PeCDF 0.05 2,3,4,7,8-PeCDF 0.5 2,3,7,8-HxCDF 0.1	0.000001	0.000001
Endrin	0.2 (a)	–
Flouride	4,000 (a)	–
Lindane	4 (a)	16
Heptachlor (b)	0.0177	0.0181
Heptachlor Epoxide	1.08	7.39
Hexachlorobenzene	0.0129	0.0129
Hexachlorobutadiene	9.34	11.2
Hexachloroethane	84.4	94.1
Hexachlorophene	0.0531	0.0532
Lead (d)	5	25
Mercury (c)	0.0122	0.0122
Methoxychlor	100 (a)	–
Methy Ethyl Ketone	4411	886667
Mirex	0.0171	0.0189
Nitrate-N	10000	–
Nitrobenzene	41.8	721

TABLE 20 (cont.) CRITERIA IN WATER FOR SPECIFIC TOXIC MATERIALS		
Substance	Drinking Water and Fish (µ/l)	Fish Only (µ/l)
n-Nitrosodiethylamine	0.0382	7.68
N-nitroso-di-n-Butylamine	1.84	13.5
PCB's	0.0013	0.0013
Pentachorophenol	129	136
Pyridine	88.1	13333
Selenium (d)	10 (a)	--
Silver (d)	50 (a)	--
1,2,4,5-Tetrachlorobenzene	1.43	1.52
Tetrachloroethylene	597	1832
Toxaphene (b)	0.044	0.0445
2,4,5-Trixhlorophenol	2767	4021
Trichloroethylene	5 (a)	--
1,1,1-Trichloroethane	200 (a)	--
Total Trihalomethanes	100 (a)	--
Vinyl Chloride	2 (a)	94.5

(a) Based on maximum contaminant levels specified in 25 TAC Section 337.

(b) Calculations based on measured bioconcentration factors, and no lipid content correction factor applied.

(c) Calculations based on US Food and Drug Agency levels for fish tissue concentrations.

(d) Indicates that the criteria for a specific parameter are for the dissolved portion in water. All other criteria are for total recoverable concentrations.

(Reproduced from 31 Texas Administrative Code Section 307.6)

Irrigation - The availability of water in sufficient quantities and of suitable quality is essential for all agricultural uses in the District. By minimizing water losses, the quantity of water is projected to be adequate for multiple uses leaving water quality as the primary determining factor for the various uses.

Agricultural uses of BMA District water require a low potential for salinity, as measured by the concentration of total dissolved solids, but can be more tolerant of concentrations of chemical constituents than municipal, industrial, and recreational uses. Soluble salts found in soils include sodium, calcium and magnesium. Chloride and sulfate anions also occur in soils and concentrations can be increased through irrigation.

Water that is not used by plants or lost to evaporation becomes more concentrated with dissolved salts and can remain close to the surface. Waters with total dissolved solids (TDS) concentrations of less than 500 mg/l can be used for irrigation with little risk of significantly increasing soil salinity. As TDS concentrations increase, crop sensitivity to salinity becomes a serious consideration.

Watering of Livestock - Water consumption by livestock varies with climatological conditions as well as the type of animal. Generally, livestock require water quality that has TDS levels under 3,000 mg/l. There are few other standards for chemical or bacteriological parameters for water for livestock.

Recreational Uses

Water Contact Sports - Waters used for swimming should be free from obnoxious odors, floating or suspended substances, and color. These waters should also be reasonably free of toxic agents and have a low probability of containing pathogenic organisms.

As an indicator of potential pathogens, the fecal coliform level for waters used for swimming should be below 200 per 100 ml. Most waterways may experience high bacterial concentrations after storm events in both urban and agricultural areas. Bacteria in runoff can come from a number of sources including birds, livestock, domestic animals, and wildlife. Septic tanks and wastewater systems that are surcharged during wet weather can also be significant sources of bacteria.

Fishing - The tolerance of fish to variations in aquatic habitat is to a large part species dependant. Such factors as water temperature and depth, aquatic vegetation, turbidity, turbidity, and dissolved oxygen affect the survival and reproduction of different species to differing degrees.

To be fit for human consumption, there are other factors that affect fish that must be considered. Bacterial concentration and the concentration of various compounds prone to bioaccumulation are important standards for determining whether waters are suitable for fishing.

As previously mentioned, Table 19 lists a number of pesticides and other compounds that are specifically identified by numerical limits by the rules of the Texas Natural Resource Conservation Commission. As noted in Table 19, several of the listed concentrations of constituents are listed according to bioconcentration. These limits affect all waters which have the potential for sufficient fish production to create a significant long-term human consumption of fish. In other words, if a waterway is used for fishing, then the water quality must meet the specific levels for those compounds listed.

Municipal and Industrial - With the exception of certain manufacturing processes that require extraordinarily high quality process water, such as the semiconductor industry, domestic water supplies typically exceed the quality needs of industrial users. Industrial water uses include an element of the manufacturing process, cleaning, a coolant, and a source of steam.

For those industrial operations that rely on raw surface waters there certain minimum standards that the supply source should meet. First, the water should be free of settleable solids. Secondly, the water should be free of floatables and oils in quantities that make the water unsightly. And finally, the water should be free from nuisance colors and odors.

Since municipal water systems usually supply water that exceeds these minimum requirements for industrial use, most industries rely on public water supply systems for treatment. The development of surface water sources as municipal supplies must adhere to the requirements of the TNRCC as detailed in 31 TAC Section 290.

According to the state regulations, prior to development of surface water sources, public water suppliers are required to evaluate the potential for adverse effects of municipal, agricultural, or industrial wastes within the watershed above the water source. Using sanitary surveys and laboratory analyses, the developer of the water source of supply is required to report to the TNRCC its conclusions of whether the raw water source is adequately protected form all sources of contamination.

Most substances listed in Table 19 are not significantly affected by the routine treatment processes of coagulation, sedimentation, and filtration. If a potential raw water supply is shown to have concentrations of such substances, additional treatment processes must be included by the public water supplier before water can be distributed to the public.

After plans for use of the raw water supply are approved and production begins, water supplied by the municipal water system must continually meet the standards of chemical quality mandated by the Safe Drinking Water Act. The maximum contaminant levels (MCL) for inorganic chemicals in public water supplies are shown in Table 20.

TABLE 21 MCL FOR INORGANIC CHEMICALS IN DRINKING WATER	
Constituent	**Level, mg/l**
Arsenic	0.05
Barium	1.0
Cadmium	0.010
Chromium	0.05
Flouride	4.0
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.0
Selenium	0.01
Silver	0.05

Source: 31 TAC Section 290.3

Using data on the effects of acute and chronic exposure to pesticides, the Safe Drinking Water Act includes maximum contaminant levels for pesticides, both organochlorine and chorophenoxy. These levels are considered to provide a safety factor that accounts for other sources of exposure, such as food and air. The MCL for each compound listed in the Safe Drinking Water Act should not be considered as a finite margin between safe and dangerous concentrations. The maximum contaminant levels for organic chemicals are listed in Table 21.

TABLE 22 MCL FOR ORGANIC COMPOUNDS IN DRINKING WATER	
Constituent	Level (mg/l)
Endrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8-dimethanonapthalene)	0.0002
Lindane (1,2,3,4,5,6-hexachloro-cyclohexane, gamma isomer)	0.004
Methoxychlor (1,1,1-Trichloro-2,2-bis-[p-methoxyphenyl]ethane)	0.1
Toxaphene ($C_{10}H_{10}C_{18}$-Technical chlorinated camphene, 67-69% chlorine)	0.005
Chlorophenoxys 2,4-D (2,4-Dichlorophenoxyacetic acid) 2,4,5-TP Silvex (2,4,5-Trichloro-phenoxypropionic acid)	 0.1 0.01

Source: 31 TAC Section 290.3

MEDINA RIVER WATER QUALITY

Water quality data for the Medina River within the BMA District has been collected by the State of Texas and the USGS since at least the early 1970's. Since January, 1987 the water quality monitoring station at La Coste has continuously recorded specific conductance, pH, water temperature, and dissolved oxygen. Other parameters of chemical and biochemical analyses are gathered less frequently.

The Medina River between Chacon Reservoir and the Diversion Lake is of relatively high quality, meeting applicable water quality standards. The applicable water quality standards according to the State of Texas Water Quality Inventory for stream segment 1903 are listed in Table 23.

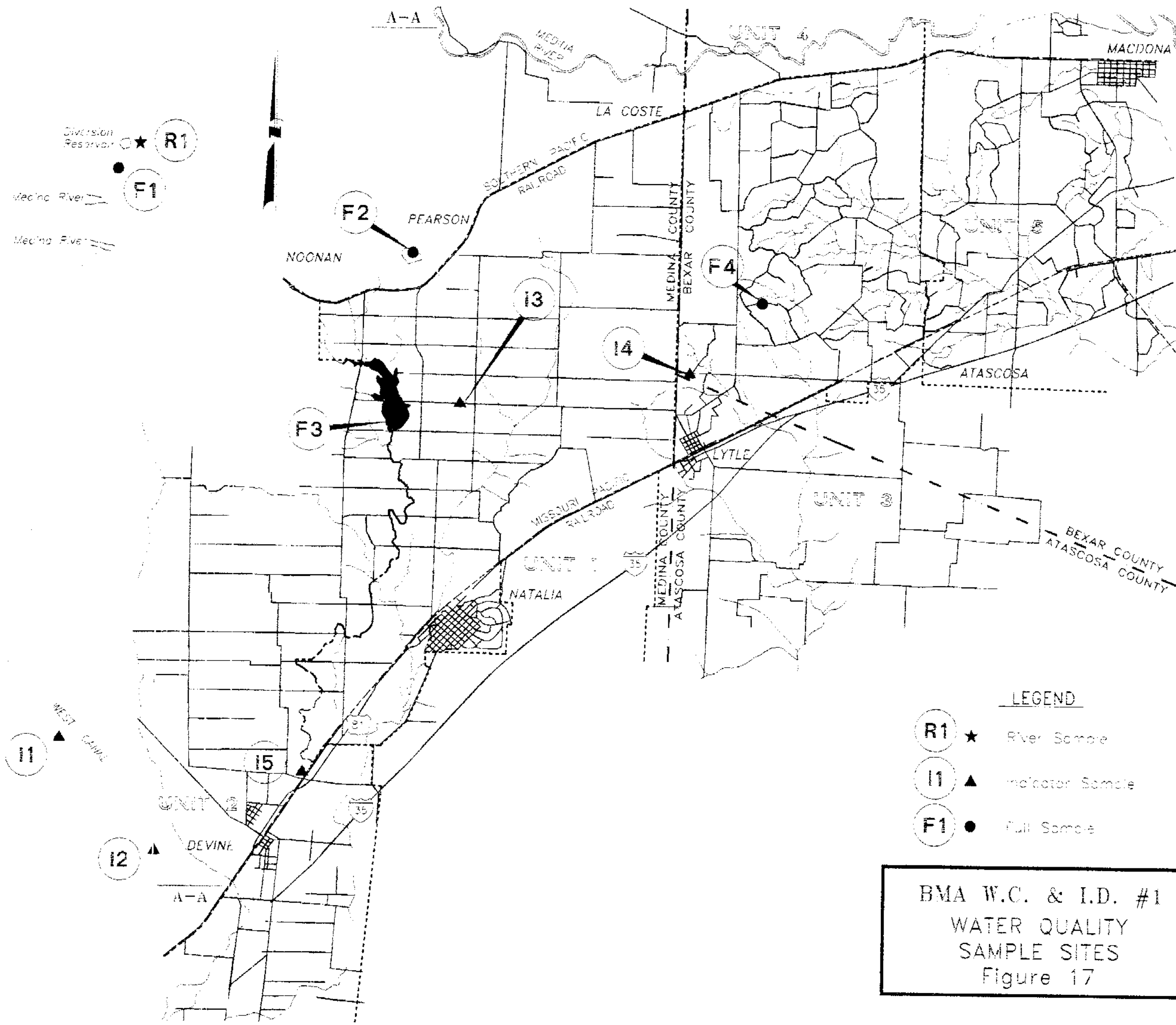
TABLE 23 Applicable Water Quality Standards Segment 1903 - Medina River	
Parameter	**Limit**
Chloride (avg. not to exceed)	120 mg/l
Sulfate (avg. not to exceed)	120 mg/l
Total Dissolved Solids (avg. not to exceed)	700 mg/l
Dissolved Oxygen (not less than)	5.0 mg/l
pH Range	7.0-9.0
Fecal Coliform	200 /100ml
Temperature	90 °F

The averages presented are for a stream segment that is approximately 80 miles in length, reaching from the Diversion Dam downstream to the San Antonio River confluence. The average water quality for the segment appears to be lower in some respects due to the influence of Leon Creek, the receiving stream for the City of San Antonio's wastewater treatment plant.

Water quality data gathered from the La Coste monitoring station and that from grab samples collected as a part of this report indicate that the upper reaches of this segment of the Medina River exceeds the minimum water quality standards. In order to evaluate the quality of the Medina River for parameters not included in the above table, a comparison of existing ground and surface water qualities is included for reference in Table 24.

TABLE 24 Existing Ground and Surface Water Quality			
Parameter	**Units**	**Edwards Aquifer**	**Surface Water Major Streams**
pH		6.5-8.0	7.1-8.0
Dissolved Solids	mg/l	250-450	200-300
Hardness	mg/l	250-300	200-250
Arsenic	µg/l	0-2	0-3
Cadmium	µg/l	0-1	0
Calcium	mg/l	80-100	50-70
Chloride	mg/l	10-30	10-30
Chromium	µg/l	0-15	0
Copper	µg/l	0-40	0-4
Fluoride	mg/l	0.1-0.5	0.1-0.2
Lead	µg/l	0-10	0-4
Mercury	µg/l	0-1.5	0
Total Nitrogen	mg/l	1.5-3.0	0.2-3.0
Total Phosphorous	mg/l	0-0.1	0.1-0.2
Sulfate	mg/l	10-30	10-50
Fecal Coliform	C/100 ml	0-150	0-200
Aldin	µg/l	0	0
Chlordane	µg/l	0	0
Endrin	µg/l	0	0
PCB's	µg/l	0	0-0.5
Toxaphene	µg/l	0	0
2,4-D	µg/l	0	0-0.3

Source: Bureau of Reclamation, BMA Technical Report, August, 1992



BMA W.C. & I.D. #1
WATER QUALITY
SAMPLE SITES
Figure 17

Water quality records for the years 1987 through 1993 for the Medina River at La Coste are included as Appendix 5. By reviewing those records, it is evident that the Medina River exceeds the minimum water quality standards listed in Table 22.

In order to supplement the historical water quality data, samples were collected in September, 1994 and analyzed for biological and chemical parameters. The results of those analyses, which are included in Appendix 4, also revealed the water quality of the Medina River to exceed the minimum standards. Pictures of the the specific sampling sites are included in Appedix 1 (See PHOTO 19 - 28).

BMA DISTRICT CANAL WATER QUALITY

In addition to the sampling and analysis of Medina River water, three points along the canal system and the Chacon Reservoir were selected for sampling. In addition to the biological and chemical parameters analyzed for the Medina River, these samples were also analyzed for organic compounds.

Testing for pesticides and herbicides revealed no compound above the analytical limits. All other parameters for these samples were similar to the results of the analysis of the Medina River water, with the exception of coliform bacteria in two locations.

WASTEWATER TREATMENT UTILIZING CONSTRUCTED WETLANDS

Natural wetlands occur in landscape low spots and through geological time they have adapted to and benefited from runoff borne substances carried in from adjacent upland regions. Since human societies first began to concentrate in villages and towns, natural wetlands received and processed their wastes. But waste loadings from larger populations in cities soon overloaded nearby wetlands damaging these systems and destroying their ability to process wastewater. Without natural wetlands buffering and treatment, concentrated wastes soon impacted streams, rivers and lakes. The developing technology of using constructed wetlands for wastewater treatment is merely an attempt to understand and use an important water quality improvement function of natural wetlands. And a natural method of wastewater treatment is much less expensive to construct and to operate than mechanical methods because a properly designed biological system is largely self-maintaining.

Constructed wetlands presently treat municipal, domestic, agricultural, industrial, acid mine drainage, and non-point source wastewaters as well as urban stormwater runoff in many countries around the world. Specific applications include town and city municipal sewage, acid water drainage from strip-mines, deep mines, coal and ash storage areas, textile, food processing and pulp-paper manufacturer wastes, livestock wastes, and campground/visitor center waste. The volume of effluent is not a limiting factor since constructed wetlands operate at individual home sites treating discharge from failed septic tank systems, small or large housing developments, towns and small cities. Mining, industrial and agricultural applications may vary from very small waste streams to millions of gallons per day.

A wetlands constructed for wastewater treatment is a man-made marsh, designed, built and operated to simulate and enhance the physical, chemical, and biological processes in natural wetlands to treat wastewaters in lieu of complicated mechanical systems. The constructed wetland design integrates wetlands plants, microscopic organisms, aerobic and anaerobic substrates, and a meandering water course. This process is capable of removing nutrients, organic compounds, and trace metals while increasing oxygen and pH levels in a variety of wastewaters. It also has the ability to tolerate wide variations in water quality, fluctuating water levels, and can be adapted to most climatic regions.

In the typical facility, wastewater flows through a pipe from the primary wastewater treatment system into the constructed wetland. The water can flow either above the soil (Free-water Surface System) or through a porus media of consistently sized rock (Submerged Flow System). Flow is distributed uniformly across the width of the cell to ensure that the entire area is utilized. The cell is planted with wetland vegetation that includes cattails, rushes, reeds, iris, elephant ear, arrowhead, duckweed, and water hyacinths. Roots and stems of the plants form a dense mat which filters the water and removes a high percentage of contaminants. Since the plants transpire water into the atmosphere the wetlands may or may not discharge into a receiving stream.

Operating costs are much lower than for conventional wastewater treatment systems. Since most constructed wetlands are designed as gravity flow systems, pumping and energy costs are eliminated and chemical additions are also unnecessary. Operating and maintenance typically consists of inspecting dike integrity and vegetation health and grounds keeping-mowing dikes and associated areas. A properly designed and carefully constructed wetlands system is largely self-maintaining with little need for inputs or adjustments.

Land requirements vary with the level of pretreatment and desired discharge levels. For example, with only basic pretreatment (settling, degritting and/or communation) approximately twenty-five (25) acres per million gallons per day (MGD) will be needed to consistently meet the following secondary discharge standards:

Biological Oxygen Demand (BOD)	30 ppm
Total Suspended Solids (TSS)	30 ppm
Nitrogen (NH_3)	4-10 ppm
Coliforms	< 200

However, only ten (10) to fifteen (15) acres per MGD may be necessary to polish effluent from a lagoon, septic tank or package treatment plant to similar discharge standards. Tertiary treatment or nutrient removal will require larger effective treatment areas but actual area varies widely with the level of pretreatment and target discharge levels. Constructed wetlands are efficient at removing nutrients from the effluent of conventional systems providing excellent treatment at very low cost.

TABLE 25
WETLANDS TREATMENT

CONTAMINANT	REMOVAL PROCESS							
	SEDIMENTATION	FILTRATION	ABSORPTION	CHEMICAL PRECIPITATION	CHEMICAL DECOMPOSITION	MICROBIAL INTERACTION	UPTAKE BY VEGETATION	NATURAL DIEOFF
BOD		●			●	●		
Settleable Solids	●	●						
Colloidal Solids	●	●	●		●	●		
Nitrogen	●				●	●	●	
Phosphorus	●		●	●			●	
Metals	●		●	●		●	●	
Viruses	●					●		●
Bacteria	●					●		●
Coliform	●							●
Refractory Organics	●		●		●	●	●	
pH				●	●		●	

MUNICIPAL WATER DEMANDS

Blackwell, Lackey, & Associates (BLA) recently completed a study for Bexar-Medina-Atascosa Counties WCID#1 and Bexar-Metropolitan WSC which investigated the use of surface water from Medina Lake as an alternative means of supply for the area in and around the District and to reduce the reliance of pumping from the Edwards Aquifer. Table 26 summarizes the various systems existing facilities within the service area include the following entities:

TABLE 26
POTENTIAL TREATED WATER CUSTOMERS

Description	1993 Connections	Gal. per Connection per Day	No. of Wells	Total Well Capacity (GPM)	Source
Bexar Metropolitan Southside	28,480	421	15	41,200	Edwards Aq.
Bexar Metropolitan Lackland /Columbia	7,100	412	5	8,370	Edwards Aq.
City of Hondo	2,290	704	4	4,800	Edwards Aq.
Atascosa Rural WSC	1,700	393	2	2,000	Edwards Aq.
East Medina County WSC	1,520	334	4	3,050	Edwards Aq.
City of Devine	1,450	127	7	3,435	Edwards Aq.
Benton City WSC	1,400	250	2	905	Edwards Aq.
Yancy WSC	1,240	286	4	2,200	Edwards Aq.
City of Lytle	990	520	2	1,100	Edwards Aq.
City of Castroville	840	749	3	1,475	Edwards Aq.
City of La Coste	450	452	2	2,020	Edwards Aq.
West Medina WSC	280	364	1	600	Edwards Aq.
Medina County WCID #2	210	577	1	400	Edwards Aq.
Rio Medina	70	384	1	145	Edwards Aq.
TOTALS	**48,020**	**390**	**53**	**71,700**	

As can be seen, the water usage within the area has a large range to it. In particular, the usage averages 390 gallons per connection per day with a high of 749 gallons per connection per day for the City of Castroville and a low of 127 gallons per connection per day from the City of Devine. The variations may include industrial water usage as opposed to domestic water usage, unaccounted water loss or lack of conservation controls. The average water usage was used in the BLA study to project future water needs.

POPULATION PROJECTIONS

Population growth in Medina and Bexar Counties averages approximately 2% per annum. Medina County's growth rate is approximately 1% per year, while Bexar County is somewhat higher at 3%. The cities and areas west of San Antonio are expected to have a good growth rate as more and more people move out of San Antonio and into the more rural communities. Tables 27 and 28 present the Medina and Bexar Counties population projections for the years 1990 through 2026. These were prepared from information provided by the State Comptroller's office.

TABLE 27
MEDINA COUNTY POPULATIONS

Year	Total	White	Hispanic	Black	Other
1990	27,312	14,946	12,126	71	169
1995	29,185	15,660	13,276	71	178
2000	30,742	16,171	14,313	72	186
2005	32,077	16,567	15,245	71	194
2010	33,312	16,955	16,096	68	193
2015	34,428	17,293	16,877	64	194
2020	35,344	17,527	17,576	55	186
2025	35,939	17,596	18,111	51	181

TABLE 28
BEXAR COUNTY POPULATION PROJECTIONS

Year	Total	White	Hispanic	Black	Other
1990	1,185,394	497,074	589,123	81,533	17,664
1995	1,254,336	506,176	641,791	85,174	21,195
2000	1,308,192	508,715	686,861	87,833	24,783
2005	1,351,241	507,041	725,858	89,907	28,435
2010	1,385,404	501,808	759,933	91,517	32,146
2015	1,411,449	494,087	789,057	92,436	35,869
2020	1,425,165	482,656	810,474	92,391	39,644
2025	1,425,484	467,591	823,077	91,515	43,301

WATER DEMANDS

One of the main purposes of any Water Plan is to determine the demand for water over the length of the Planning Study. In doing so, population and water use projections have been developed for the average growth scenario. The growth-related water demand forecast is then assessed for both with and without conservation.

In general, the methods developed by the Texas Water Development Board for protecting population and water demands were used in the BLA study, and modified based on additional water use data and local input. Demand forecasting has been prepared and analyzed for the following categories of water use:

Municipal Water Demand - Includes quantities of fresh water used in homes, offices, public buildings, restaurants, and stores for drinking, food preparation, bathing, toilet flushing, clothes laundering, lawn watering, car washing, air conditioning, swimming pools, fire protection, street washing, and other sanitation and aesthetic uses.

Irrigation Water Demand - The water required to meet consumptive use requirements of agricultural crops cultivated in the study area.

Mining Water Demand - The water used in sand and gravel washing operations and in the recovery of oil and gas.

Livestock Water Demand - The water required for drinking and sanitation associated with various livestock operations including: beef cattle, dairies, swine, sheep, goats, and poultry.

Manufacturing Water Demand - The water used in the normal operation of an industry for cooling water, process/product makeup water, sanitation, and landscaping.

Steam Electric Demand - The water needed to replace steam or induced evaporation generated through the operation of boilers, cooling the generation equipment and for general plant uses.

PER CAPITA DEMANDS

Per capita demands, or the average volume of water used in gallons per person per day is multiplied by the population to arrive at water demand. For the purpose of their report, BLA evaluated the historical demands in relation to accepted norms, water conservation goals, and economic impacts for each of the existing systems shown in Table26. The documents used for this analysis were obtained from the Texas Water Development Board (TWDB).

The number of connections water pumpage rates and peak monthly water pumpage were then analyzed. Growth in service connections were calculated and projected over the life of the plan. Table 29 represents the anticipated growth rate of service connections within the study area.

TABLE 29 WATER SYSTEM CONNECTION					
Description	1993	1995	2000	2010	2015
Bexar Metropolitan Southside	28,480	29,610	32,750	39,870	44,140
Bexar Metropolitan Lackland City/Columbia	7,100	7,375	8,160	9,930	10,995
City of Hondo	2,290	2,380	2,635	3,200	6,550
Atascosa Rural WSC	1,700	1,770	1,955	2,380	2,635
East Medina County WSC	1,520	1,580	1,750	2,130	2,355
City of Devine	1,450	1,510	1,670	2,035	2,255
Benton City WSC	1,400	1,450	1,610	1,960	2,170
Yancy WSC	1,240	1,290	1,425	1,735	1,925
City of Lytle	990	1,030	1,140	1,390	1,540
City of Castroville	840	870	960	1,170	1,300
City of La Coste	450	465	515	625	690
West Medina WSC	280	285	315	385	430
Medina County WCID #2	210	215	240	290	325
Rio Medina	70	75	80	100	110
TOTAL CONNECTIONS	**48,020**	**49,905**	**55,205**	**67,200**	**75,165**

PEARSON LAKE WATER TREATMENT PLANT

A water treatment plant site at Pearson Lake has previously been selected by earlier studies due to the following:

1. A central location between the consumer and the raw water storage facility (Medina Main and Diversion Lakes);
2. BMA owns the property which the treatment facility will be located on, and;
3. The site is presently used as a storage facility for irrigation waters and can be easily adapted to provide flow equalization during peaks and lows.

As previously mentioned, the central Texas region typically receives low amounts of precipitation while having relatively high evapotranspiration rates. These conditions combined with soils possessing a low permeability rate, result in only small amounts of continuous runoff. Heavy runoff for limited periods during times of intense storms is also representative of the area. The intense groundwater use throughout the region has significantly reduced both the levels of and well pumpage yields from the Edwards Aquifer. This has led to a severe decline of spring flows in recent history which has threatened the habitats of many endangered species of wildlife. These events have increased the publics awareness of the fact that our water resources are limited and the trends of its use is changing. The State's total yield of ground and surface water resources is estimated to be 16 million acre feet per year and are currently 75 to 80 percent developed. Texas has experienced a state-wide decline in the total irrigated acreage (approximately 670,000 acres during the period between 1985 and 1989) while the population has continued to increase, causing a shift in water use from agricultural to municipal and industrial (M&I).

In the past, the Edwards Aquifer has been utilized to satisfy the demands for M&I uses throughout the region, however, the aquifer can only supply a limited amount of water before it is in danger of depletion. Because of the recent decline in Aquifer levels, new regulations have placed restrictions on continued development within the Edwards Underground Aquifer. This change has focused new attention to Medina Lake and its ability to meet this challenge.

The proposed plan of development of the Pearson Lake Water Treatment Plant is to initially serve designated customers by reducing their 1993 pumpage by 25% and serving all new growth through a surface water supply. The water utilized here will be delivered to the well production plants (existing well sites currently pumping out of the Edwards) for distribution through their existing facilities.

Table30 is a summary of the projected connections, customers to be served, water treatment plant capacity and projected water usage. Plant sizing is based on the Texas Natural Resource Conservation Commission's (TNRCC) minimum criteria of 0.6 Gallons Per Minute per Connection, for peak day water needs. Average water usage through the plant, was based on the average daily demand of 390 Gallons per Connection per Day, plus a 10% add on factor for system water loss in the delivery system. The average water use in this situation equates to approximately one half of the peak day usage requirements.

TABLE 30 PROPOSED TREATMENT PLANT CAPACITY				
Year	Total Service Connections[1]	Initial Service Connections[2] (25% of Total)	TNRCC Criteria For Capacity[3] (MGD)	Avg. Water Use[4] (MGD)
1995	49,927	13,923	12.0	6.75
2000	19,203	55,207	16.6	9.32
2010	62,207	31,203	26.9	15.14
2015	74,409	38,405	33.2	18.63

1) From Table 29
2) From Table 29 utilizing 25% of 1993 connections plus an additional 2% annual growth for new connections
3) Projection based on TNRCC criteria of 0.6 Gallons per Minute per Connection for minimum peak day production
4) Projection based on 1993 average usage of 390 Gallons per Connection per Day with 10% water loss through the proposed system.

Based on the projected demands a 16 Million Gallon per Day (MGD) initial water treatment plant is required to meet the proposed demands through the year 2000. Subsequent plant additions are sized as 8 Million Gallons per Day treatment modules which can be added on as needed. Key components of the treatment facility are sized in Table 31.

On-site storage of approximately seven days has been planned for it to provide flexibility in the operation of the delivery system from Medina Diversion Lake and the Irrigation Canals. Sizing of the treatment units is based on TNRCC criteria for public water system design. Coagulant chemicals of aluminum or iron salts (alum or ferric chloride) and polymer are proposed for sedimentation. The turbidity and sediments will be removed by addition of the coagulant chemicals and settling through an upflow, solids contact clarifier. This unit minimizes process sizing, while saving chemical costs, by its ability to recirculate settled sludge to aid in water treatment. Final treatment will be through mixed media gravity filters to insure thorough treatment performance. Chlorine and ammonia will be used as disinfectants prior to on-site storage of the treated water in a 2 million gallon clearwell.

TABLE 31 KEY COMPONENT SIZING	
Component	**Sizing**
Max Flow Rate	16 MGD = 11,100 Gallons per Minute
Number of Connections (@ 0.6 GPM/Connection)	18,500 Connections
Average Water Usage	433 Gal./Day/Conn. = 8.0 MGD = 24.6 Ac-Feet/Day
Avg. Raw Water Withdrawal from Medina Diversion	8,979 Acre Feet per Year - Firm Yield
On-Site Raw Water Storage	7 Days = 172 Acre-Feet
Raw Water Pump Stations	4 @ 3,700 GPM Each
Solids Contact Clarifier	2 Each @ 12' SWD X 120' Diameter
Mixed Media Gravel Filters	12 Each - 15' X 15'
Water Treatment Plant Clearwell	2 Million Gallons
High Service Pumps	4 @ 6,000 GPM Each

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are made based upon an analysis of the BMA system and operations:

CONVEYANCE SYSTEM EFFICIENCY

- ❑ In a study being prepared by the University of Texas at Austin LBJ School of Public Affairs for the Texas Water Development Board on water conservation efforts in LCRA's Gulf Coast Irrigation District, Professor David Eaton found that for every mile of canal rehabilitated, annual water diversion was reduced by an average of 544 acre-feet. He went on to point out that there was an extremely strong relation between the incremental amount expended on maintenance (effort) and water savings. Removal of vegetation, reshaping of the canals, and continued maintenance can yield significant annual water savings.

- ❑ As tracts are subdivided, BMA should require that the landowner install a piped delivery system to serve each tract in an easement deeded to the District.

- ❑ Tracts smaller than ten acres should be dropped from the District service area.

- ❑ Construct additional off-system holding ponds to capture water from the canals when the system is turned off. Under current methods of operation, if it rains in the District and orders drop off, the excess water from the canals that cannot be retained in the existing reservoirs (Pearson, Chacon, and Jungman) is diverted to streams via waste structures. Installation of holding reservoirs at strategic locations throughout the District would not only reduce this significant loss of water, but also allow the initial orders to be filled faster. Storage improvements should include:
  1) Removal of approximately 315,000 cubic yards of silt from Chacon Lake. This would provide an additional 195 acre-feet of storage at an estimated cost of $2,264,000.
  2) Expand the capacity of Pearson Lake from the present 230 acre-feet to 350 acre-feet. The estimated cost would be $1,391,000.
  3) Expand the capacity of Jungman Lake from the 23 acre-feet to 40 acre-feet. The estimated cost of this work is $370,000.
  4) Construct a reservoir on A-1 near the Bexar County line with a capacity of 36 acre-feet. The estimated cost of $134,000 is based on using material from either Jungman or Pearson Lake expansions.
  5) Construct a reservoir south of IH-35 on D-2 with a capacity of 34 acre-feet. The estimated cost of $211,000 is based on using material from either Jungman or Pearson Lake expansions.

- In the 9,000 foot canal segment isolated by the construction of a siphon at flume site 11, control structures should be constructed on the upstream and downstream ends to allow for water storage and a wildlife preserve. The estimated cost to design and construct the inlet and outlet structures is $20,000. Lining the entire length would cost an additional $825,000.

- Line the main canal from the end of the existing concrete lining to Pearson Lake and A-1 from Pearson Lake to the Bexar County Line. Check structures should be constructed at regular intervals along the canal to create storage in the system. These structures should be designed to allow for future automation (remote control) and overflow protection that allows excess water to flow over a weir to either continue down the canal or out of the system through a waste structure. Additional storage capacity could be achieved by increasing the freeboard in the main canal with the soil from the spoil piles along the route.

- The following canal segments should be considered high priority for lining:
  1) D-1 from Jungman Lake to the D-2 cross-connection.
  2) D-2 from Chacon Lake to Canal 35-A.
  3) B from the Bexar County line to Lucky Rd.
  4) Natalia canal from A-3 to US-81.

Table 32 summarizes the estimated costs and water savings from lining/piping of the Main, A-1, B, lower D-1, D-2, and Natalia Canals. The water savings are based on an average use of each canal segment.

TABLE 32
CANAL IMPROVEMENT COSTS VERSUS WATER SAVINGS

Canal	Estimated Cost	Estimated Annual Water Savings (acre-feet)
Main (Diversion Lake to Pearson)	$17,302,000	11,000
A-1 (Pearson Lake to Bexar Co.)	$2,934,000	6,500
B (Bexar Co. line to Luckey Rd.	$1,828,000	1,600
D-1 (Jungman to D-2)	$4,232,000	5,900
D-2 (Chacon Lake to 35-A)	$5,614,000	4,600
Natalia (A-3 to US-81)	$1,144,000	1,300

- ❑ Structures along the canals should be modified to capture stormwater runoff in the canal system for storage and future use. Care must be taken to ensure that runoff exposed to potential sources of pollution is minimized.

- ❑ As segments of the canal system are lined, wildlife stairs should be installed to permit animals an escape route.

- ❑ Laterals in areas with sandy soils should be piped. Once these have been completed, the District should budget resources to annually pipe a minimum of 5 miles of lateral each year.

OPERATIONAL

- ❑ During the initial filling of the canal, soils forming the lining absorb a large amount of water until reaching saturation and seal. In order to minimize this loss, farmers served by common canals should be encouraged by the District to irrigate during the same time period. This will reduce water losses due to saturation and sealing of laterals when the water is first turned down the lateral. Eventually the District could expand this into a scheduling program based on the type of crop, date of last irrigation, estimated depletion of soil moisture, and the general weather forecast.

- ❑ The District should move forward quickly with implementation of volumetric billing. This will not only encourage water conservation by the agricultural customers but also provide BMA with valuable information useful in managing this valuable resource. During the first year of volumetric billing, LCRA placed a ten percent cap on the amount that a bill would increase over the previous year. This allowed farmers an opportunity to see what the financial impact of the new system would be if they continued their current irrigation practices.

- ❑ An early warning system should be installed at key locations to warn District personnel of high water levels in the main canal. This would minimize the chance of water overtopping and breaching the levee by allowing response personnel time to locate the cause of blockage and eliminating it.

WATER QUALITY

- ❑ Water quality in both the Medina River and the BMA Canal system is suitable for agricultural, municipal and industrial, and recreational uses. While sediment, chemical, and biological loadings are relatively low during normal flow conditions, two potential sources for water quality problems should be the subject of further assessment. These are nonpoint source pollution and discharges from the Castroville wastewater treatment plant.

- The 3,000 feet of canal isolated by the construction of siphon at flume site 6 could be modified as a wetlands treatment cell for the City of Castroville's wastewater treatment plant effluent. This additional treatment could make the water available for reuse by the District while eliminating a factor causing the slope failures along one section of canal and potential source of contamination. The wetland could also serve to mitigate other sites disrupted by the lining of the canal system if required. Estimated cost to design and construct the inlet and outlet structures, 1,500 linear feet of force main from the wastewater treatment plant, and install the appropriate vegetation is $55,000.

- Since traces of pesticides and herbicides can pass through standard water treatment processes, positioning a raw water intake such that the acreage in the watershed subject to cultivation is minimized would benefit the future operation of the plant. The site for the proposed Pearson Lake surface water plant may simplify monitoring for identification of the magnitude of any potential problems associated with storm runoff in the watershed above the proposed plant intake. An analysis of nonpoint source pollution sources and effects under current conditions would identify any potential problems that might affect development of a surface water plant and would provide baseline data that could be used to assess the impact of future development in the area.

- While the treated effluent from the City of Castroville wastewater treatment plant is a potential source of contamination of the BMA District's waters, uncontrolled and improperly controlled recreational activities at the Chacon Reservoir can also have adverse impacts on water quality. A septic tank drain field near the dam can introduce significant loads of nitrogen and coliform bacteria to the lake. Construction of a small lift station to transport sewage from the campgrounds away from the reservoir would minimize the effects of recreation on water quality.

MUNICIPAL WATER DEMAND

- As the area continues to urbanize, the need for alternative water sources will be required to relieve the intense pressure on the Edwards Aquifer. The cost of constructing a water treatment plant and the required transmission system is detailed in Tables 33 and 34.

TABLE 33
PROPOSED TRANSMISSION MAINS

Trans. Main	Description	Size	Approx. Length	Projected 2015 Flow	Project Cost
TM 1	From Pearson WTP to East	60"	25,000 FT	30,400 GPM	$3.75M
TM 2	From Pearson to Devine	20"	60,000 FT	3,520 GPM	$3.60 M
TM 3	From Pearson to Castroville	20"	28,000 FT	3,300 GPM	$1.68 M
TM 4	FM 2790 South to Lytle	54"	20,000 FT	28,700 GPM	$2.70 M
TM 5	Along I-35 to Loop 1604	54"	46,000 FT	27,500 GPM	$6.21 M
TM 6	Along I-35 to Bexar Met South	48"	48,000 FT	22,000 GPM	$2.64 M
TM 7	Along Loop 1604 to Lackland City	24"	50,000 FT	5,500 GPM	$3.60 M
TM 8	Along FM 2790 to La Coste	8"	10,000 FT	400 GPM	$0.24 M
TM 9	Along Irrig. Canal to Atascosa WSC	12"	5,000 FT	1,300 GPM	$0.18 M
TM 10	Along I-35 Between Devine & Lytle	10"	50,000 FT	1,100 GPM	$1.50 M
TM 11	Along FM 173 From Devine to Hondo	16"	45,000 FT	1,850 GPM	$2.16 M
TM 12	Along FM 173 From Devine to Hondo	12"	45,000 FT	900 GPM	$1.62 M
TM 13	Castroville to Rio Medina	6"	40,000 FT	110 GPM	$0.72 M
TM 14	Castroville to Quihi	16"	48,000 FT	2,500 GPM	$2.30 M
TM 15	Quihi to Hondo	12"	42,000 FT	1,350 GPM	$1.51 M
TM 16	Hondo to D'Hanis	8"	40,000 FT	480 GPM	$0.96 M
	TOTAL				**$35.37 M**

TABLE 34 PROPOSED WATER FACILITIES	
Description	**Costs**
Pearson Water Treatment Plant	$16.00 M
Pearson WTP Booster Station & Ground Storage	$2.70 M
Loop 1604/I-35 Booster Station & Ground Storage	$2.00 M
FM 173 to Hondo Booster Station & Ground Storage	$0.15 M
Quihi to Hondo Booster Station & Ground Storage	$0.18 M
Hondo to D'Hanis Booster Station & Ground Storage	$0.03 M
TOTAL	**$21.06 M**

PHOTO 1 - TYPE A CANAL (Main at US-90)

PHOTO 2 - TYPE B CANAL (Upper Portion of D - 1)

PHOTO 3 - TYPE C CANAL (D -2 Near E. Calame Rd.)

PHOTO 4 - TYPE D CANAL (Beyond Check, Natalia Canal)


PHOTO 5 - TYPE E (Pull Ditch Near N. Calame Rd.)

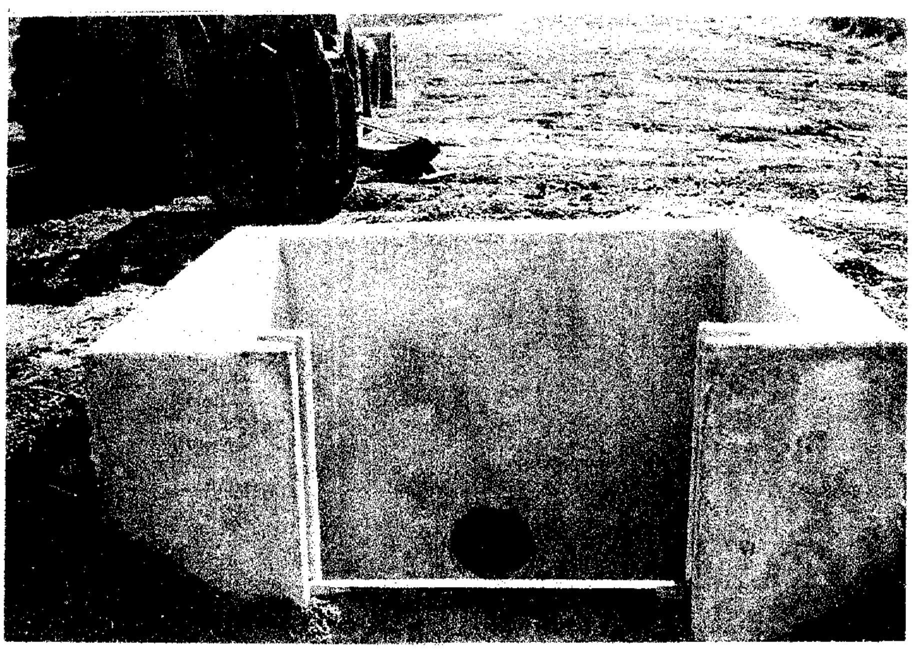


PHOTO 6 - ENTRANCE TO RECENTLY PIPED SECTION OF 35-E

PHOTO 7 - PEARSON LAKE

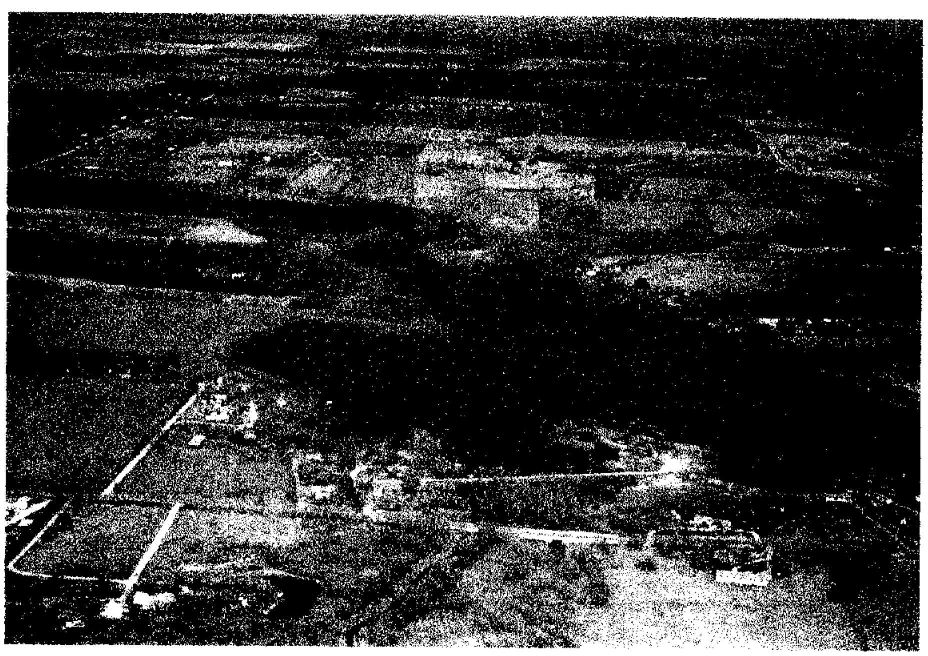


PHOTO 8 - CHACON LAKE

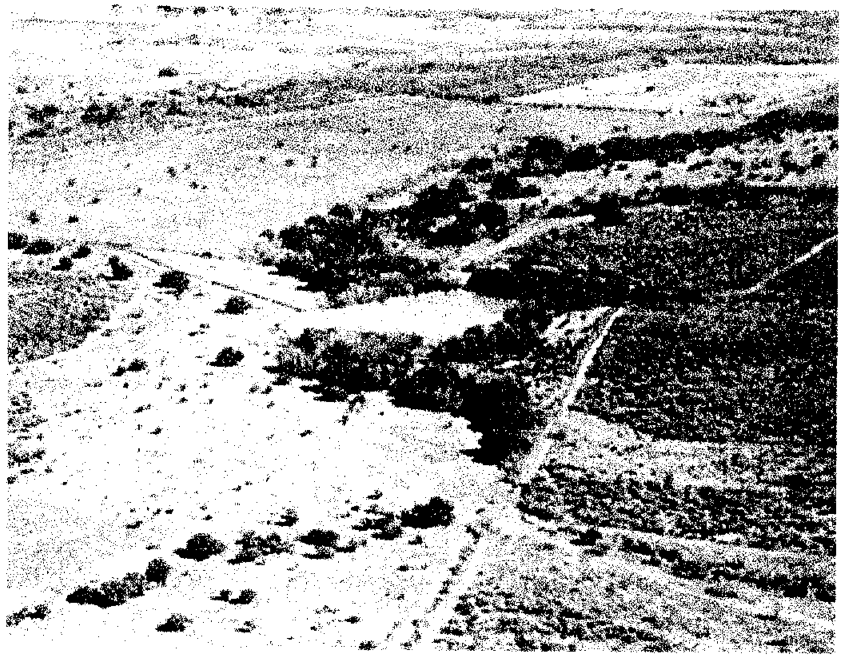


PHOTO 9 - JUNGMAN LAKE

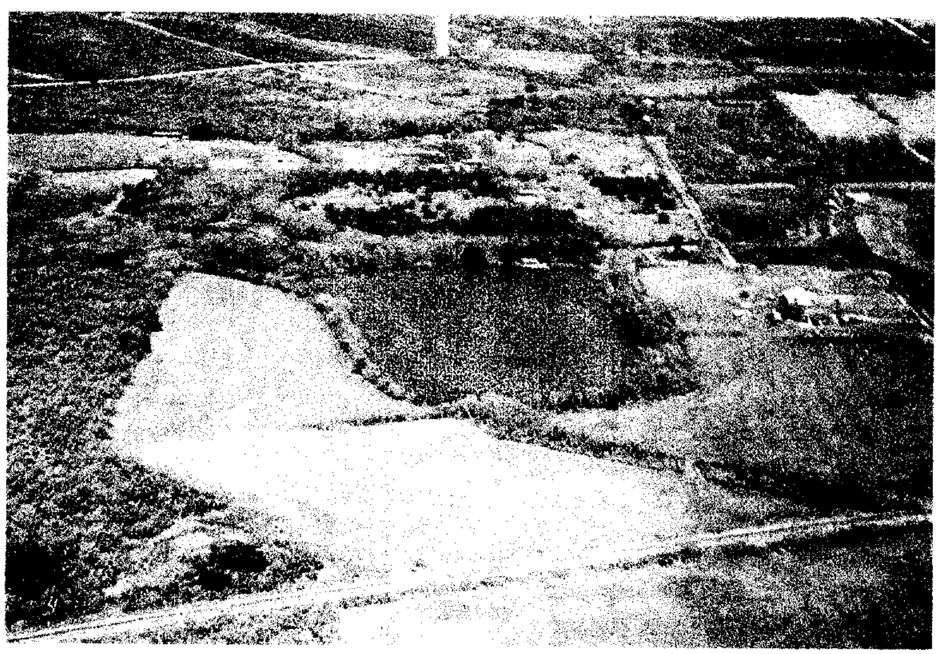


PHOTO 10 - KIRBY LAKE

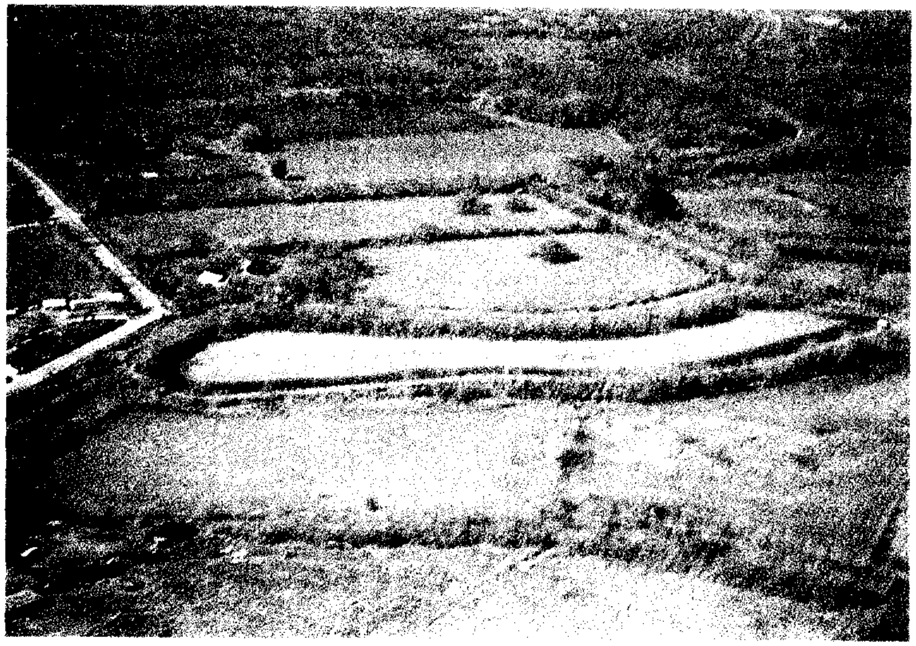


PHOTO 11 - BALL LAKE

PHOTO 12 - DUBOSE LAKE (Dry)

PHOTO 13 - SLOPE FAILURE ABOVE SIPHON 5

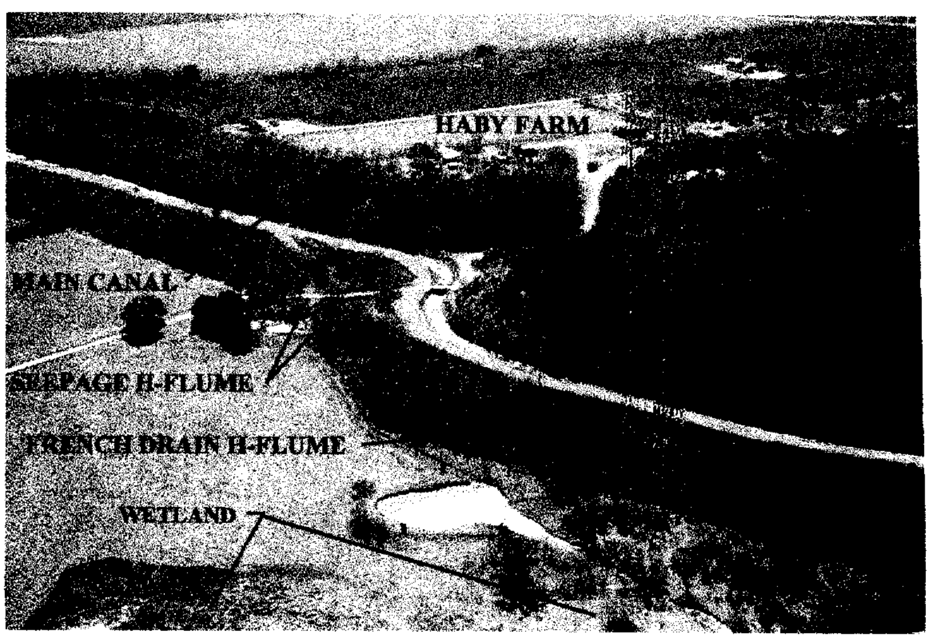


PHOTO 14 - WETLAND DUE TO SEEPAGE FROM MAIN CANAL

PHOTO 15 - EXCAVATOR CLEANING MAIN CANAL
(Note Excessive Vegetation on Far Canal Bank)

PHOTO 16 - OVERGROWN CANAL (D-2 at Dubose Lake)

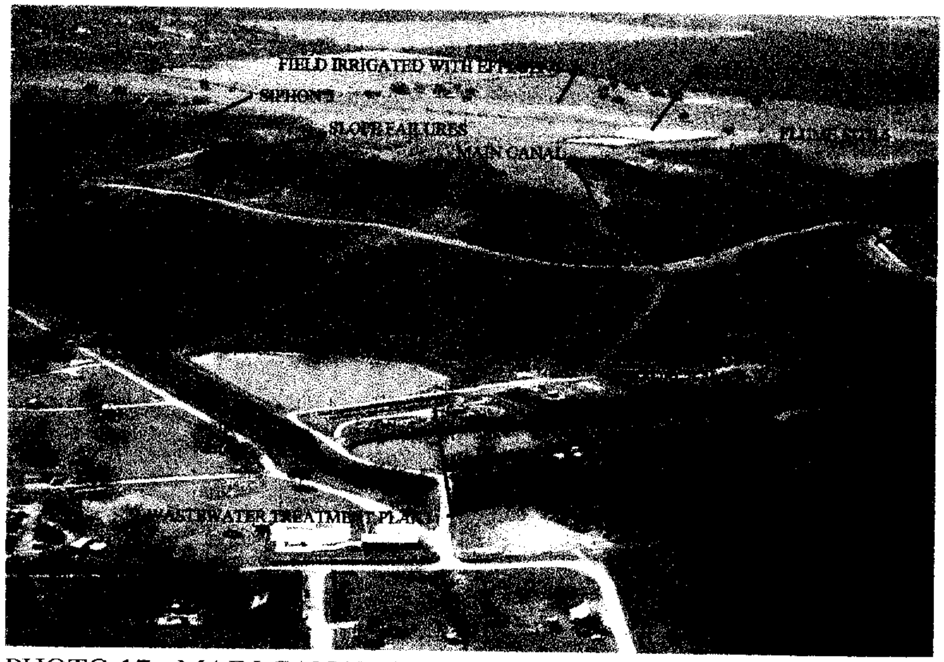


PHOTO 17 - MAIN CANAL AT CASTROVILLE

PHOTO 18 - SEEPAGE IN SLOPE FAILURE NEAR SIPHON 5

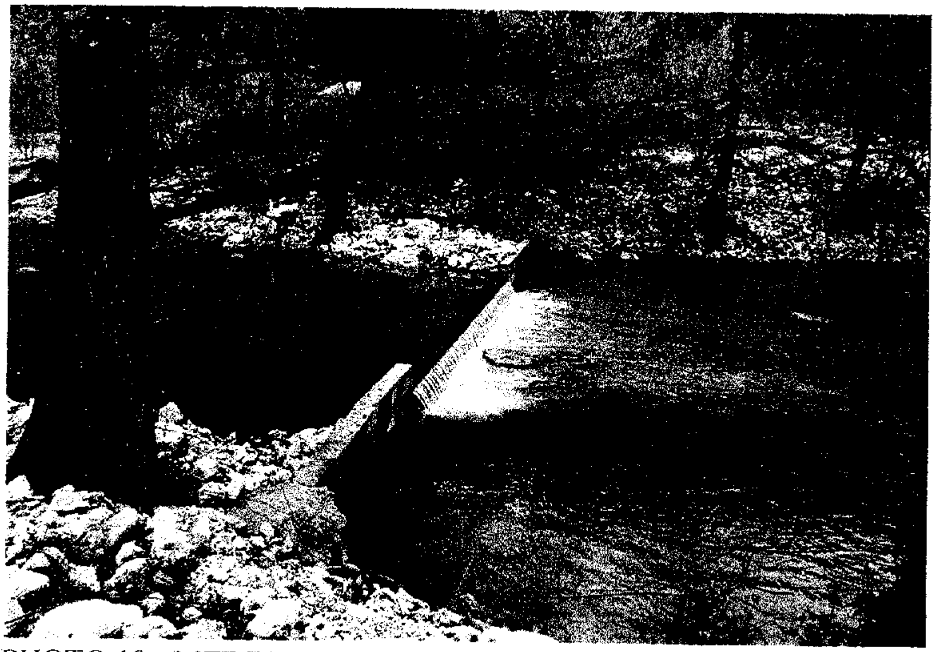


PHOTO 19 - MEDINA RIVER WEIR BELOW DIVERSION DAM

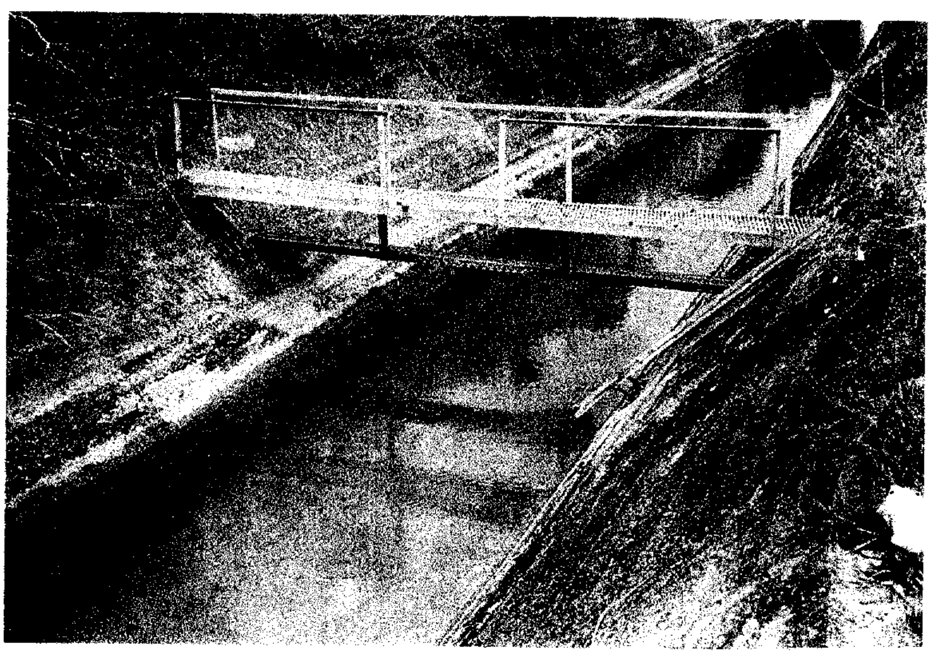


PHOTO 20 - MAIN CANAL AT OLD USGS GAGING STATION

PHOTO 21 - MAIN CANAL, SOUTH OF US-90

PHOTO 22 - MAIN CANAL AT SIPHON 5

PHOTO 23 - PEARSON LAKE (Sample Taken Near Outlet Structure)

PHOTO 24 - CHACON LAKE (Sample Taken Near Boat Ramp)

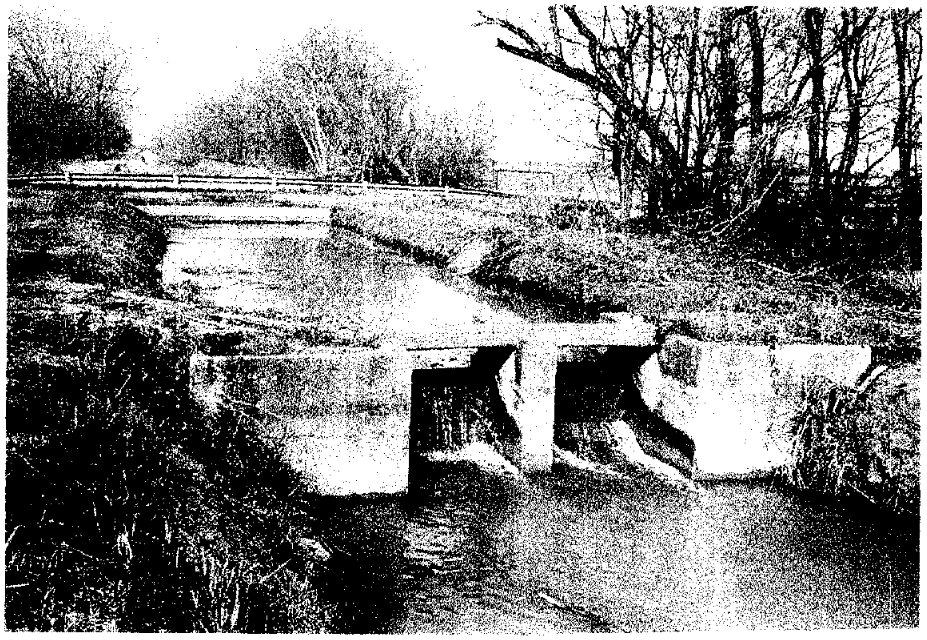


PHOTO 25 - NATALIA CANAL, SOUTH OF FM 463

PHOTO 26 - D-2 CANAL AT THE INGRAM REDI MIX PLANT
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R-90-19

LOWER COLORADO RIVER AUTHORITY WATER BOX CALIBRATIONS

October 1990

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Denver Office
Research and Laboratory Services Division
Hydraulics Branch

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16. ABSTRACT
The LCRA (Lower Colorado River Authority) in Austin, Texas, requested the Bureau of Reclamation to study the implementation of rectangular stop plank style turnout structures for water measurement. A full-scale 4-foot and a 2/3-scale model of 6-foot LCRA water boxes were calibrated in the Denver Office laboratory in both weir and orifice modes of operation. It was determined that metal edges should be installed on the stop planks if the structures are to be used for water measurement. Metal edges were designed which could be installed and still allow the tongue-and-groove planks to be used for shutoff. The weir calibration was generalized in terms of unit discharge and can be applied for all box sizes. The orifice calibration was generalized in dimensionless form and can be used for all orifice lengths, openings, and elevations to within one orifice dimension of the box bottom.

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UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

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The help of Mike Shoppa of LCRA is greatly appreciated. He provided drawings and data needed to model the water boxes and visited the laboratory to explain how the boxes are used in the field. Brent Mefford of the Denver Office supervised the study and performed the trial and error fits of the orifice calibration functions. The continued interest of Tim Flanigan of the Great Plains regional office is greatly appreciated.

CONTENTS

FIGURES

INTRODUCTION AND BACKGROUND

About 2,000 water boxes are used by LCRA (Lower Colorado River Authority) to deliver water to rice farmers of the Gulf Coast Irrigation District near Austin, Texas. In order to conserve water, the LCRA plans to improve their accountability of water delivered at each turnout by treating the water box turnouts as weirs or orifices. Water passes over the top stop planks when used as weirs; to create an orifice, spacers are placed between one set of the tongue-and-groove stop planks to separate them, thus forming rectangular orifices. LCRA requested that the hydraulic laboratory evaluate the water boxes and modes of operation as possible water measuring devices. If necessary these boxes will be modified and limits on their usage will be specified.

The conversion to a more precise measurement program will take place in two stages. The first stage, covering a 2,000-acre pilot project containing about 20 boxes, started in April 1990. The second stage will consist of converting the remaining boxes in 1991. The desired target water measurement accuracy is ±10 percent.

Operators describe a "box of water" as 3,000 gal/min or 6.68 ft^3/s which, in a 4-foot box used as a weir, is assumed to occur at about 6 inches of head. Generally, after a mode of operation and position of planks have been selected at a site, the weir or orifice geometry is unchanged from then on. However, weir and orifice elevations, flow approach depth, and downstream submergence can vary considerably with time and between different measurement sites. In addition the edge shape of tongue-and-groove planks can change due to damage and wear. There can even be variation of milling of the wood. Thus, the present method is at best an estimate.

CONCLUSIONS

The following are based on laboratory observations, data, and calibration parameters:

- Metal-edged orifices and weirs installed in LCRA boxes are adequate measuring devices.

- Unit discharge equation 3a for the 4-foot box metal-edged weir should be used for all box sizes. The standard deviation for the weir equation is ±2.0 percent discharge including the uncertainty of estimating between hundredth divisions on the staff gauges.

- Rounding of orifice and weir edges by poor machining or damage and wear can affect the discharge measurement considerably. Thus the use of wood blades is not recommended because of variation of the tongue-and-groove milling and inevitable damage and wear during use.

- The weir crest should be at least a distance equal to two maximum measuring heads from the invert of the box (immediately upstream of the weir crest). Weir lengths should be measured for each box after setting the blade level as a precaution against construction errors, form slipping and walls being out of plumb. Corrected values of blade length (L) should be used in the weir equations.

- Metal orifice and weir blades can be installed on the planks and still allow the tongue-and-groove to seal and shut off the flow.

- Because LCRA water boxes lack a field data base as measuring devices, it is recommended, especially during the early stages of the conversion program, that careful current meter checks be made for box sizes tested in the laboratory and those not tested.

- Flow through LCRA weirs seals against the slot projections and prevents nappe ventilation when the downstream water level rises to within 0.5 foot of the crest elevation. Therefore, the water surface downstream should be kept at least 0.5 foot below the weir crest.

- The metal-edged orifice coefficient curves on figure 1 can be used with equation 7 to determine discharge. The coefficient of discharge can be determined from the conic least square fit equations 9 and 10. The average standard deviation of the coefficient for elliptical orifice fits is 0.01. The discharge coefficients presented can be used for all sizes of boxes, orifice openings, orifice lengths, and elevations to within one orifice opening from of the upstream box bottom.

- The outside edge of the orifice opening spacers should be parallel and in line with plank slot projections. The length and opening should be measured for each box after each setting of blade level as a precaution against construction errors, form slipping, and walls being out of plumb.

- Staff gauge zero reference elevations and orifice dimensions should be determined after the wood planks have become water saturated. Orifice and weir installations and boxes should be checked routinely for tilting and shifting relative to the staff gauge.

- Since plugging occurs where it cannot easily be seen, the orifices need to be checked frequently for plugging with weeds and other debris.

- Sediment deposits on the bottom of the approach near shallow orifices can affect flow measurement accuracy. Special effort should be made to ensure that there is not a deposit that slopes up to the orifice edge. Sediment deposits upstream of the measuring head staff gauge and the stop planks should be cleaned out to a distance equal to at least six deposit depths.

- If the right and left measuring heads differ by more than 0.02 foot, turning and blocking baffles should be placed upstream to correct the difference to within 0.02 foot.

- The laboratory calibrations presented for the tongue-and-groove weirs and orifices (figs. 4 and 6) are not recommended for general use because they are based on wooden blades.

- The simultaneous use of weir and orifice flow should not be used for flow measurement. Discharges determined under this combined flow condition should be considered as rough estimates only.

THE MODEL

Test Plan

The following is basically the study plan as submitted to LCRA. The 4-foot box is the most commonly used. Therefore, this size was installed in the laboratory and tested first. The tests were directed mainly at determining the orifice and weir boundary and edge effects. It was expected that this would require tests of the orifices at different distances from the invert and different distances from the water surface. Weir and orifice tests with and without the slot protrusions might be required as well as tests of weirs with protruding slots with and without the spacers and their rods. A vertical center railroad track used as a brace in the 6-foot box would be removed to determine its effect on discharge. Then the 6-foot box unit discharge equation would be predicted from the 4-foot unit discharge equation and compared to a calibration done with a 2/3 scale 6-foot box installed in the laboratory. Depending upon the degree of this comparison, the remaining sizes of the boxes would be installed and tested. Due to the expense of converting 2,000 boxes to ideal weir and orifice measuring systems, it was decided that tests would be performed to attain an acceptable accuracy with the least amount of modification necessary.

Laboratory Installation and Measurements

The water box, weirs, and orifices were installed in a 6-foot-deep, 7-foot-wide, and 22-foot-long rectangular channel (fig. 5). Water was supplied to the model test channel using the standard laboratory water delivery system. Discharge through the model was measured with the volumetrically calibrated venturi meters that are a permanent part of the hydraulic laboratory equipment. The volumetric tank water measurement system can measure discharge to within less than ±1 percent. Thus with careful venturi differential readings the discharge measurements have a traceable accuracy of ±1 percent. Before passing through the water boxes, the water was distributed and stilled by passing it through a gravel baffle. The downstream submergence head was controlled by positioning a flap-type tailgate. Head measurements were made using metal staff gauges that have 0.01-foot minimum divisions. Therefore, bankside staff gauge readings can be estimated to ±0.005 foot.

WEIR CALIBRATIONS

Conditions for standard sharp-crested weirs specified in the Water Measurement Manual (Bureau of Reclamation, 1981 reprint) are:

- The weir crest elevation should be at least two maximum measuring heads above the approach channel invert.
- The approach flow area should be at least eight times the flow area above the crest.
- The velocity of approach should be less than 0.5 ft/s.
- The blade crest length should be greater than three maximum measuring heads.

- The approach channel to the weir should be straight for a distance equal to 10 average channel widths.

- The top of the weir blade should not be more than 1/16 inch thick and have a sharp upstream corner.

These conditions can only be relaxed at the expense of determining more complicated equations with variable discharge coefficients, obtaining specific site and geometry calibrations and making velocity of approach corrections. Additional improvements in the field may also be required such as installing baffles to correct approach flow distribution.

The prediction of hydraulic relations can frequently be approximated by a form of a power function, that is, they plot as straight lines on log-log graph paper. But exponents and coefficients derived in this manner do not generally relate directly to the actual physics. For example the coefficient has to assume dimensional units that are commensurate with the independent variable raised to its exponent to obtain the proper units for the dependent variable. However, statistical best fit parameters such as correlation coefficient, standard deviation and mean error can be used to tune coefficients of simplified equations to achieve predictions within the limits of experimental error. To a degree, varying the coefficients and exponents can compensate for poor compliance of the above-mentioned conditions for standard weirs.

Discharge (Q) and measuring head (H) can be equated as:

$$Q = C_d H^n \tag{1}$$

Dividing equation 1 by the crest length (L) results in the unit discharge form,

$$q = Q/L = (C_d/L)H^n \tag{1a}$$

letting

$$c = C_d/L$$

then

$$Q = qL = cLH^n \tag{1b}$$

Four-Foot Weir Calibrations

The calibration curve for the 4-foot box with flow over a stop plank tongue acting as a weir blade is shown on figure 6. The least square fit equations are

$$Q = 12.74 H_1^{1.381} \tag{2}$$

$$Q = 3.493 L H_1^{1.381} \tag{2a}$$

where:

H_1 = upstream head measured at the staff gauge.

The correlation coefficient for these equations is 0.9985 and the standard deviation (σ) is 1.8 percent discharge. Percent discharge was calculated as

$$Q_{\%} = 100\,[(Q_m - Q_e)/Q_m]$$

where:

Q_m = measured discharge.
Q_e = discharge based on least square fit equation.

Assuming a normal statistical distribution, 68.3 percent of the data points are expected to be within $\pm\sigma$, 95.4 percent to be within $\pm 2\sigma$ and 99.7 percent to be within $\pm 3\sigma$. The value of 3σ can be considered the maximum expected error. Any measured data pair that had a deviation greater than 3σ was considered to be a misreading and was removed from the least squares fit.

Rounding of weir blades has a considerable effect on accuracy. Ackers et al. (1978) found that at measuring heads of about 0.5 foot, the increase in the coefficient of discharge in percent is equal to the radius of rounding in millimeters. Thus, the use of tongue-and-groove wood weirs is not generally recommended because of variations in milling and inevitable damage and wear in time.

A method of incorporating metal blades is shown on figure 7. The metal blades could be used for weir or orifice configurations and still allow the tongue-and-groove to seal for shutting off the flow.

The equations for the metal-edged weir blade in a 4-foot box are

$$Q = 12.18H_1^{1.441} \tag{3}$$

$$Q = 3.340LH_1^{1.441} \tag{3a}$$

The correlation coefficient for this equation is 0.9984 and the standard deviation is 2.02 percent discharge. The calibration curve and measured data are shown on figure 2. Note that equation 3 is for one crest length (3.67 feet); therefore, equation 3a should be used to correct calibration for difference in crest length.

A comparison of calibrations between the sharp metal edge and the tongue plank edge indicates the sharp edge metal weir delivers about 10 percent less discharge than the plank tongue weir blade at the same head.

To investigate the sensitivity of weir discharge measurements to both precision of head measurement and zero elevation setting, equation 3 was used to compute discharge errors. For a zero or head reading error of one-half the minimum staff gauge division or ± 0.005 foot, the discharge error varies from ± 1 to ± 4 percent as head varies from 0.6 to 0.2 foot. Over the same head range, assuming the head reading or staff gauge zero is off ± 0.01 foot, additional errors in discharge ranging from ± 2.5 to ± 7 percent occur.

Six-Foot Metal Weir

The 2/3 scale model of a weir with a center rail support in a 6-foot box was calibrated similar to the 4-foot version. The influence of the support rail on the discharge calibration was determined by conducting flow calibrations with and without the rail in place (fig. 3). Within experimental error the rail was not found to affect the calibration. The best fit equations are

$$Q = 18.71H^{1.402} \tag{4}$$

$$Q = 3.30LH^{1.402} \tag{4a}$$

Note that equation 4 is for one crest length (5.70 feet). The correlation coefficient is 0.9993 and the standard deviation is 1.89 percent.

Equation 4a compares closely to equation 3a and since the 6-foot box is from model data where experimental errors are amplified by the scale ratio along with other possible minor scale effects, it is recommended that equation 3a be used for all sizes of weirs.

ORIFICE CALIBRATIONS

Conditions for standard orifices specified in the Water Measurement Manual (Bureau of Reclamation, 1981 reprint) are:

- The orifice blade should be at least two minimum orifice dimensions from all approach flow boundaries.
- The approach flow area should be at least eight times the orifice area.
- The velocity of approach should be less than 0.5 ft/s.
- The downstream submergence head (measured from the top orifice edge) should be greater than two minimum orifice dimensions.

As with weirs, these standard requirements can only be relaxed at the expense of defining more complicated equations with variable discharge coefficients, obtaining specific site and geometry calibrations and making velocity of approach corrections.

Submerged Orifice Theory

Rouse (1950) shows that the energy equation can be used to derive an approximate general orifice equation as follows

$$Q = C_c bL[2g(\Delta H + V_1^2/2g)]^{1/2} \tag{5}$$

where:

ΔH = $(H_1 - H_2)$.
H_1 = upstream measuring orifice head relative to orifice bottom
H_2 = submergence head relative to orifice bottom.
V_1 = approach velocity.
g = acceleration of gravity, 32.2 ft/s^2.
b = opening between planks.

L	=	length of orifice.
C_c	=	coefficient of contraction.

The coefficient of contraction, C_c, and the approach flow velocity head, $V_1^2/2g$, are governed by the flow geometry. These can be combined into a coefficient of discharge, C_d, where:

$$C_d = \phi(H_1/b,\ H_2/b) \qquad (6)$$

Equation 5 can then be rewritten as:

$$Q = C_d bL(2gH_1)^{1/2} \qquad (7)$$

Four-Foot Box Tests Using Tongue-and-groove Planks as Orifice Edges

Generalized calibration curves were developed from test data measured using three typical orifice configurations. Two 3-inch orifice geometries were tested, one with its bottom orifice edge 3.5 inches from and the other 8 inches from the invert of the box. The third orifice geometry was a 6-inch orifice located 8 inches above the box invert.

Tests of each orifice geometry were conducted at constant discharges equal to 1, 3/4, 1/2, and 1/4 boxes of water (6.68 ft^3/s). For each nominal discharge, the submergence head was reduced in increments and both the upstream and submergence head were measured. A typical plot of upstream head versus submergence head for a 3-inch opening is shown on figure 8. For high upstream and submergence heads, the curves approximate 45° lines; however, as the downstream water surface approaches the top of the orifice, it becomes influenced by the orifice jet. The curves then bulge towards the ordinate and then drop nearly vertical. The horizontal lines shown represent constant values of (H_2/b), one of the parameters of equation 6.

To develop coefficient of discharge curves, where the horizontal (H_2/b) lines (fig. 8) intersect the head curves the approach heads (H_1/b) are read from the abscissa. The corresponding discharge is interpolated between the associated venturi discharge measurements. Coefficient of discharge values can then be calculated and plotted against (H_1/b) for constant values of (H_2/b) (fig. 4). The data measured from the different orifice geometries tested plot within the scatter of each other. Therefore, the solutions to equation 6 as given on figure 4 can be applied as general submerged orifice calibrations for different orifice openings provided the orifice is located at least one orifice height above the approach box invert. The C_d values presented on figure 4 will apply to water boxes of similar geometry but different widths.

Coefficient of discharge values can be presented in tables or directly calculated by performing a least squares fit of the dimensionless submerged orifice parameters. The coefficient of discharge curves for each submergence value of (H_2/b) on figure 4 were fitted by least squares. The calibration of orifice control below radial gates could be approximated by a conic section of elliptical form (Buyalski, 1983). The conic form of the equation is

$$x^2 + y^2 = E^2(D + x)^2 \qquad (8)$$

where:

x = the horizontal distance measured from the focus to the locus of point p.
y = the vertical distance measure from the focus to the locus of p.
E = the eccentricity equal to the ratio (r/d) (fig. 9).
D = the directrix equal to a constant distance measured from a fixed reference line to the focus.

Replacing x and y with the orifice calibration parameters given on figure 9 and solving for C_d, equation 8 becomes

$$C_d = \{E^2[D+(H_1/b-F)]^2 - (H_1/b-F)^2\}^{1/2} \tag{9}$$

where:

$$F = H_2/b + E*D/(1+E) \tag{10}$$

The best fit values for (E) and (D) were found by a trial and error method (Box et al., 1978) based on calculating the variance of measured (C_d) values relative to calculated (C_d) values on a (E) versus (D) grid. After the variance was calculated for all grid intersection points, the center of the grid was adjusted to the minimum variance and the spread of the grid was reduced to increase resolution. This iterative process was repeated until increasing the grid resolution did not significantly alter the minimum variance. The mean standard deviation of the least square fit curves is 0.01 with a maximum of 0.02 and a minimum of 0.004. A plot of the curves and a table of (H2/b), (E), and (D) values are given on figure 4.

Six-Foot Box Orifice Tests With Tongue-and-Groove Planks

Tongue-and-groove orifice calibration data were also obtained with a 2/3 scale model of the 6-foot box orifice both with and without the center supporting rail track. Comparison of coefficients with and without the rail, assuming no change in orifice area due to the track, indicated that there was no significant effect of the rail on discharge. Comparing the 6-foot box coefficient data to the 4-foot calibrations on figure 4 indicates a shift of about +0.4 inch in the value of H1/b. It is believed that variation in the board milling and the projection of the slot relative to the length of opening contributed to the shift.

Metal-Edged Orifice Tests in 4-foot Box

The metal orifice was calibrated in the same manner as for the tongue-and-groove orifice. However, based on the previous test results only one orifice opening and elevation was considered necessary to determine the functional form of equation 5. Values of E and D for use in equation 8 are given for sharp-edged orifices on figure 1. The dashed line curving down and to the right is a suggested lower limit of long-term use because of difficulty of interpolating within the steep part of the (H_2/b) curves. As the curves become steeper at low values of (H_2/b) it is recommended that orifice geometries resulting in values of (H2/b) below 2 not be used.

From the dimensionless orifice plots, a relative comparison of discharge capacity under equivalent head conditions between the tongue-and-groove orifice and the sharp-edged orifice was determined.

The tongue-and-groove orifice provides increased capacity from 9 to 22 percent over that of the sharp-edged orifice, averaging 13 percent over the applicable head ranges.

Six-Foot Box With Metal Orifice Tests

Data were also obtained for the 6-foot box with metal-edged orifice. These also showed a shift in the 6-foot dimensionless data when compared to data from the 4-foot box. The shift was less than found for the wood plank orifices and was in the opposite direction, -(H1/b) from four-foot curves. Since the 6-foot box test results are from model data where experimental errors are amplified by the scale ratio along with other possible minor scale effects, it is recommended that the 4-foot box calibration equations be used for all box sizes. Current metering could be used in the field to determine if a shift in the dimensionless calibration parameters does occur.

APPLICATIONS

To use the calibrations in this report the upstream staff gauge (H_1) should be 2 feet from the stop planks for both weir and orifice measurements. For the orifice measurements the downstream staff gauge (H_2) should be in the delivery channel 3 feet downstream from the end of the side walls. The outside face of the spacer blocks and the edges of their rods should be in line and parallel to the plank slot projections.

A visual average of the staff gauge reading should be made and compared to a calculated average of observed high and low readings. Head should be estimated to at least one-half of the smallest staff gauge division or 0.005 foot. If the flow in the main supply canal is high, the water surface across the crest should be checked for level. A staff gauge on both of the approach side walls or at least a reference line above the high water line on the opposite side of the approach channel to make this check may be required. If staff gauge readings on opposing sides at a (H_1) distance from the planks differ by less than 0.02 foot they should be averaged. Differences of greater than 0.02 should be corrected by improving the approach conditions by installing turning and blocking baffles. The location and deflection angle of the baffles should be set by trial and checking that the depth of flow is relatively constant across the box width in front of the crest.

Typically weirs with good side ventilation can measure flow accurately with the downstream water level within 0.2 foot from the crest. However, the LCRA weirs do not exhibit adequate ventilation. The flow seals against the side slot projections at about 0.5 foot from crest elevation and therefore limits their use to downstream water levels 0.5 foot below the crest.

Sediment in front of shallow weirs or orifices (blade elevation less than 1 foot above the floor) can influence the discharge coefficient. The region in front of shallow measuring stations should be probed frequently to check for sediment deposits. Sediment deposits should be cleaned out to a distance equal to at least six deposit depths upstream from the measuring head staff gauge and the stop planks. Each time after the stop planks have been used to shut off the water for some period the lowest stop planks should be raised to sluice accumulated sediment through the box.

Rounding of orifice edges by poor machining or damage and wear will affect the discharge capacity. For example, Schuster (1970) cited a case of a 1-inch orifice that was rounded by 0.01 inch. The rounded edge resulted in a 3-percent increase of discharge. On a similar basis for a 3-inch orifice slot in a water box the discharge would increase 3 percent for each 1/32 inch radius of rounding.

Thus the use of wooden planks as blades is not recommended because of variation in the tongue-and-groove milling and inevitable damage and wear during use.

Submerged orifices are susceptible to plugging with weeds and other debris and may be difficult to see. Therefore, orifice boxes should be periodically checked for partial plugging and any debris removed.

The boxes should not be used for water measurement when operating with combined orifice and weir flow simultaneously. The back pressure under the weir nappe and on the orifice varies considerably with height of weir crest and orifice size and elevation.

As used in LCRA boxes, the weir and orifices are not standard water measuring devices. Thus they are lacking in terms of documented experience as measuring devices and quantity of field calibrations and checks that standard devices have. Therefore, it is recommended that careful current meter checks be made on the devices in the pilot project. It is recommended, especially during the early stages of the conversion program, that careful current meter checks be made for box sizes tested in the laboratory and those not tested. If consistent average deviation of discharge of 5 percent or more are apparent then the laboratory calibrations should be adjusted.

Orifice and weir lengths should be measured for each box after each setting of blade level as a precaution against construction errors, form slipping and walls being out of plumb. Measured values of blade length (L), not nominal length, should be used in the weir and orifice equations 3a and 7. Weir and orifice zero datums and orifice openings should be determined after the wood planks have become water saturated. The boxes should be checked routinely for tilting and shifting relative to the staff gauge.

BIBLIOGRAPHY

Ackers, P., et al., "Weirs and Flumes for Flow Measurement," John Wiley and Sons, 1978.

Box, G.E.P, et al., "Statistics for Experimenters," John Wiley and Sons, 1978.

Bureau of Reclamation, *Water Measurement Manual*," U.S. Department of Interior, 1967 Edition, 1981 Reprint.

Buyalski, C. P., "Discharge Algorithms for Canal Radial Gates," U.S. Department of Interior, Bureau of Reclamation, REC-ERC-83-9, 1983.

Rouse, H., Editor, "Engineering Hydraulics," John Wiley and Sons, 1950.

Schuster, J. C., Editor, "Water Measurement Procedures-Water Operators' Workshop," U.S. Department of Interior, Bureau of Reclamation, REC-OCE-70-38, 1970.

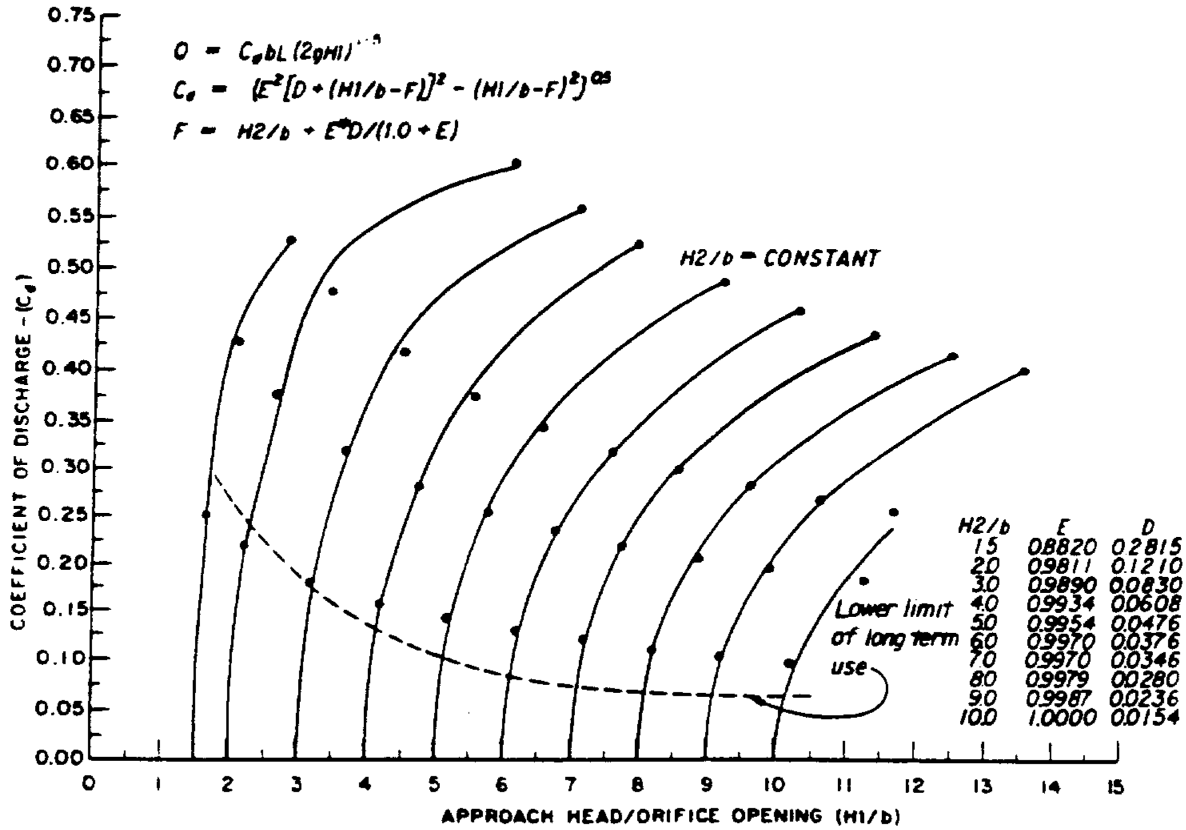


Figure 1. - Sharp-edged orifice water box calibration.

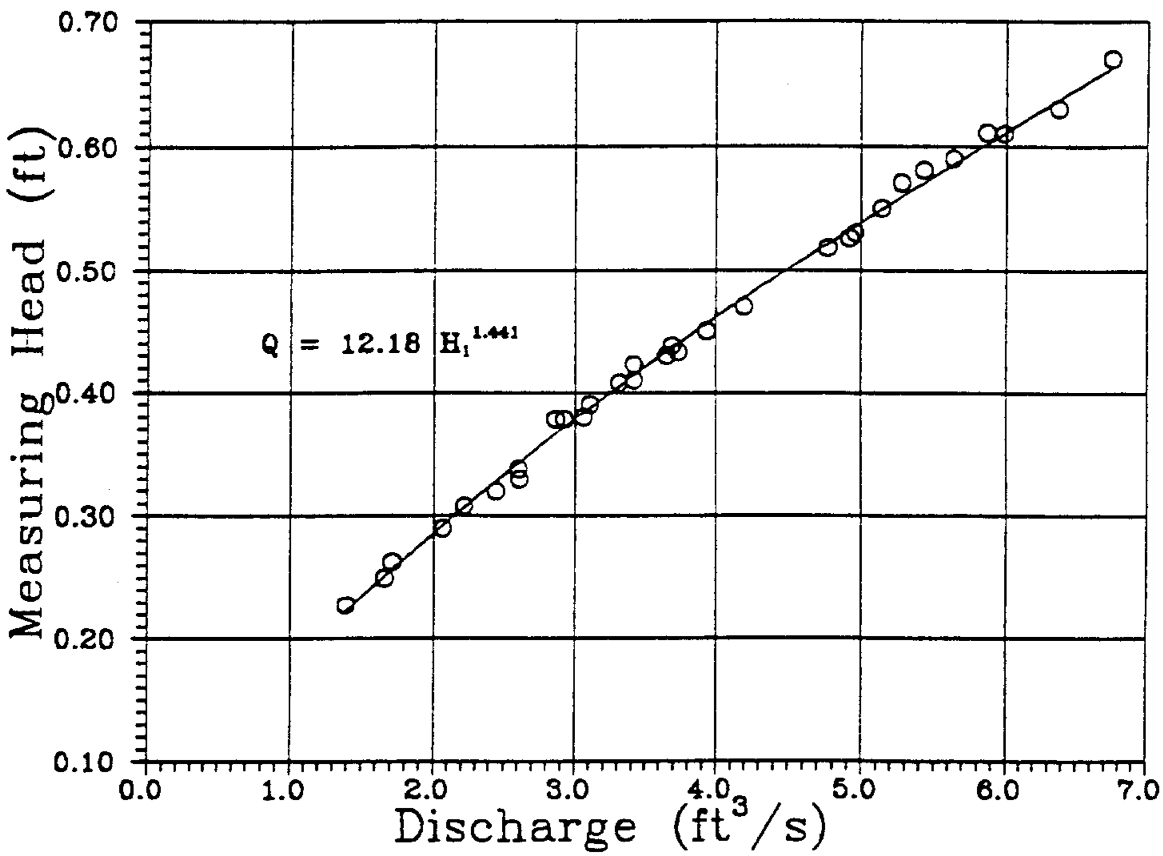


Figure 2. - Four-foot box metal-edged weir calibration.

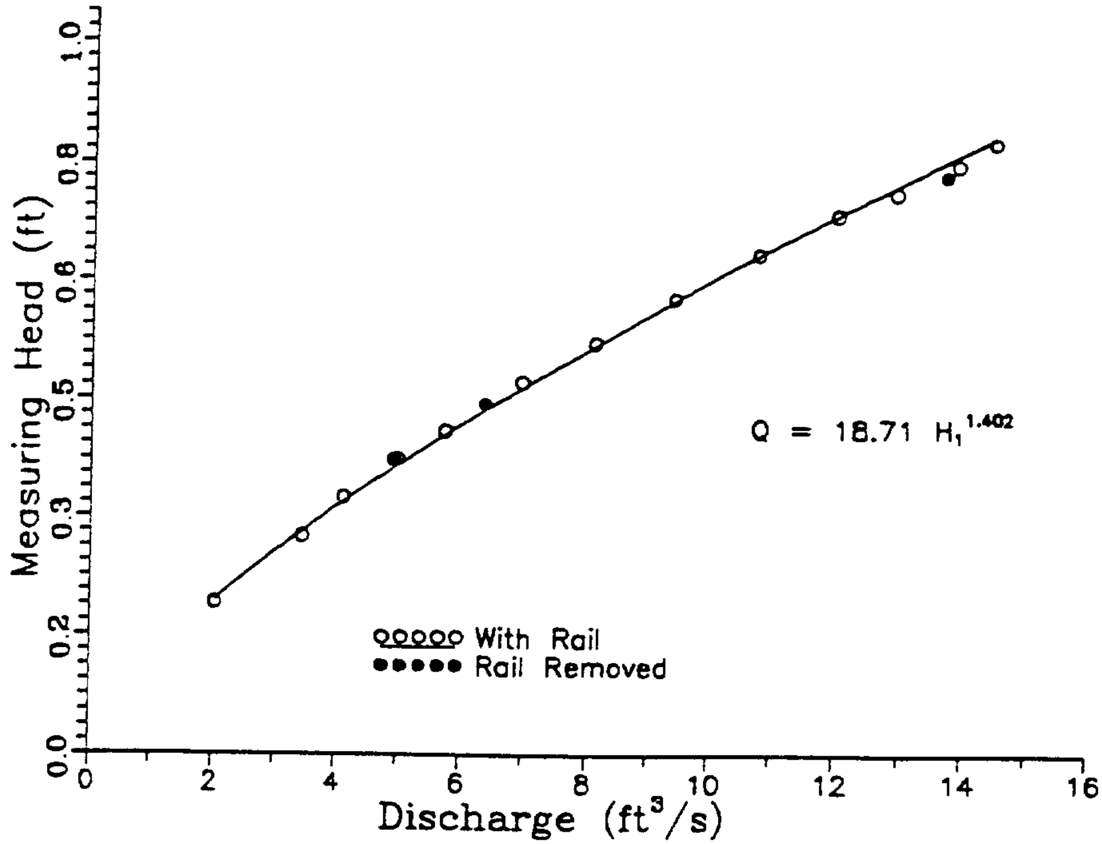


Figure 3. - Six-foot metal-edged weir calibration.

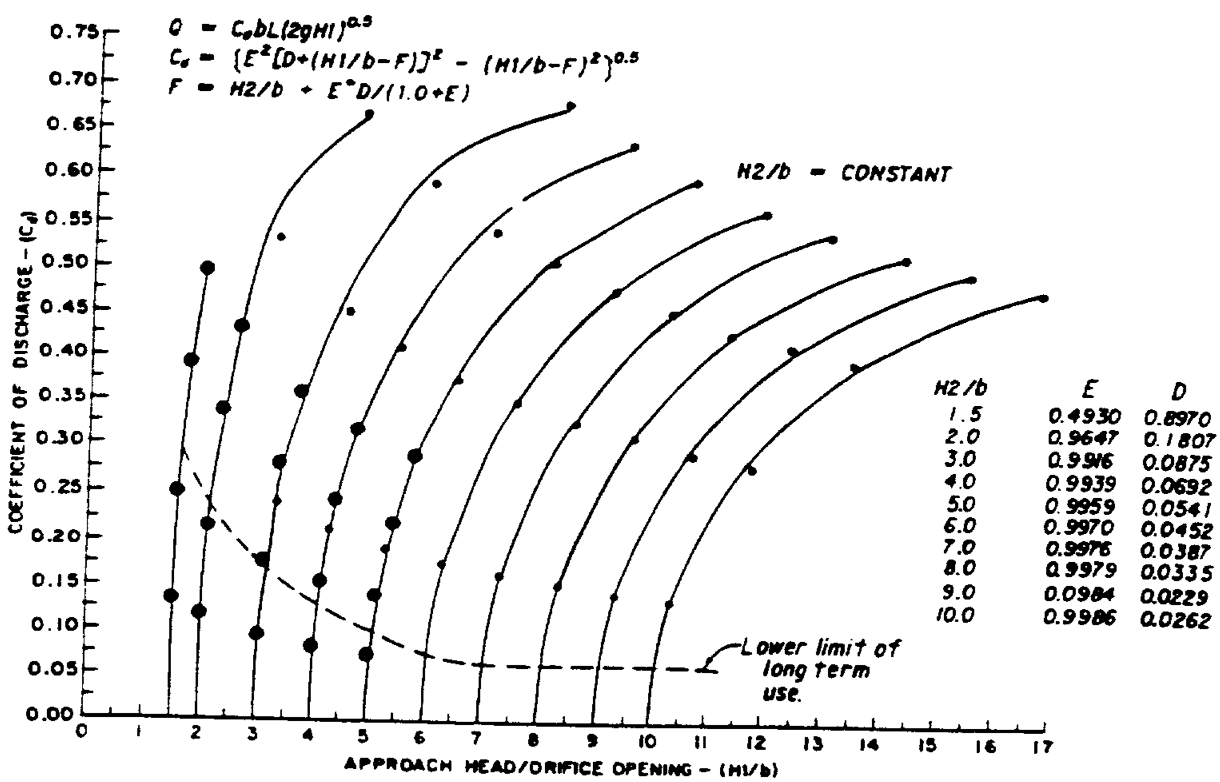


Figure 4. - Tongue-and-groove wood plank orifice water box calibration.

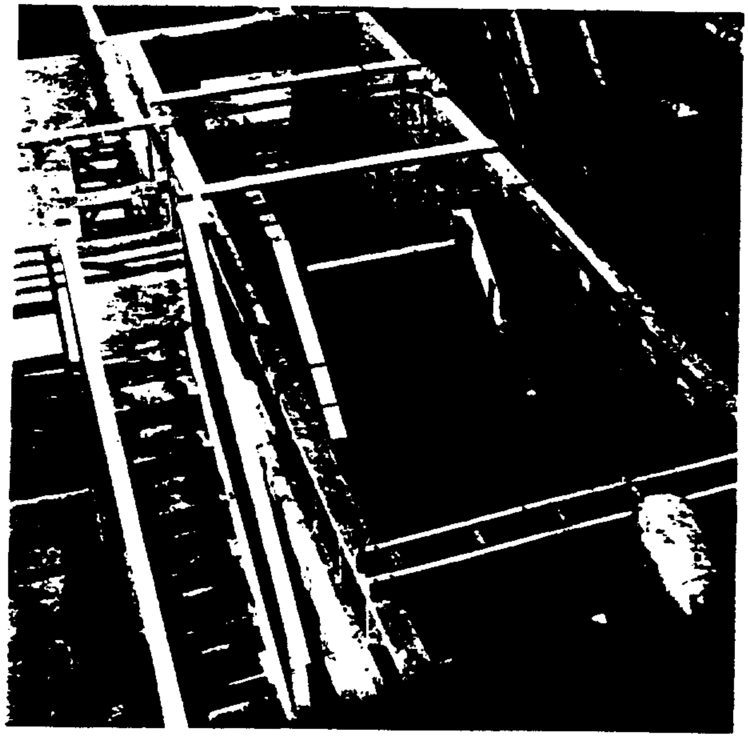


Figure 5. - Laboratory installation of water boxes.

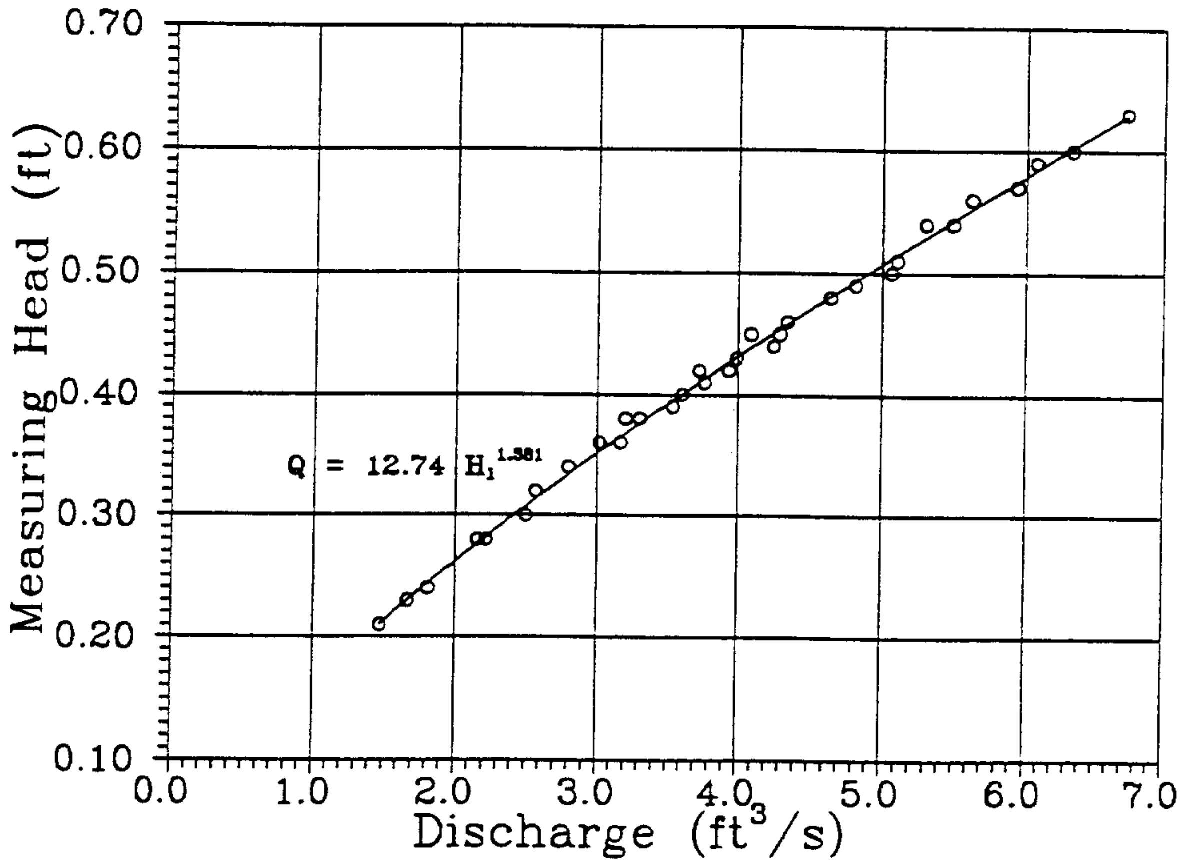


Figure 6. - Four-foot box tongue-and-groove weir calibration.

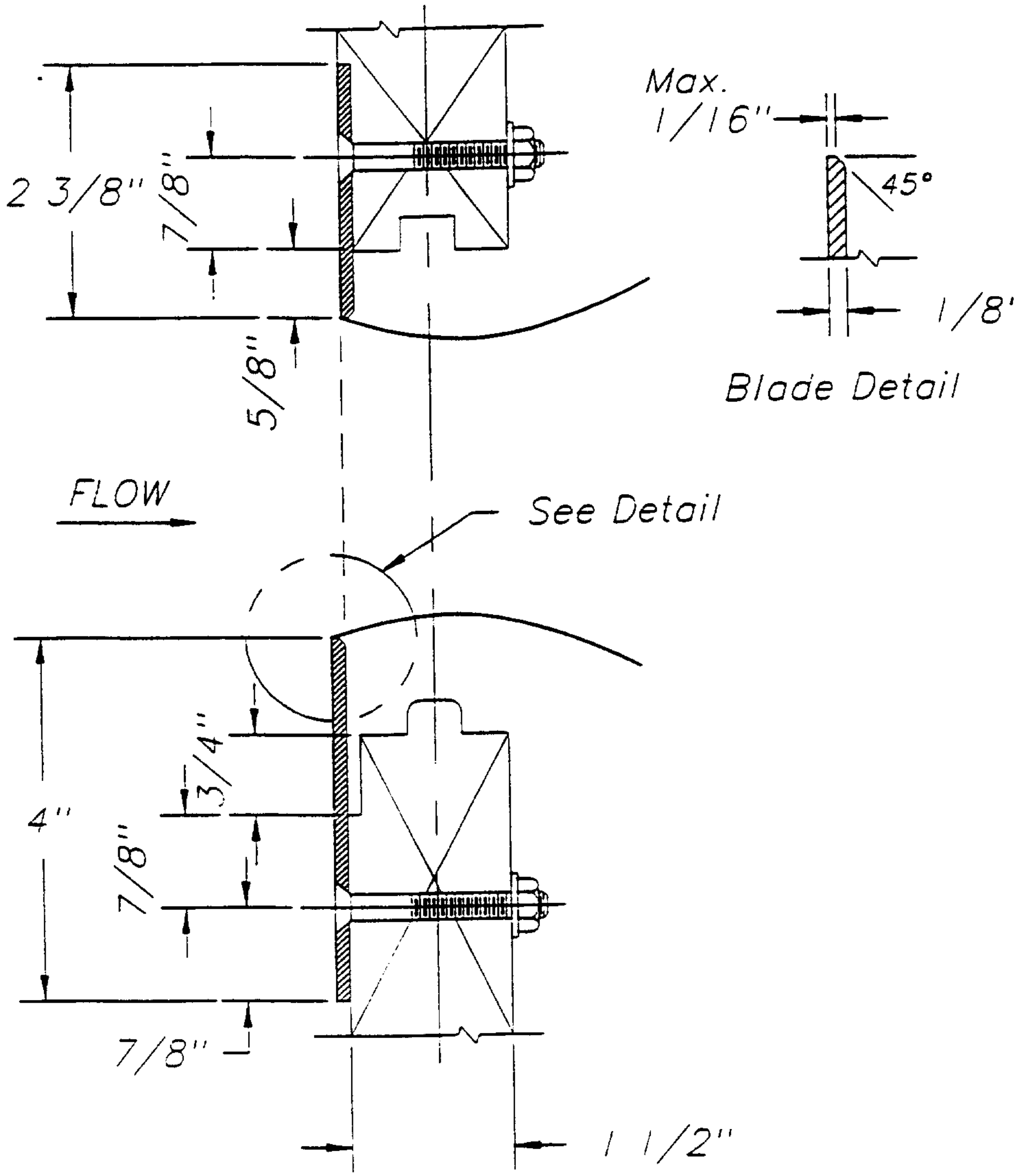


Figure 7. - Metal edges installed on tongue-and-groove planks.

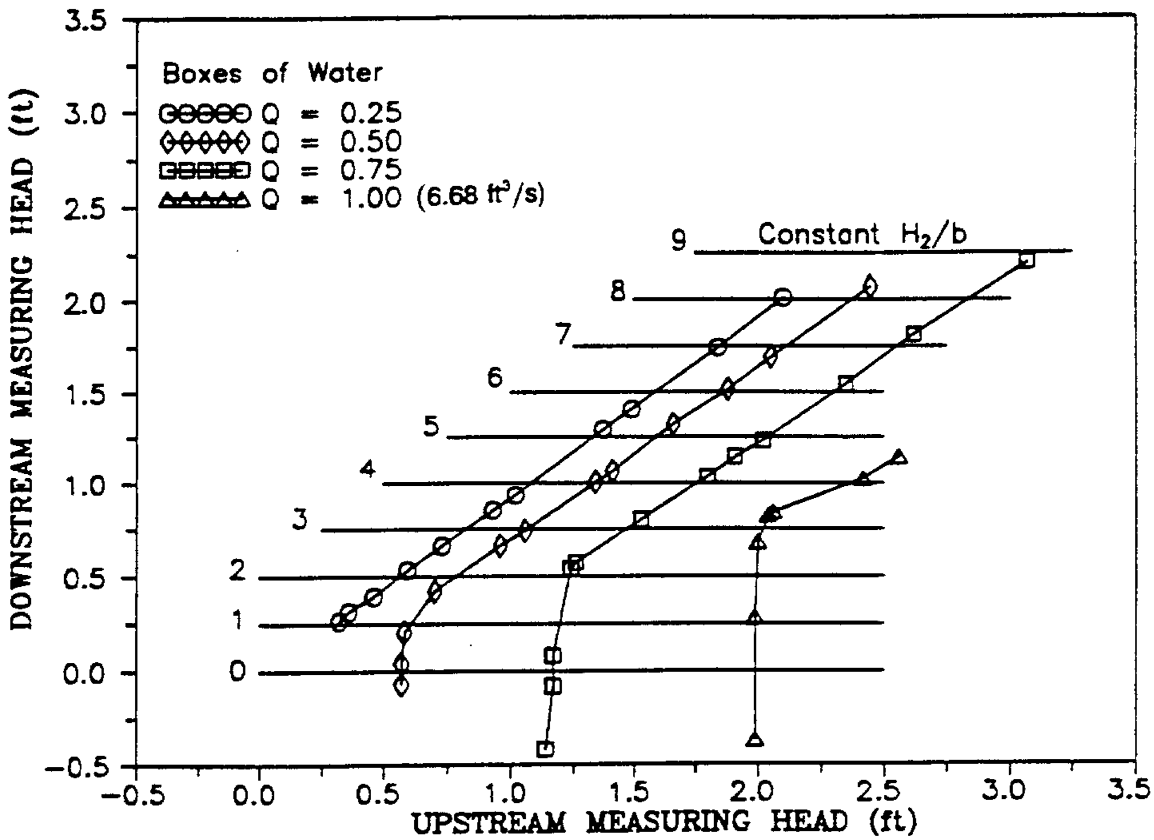


Figure 8. - Upstream head reading versus submergence head reading for a 3-inch orifice with discharge as third parameter.

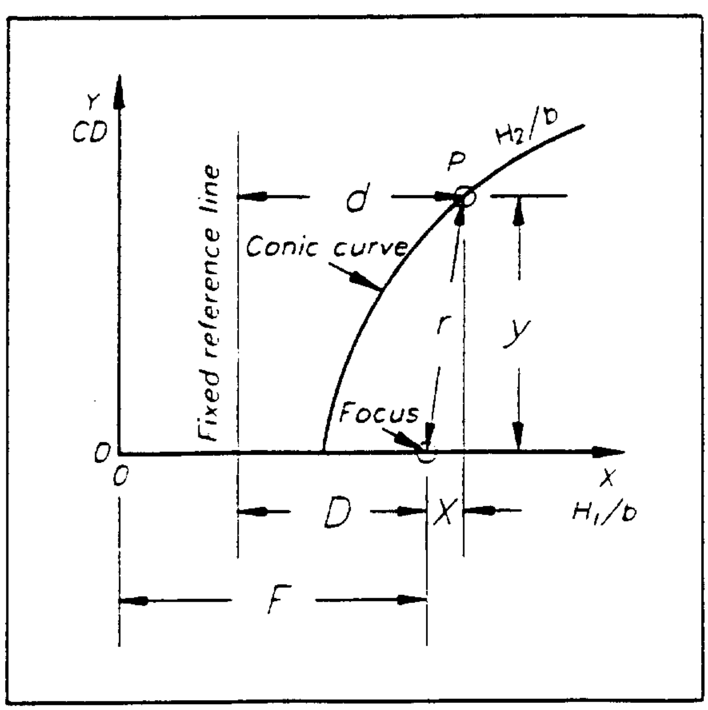


Figure 9. - Conic equation fit parameters.

* U.S GPO 1990 773-182/20,012

10952-101

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

Protecting Texas by Reducing and Preventing Pollution

JULY 11, 1994

CASTROVILLE, CITY OF
PO BOX 479
CASTROVILLE, TX 78009

Dear Permittee:

RE: PERMIT NO: WQ0010952-001
SOIL MONITORING (101) ANNUAL

THE RECORDS OF THE SELF-REPORTING SYSTEM INDICATE THAT WE HAVE NOT RECEIVED ANY REPORTS CONCERNING THE EFFLUENT QUALITY FROM THE WASTE TREATMENT FACILITY GOVERNED BY THE ABOVE-REFERENCED PERMIT FOR THE MONTH(S) OF SEPTEMBER, 1993

COMPLIANCE WITH RULES 30 TAC 319.1 - 319.11 OF THE TEXAS NATURAL RESOURCE CONSERVATION COMMISSION, IS A REQUIREMENT OF YOUR PERMIT. FAILURE TO SUBMIT THE PROPER REPORTS IS A VIOLATION OF THE COMMISSION RULES, THE PERMIT REFERENCED ABOVE AND THE TEXAS WATER CODE.

EFFECTIVE SEPTEMBER 1, 1985, THE TEXAS NATURAL RESOURCE CONSERVATION COMMISSION ASSUMED ENFORCEMENT RESPONSIBILITY PURSUANT TO SENATE BILL 249 FOR PROTECTION OF THE STATE'S WATER RESOURCES. ENFORCEMENT OPTIONS AVAILABLE INCLUDE COMPLIANCE ORDERS AND/OR ADMINISTRATIVE PENALTIES OF UP TO $10,000 PER DAY OR REFERRAL TO THE OFFICE OF THE ATTORNEY GENERAL FOR LITIGATION.

THEREFORE, YOU SHOULD COMPILE ANY AND ALL DELINQUENT REPORTS AND SUBMIT THEM AS REQUIRED. IF YOU HAVE PREVIOUSLY SUBMITTED THE REPORT(S), PLEASE SEND US A COPY FOR OUR RECORDS. WE SHOULD RECEIVE THE REPORT(S) BY JULY 29, 1994 . YOUR IMMEDIATE ATTENTION TO THIS MATTER WILL BE APPRECIATED. SHOULD YOU HAVE ANY QUESTIONS CONCERNING THIS LETTER, CONTACT ROSIE GARZA, WATERSHED MANAGEMENT, TEXAS NATURAL RESOURCE CONSERVATION COMMISSION, PHONE - 512/239-4574.

SINCERELY,

Jan Sills

JAN SILLS
PROGRAM SUPPORT ENFORCEMENT SECTION
WATERSHED MANAGEMENT SECTION

CC: TNRCC REGION 13 OFFICE

STATE PERMIT NO. 10952-01

TEXAS WATER COMMISSION
NO DISCHARGE WWTP - INSPECTION REPORT

PERMITTEE NAME	FACILITY NAME
City of Castroville	Castroville S.T.P.
PERMITTEE ADDRESS P.O. Box 479 Castroville, Texas 78009 Medina County	☑ DOMESTIC ☐ INDUSTRY - TYPE INSPECTION DATE: 6/25/92 — DISTRICT: 8

OFFICIALS	TITLE	CHECK IF CONTACTED	PHONE
Stevan Gallegos	City Administrator	☑	677-8110
Madelyn Koepp	Mayor	☐	" "
David McMillan	Director of Public Works	☑	" "
Fred Martinez	operator	☐	" "

A. TYPE TREATMENT PLANT AND DISPOSAL SYSTEM. Describe in brief terms and/or attach schematic.

The plant consists of one carrousel aeration basin, one clarifier, one oxidation ditch (utilized at clarifier), two oxidation ponds, sludge drying beds, wet well, standby generator and pumps. Effluent is pumped to two holding ponds on Ward Boehme's property and utilized for irrigation of pasture land.

B. INSPECTION SAMPLE RESULTS.

PARAMETER	MEASURED VALUE	PERMITTED VALUE	TYPE SAMPLE	COC TAG NO.	PRIMARY SOURCE OF WASTEWATER
Flow	0.335	0.350 MGD	Grab	MU 06191	Domestic
BOD	4	65 (mg/l)			
TSS	3	65 (mg/l)			
NH_3N	< 0.08 (mg/l)	–			
pH	8.0	6-9 range			
NO_3-N	13 (mg/l)	–			
D.O.	5.8 (mg/l)	–			

See Part F. for additional sample results

A.C.I.

C. HYDRAULIC LOADING. (For domestic WWTP only)

Has the plant reached 75 percent or greater of the permitted average daily flow for three consecutive months? ☐ Yes ☑ No If yes, has the permittee initiated engineering and financial planning for expansion/upgrading or requested a waiver from the Executive Director? ☐ Yes ☐ No

Has the plant reached 90 percent or greater of the permitted average daily flow for three consecutive months? ☐ Yes ☑ No If yes, has the permittee obtained necessary authorization from the Commission to commence construction of additional facilities or requested a waiver from the requirement to expand/upgrade? ☐ Yes ☐ No

Does the plant experience hydraulic overloading? ☐ Yes ☑ No If yes, is hydraulic overloading periodic or continuous? . Indicate the cause of hydraulic overloading and describe the permittee's corrective action.

D. SELF-MONITORING.

Does the permit specify self-monitoring frequencies? ☑ Yes ☐ No

Does the permittee use a commercial or in-house laboratory? Commercial . If an in-house lab is used, were any quality assurance deficiencies noted? ☐ Yes ☐ No If yes, explain.

Check the following statements and comment on "no" responses.

- ☑ Yes ☐ No Type of samples collected and measurements made conform to requirements.
- ☑ Yes ☐ No Samples are taken and measurements are made at required frequencies.
- ☑ Yes ☐ No Adequate records are maintained to document sample results.

Is the permittee complying with permit parameters as indicated by self-monitoring data? ☑ Yes ☐ No
If no, explain.

E. OPERATION AND MAINTENANCE.

1. *Operator(s).* Indicate the number of operators and certification level (for domestic WWTP only).
   One C ; One D

2. *Sludge Disposal.* Identify method of sludge disposal.
   Sludge drying beds

3. *Treatment Facilities.* Check the following statements and provide explanations. Use Attachment 3 for additional explanations if necessary.

Imhoff Tank ☐ Applicable ☑ N/A

a. ☐ Yes ☐ No — Cleaning of sides and slot adequate.
b. ☐ Yes ☐ No — Scum removal adequate.
c. ☐ Yes ☐ No — Sludge withdrawal adequate.

Ponds/Lagoons ☑ Applicable ☐ N/A

d. ☐ Yes ☑ No — Minimum freeboard maintained.
e. ☐ Yes ☑ No — Significant problems with sludge accumulation.
f. ☐ Yes ☑ No — Excessive growth of vegetation.

Irrigation System ☑ Applicable ☐ N/A

g. ☐ Yes ☑ No — Application rate satisfactory.
h. ☑ Yes ☐ No — Adequate tailwater control provided.
i. ☑ Yes ☐ No — Nuisance conditions reported or observed.
j. ☑ Yes ☐ No ☐ N/A — Compliant with chlorination/re-chlorination requirements.

Flow Measurement

k. ☑ Yes ☐ No — Flow measurement equipment adequate.

Other Facilities

l. ☑ Yes ☐ No — O&M deficiencies noted for other facilities.

Explanations: The District 8 office received an anonymous call concerning the City of Castroville discharging raw sewage on 6/18/92. Due to a backlog of work for the D-8 office an investigation was finally done on 6/25/92. →

No Discharge

During the investigation, Arthur Locke found the following deficiencies: 1) Oxidation pond no. 2 did not have adequate freeboard and was seeping out approximately < .25GPM over the spill-way. The investigator informed the Public Works director (David McMillon) that a minumum of two feet was required. Pond no. 2 had approximately 6 inches of freeboard at the spill-way.
2) The city has a no discharge permit but apparently water has been seeping into the adjacent drainage ditch thence to the Medina River. (See attached sample results). See comment sheet (attachment 4).

F. COMMENTS. Check the following areas if comments are warranted. Include comments in the space provided and use Attachment 4 for further explanations if necessary.

1.		Plant and/or disposal system modifications.
2.		Collection system or treatment facility bypasses.
3.		Special permit provisions.
4.		State compliance schedule: ☐ Schedule in effect. ☐ No schedule.
5.		Plans for expansion or major upgrading.
6.	✓	Other areas of interest or concern.

Comments: Effluent samples collected from pond #2 :
MU 06192 - B.O.D. - 12 (mg/l); T.S.S. - 20 (mg/l); NH_3N - 0.31 (mg/l);
NO_3-N - 2.45 (mg/l); pH - 9.5 - See attached results
D.O. - 19 (mg/l) - Water in pond was lime green in color.
Effluent being discharged into the Medina River:
MU 06193 - B.O.D. - <5 (mg/l); T.S.S. - 14 (mg/l); NH_3N - 0.06 (mg/l);
NO_3-N - 0.92 (mg/l); pH - 8.37; D.O. - 7.8 (mg/l).
Water color was slightly turbid.
(AL) (AL)

G. **FIELD OFFICE ACTION.** Describe action proposed or taken to address deficiencies or noncompliances.

Letter dated August 31, 1992 addressing deficiencies found during the inspection.

H. **CENTRAL OFFICE ACTION REQUESTED.**

None

District Manager [signature] for Billy H. Boggs

Investigator [signature]

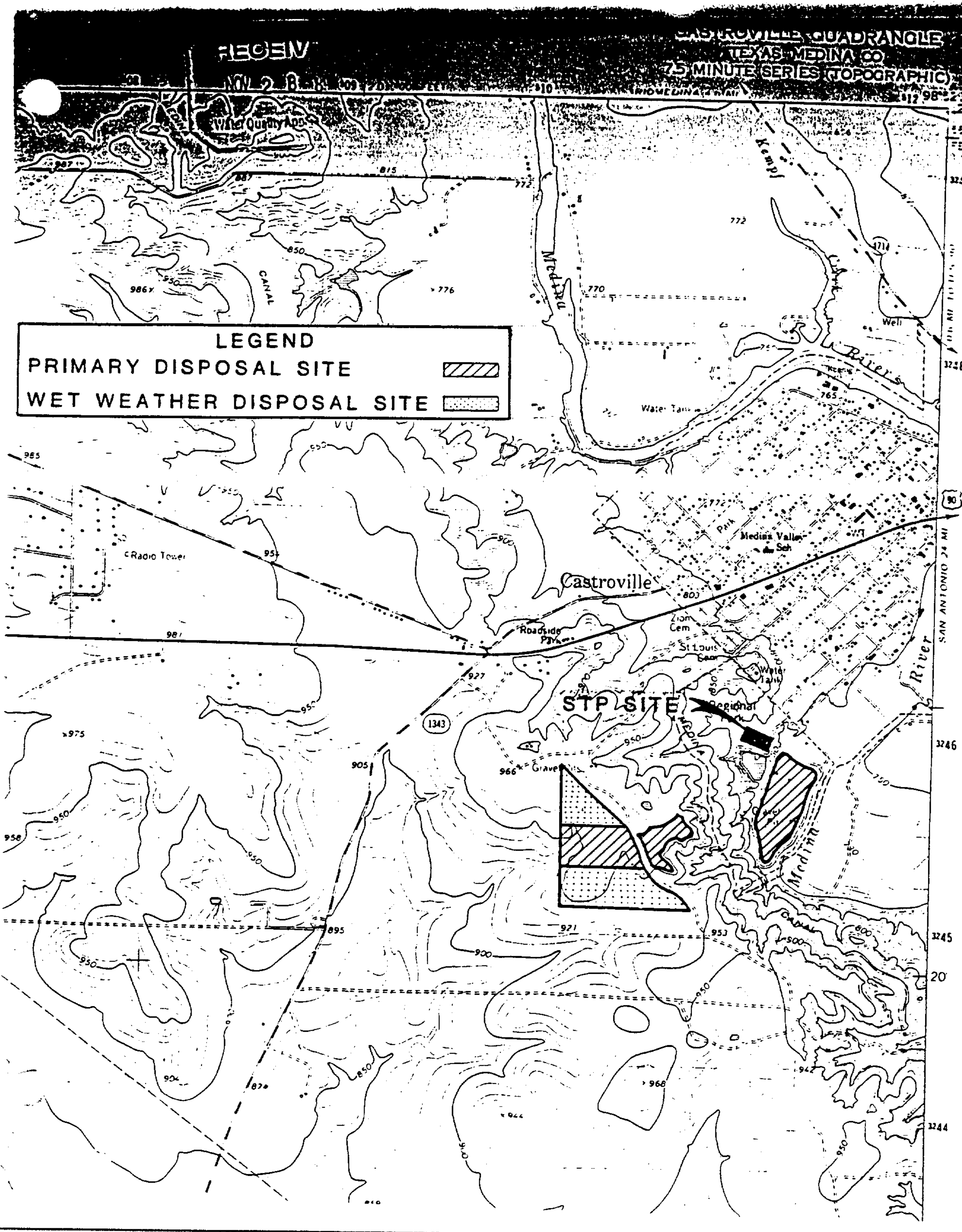
Signature Date 8/31/92

No Discharge

COMMENTS

3) The city needs to develop an operation and maintenance log, which should include: flows, sludge records, application rates on park, etc., maintenance problems etc. These records should be maintained at the plant site.

The water being discharged into the river was approximately 5 GPM. The additional flow was attributed to springs or BMA canal water seeping from the adjacent hills. See part F. for the sample results.


CASTROVILLE QUADRANGLE
TEXAS-MEDINA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
LEGEND
PRIMARY DISPOSAL SITE
WET WEATHER DISPOSAL SITE
Water Quality App
CANAL
Medina
Kempf
Creek
Well
Medina River
Water Tank
Radio Tower
Castroville
Park
Medina Valley Sch
Roadside Park
Zion Cem
St Louis Cem
Water Tank
STP SITE
Regional Park
1343
Gravel Pits
Medina
River
CANAL
SAN ANTONIO 24 MI

NET NATIONAL ENVIRONMENTAL TESTING, INC.

Austin Division
2621 Ridgepoint Drive
Suite 130
Austin, TX 78754
Tel: (512) 928-8905
Fax: (512) 928-3208

ANALYTICAL RESULTS REPORT
and
QUALITY CONTROL DATA REPORTS

John Ward
B-M-A
WCID #1
P.O. BOX 170
Natalia, TX 78059

10/18/1994

NET Job Number: 94.02731

Page 1

Project Description:
Job Description: SCS Water Quality Study

Enclosed are the Analytical Results and Quality Control Data Reports for the following samples submitted to NET, Inc. - Austin Division for analysis:

Sample Number	Sample Description	Date Taken	Time Taken	Date Received
109784	River	09/27/1994	09:27	09/27/1994

This Quality Control report is generated on a batch basis. All information contained in this report is for the analytical batch(es) in which your sample(s) were analyzed.

Project Manager

NOTE: Results apply only to the samples analyzed. Reproduction of this report is permitted only in its entirety.

OCEAN GROUP

NATIONAL ENVIRONMENTAL TESTING, INC.

Austin Division
2621 Ridgepoint Drive
Suite 130
Austin, TX 78754
Tel: (512) 928-8905
Fax: (512) 928-3208

ANALYTICAL RESULTS REPORT

John Ward
B-M-A
WCID #1
P.O. BOX 170
Natalia, TX 78059

10/18/1994

NET Job Number: 94.02731
Sample Number: 109784

Project Description:
Job Description: SCS Water Quality Study

Sample Description: River

Parameter	Flag	Result	Units	Analytical Method	Date Prepared	Date Analyzed	Analyst	Prep Batch Number	Run Batch Number	Reporting Limit
Alkalinity, bicarb (CACO3)		152	mg/L	E-310.1		09/30/1994	amr		174	1
BOD, Five Day		<2	mg/L	E-405.1		09/28/1994	ndk		418	2
Chloride		12	mg/L	E-325.3		09/30/1994	amr		235	1
Conductivity		390	umhos/cm	E-120.1		09/29/1994	amr		126	1
Fluoride		0.3	mg/L	E-340.2		09/30/1994	amr		163	0.1
Hardness, Total		96	mg/L	E-130.2		10/11/1994	amr		63	4
P[illegible] Ammonia, Aqueous		complete		E-350.2		09/30/1994	amr	45		
N-Ammonia		0.10	mg/L	E-350.2	09/30/1994	10/03/1994	amr	45	229	0.01
N-Kjeldahl		<0.50	mg/L	E-351.2		10/06/1994	mas		206	0.50
N-Nitrate		0.60	mg/L	SM-4500 D		10/03/1994	kmd		5	0.1
N-Nitrate/Nitrite		0.60	mg/L	SM-4500 D		10/03/1994	kmd		6	0.1
N-Nitrite		<0.01	mg/L	E-354.1		09/28/1994	kmd		224	0.01
N-Organic		<0.50	mg/L	E-354.1		10/10/1994	kmd		36	0.10
Oxygen, Dissolved		6.6	mg/L	E-360.1		09/27/1994	ndk		349	1.0
pH		7.3	units	E-150.1		09/28/1994	amr		804	0.1
Phosphorus, Total		0.17	mg/L	E-365.2		09/29/1994	kmd		170	0.03
Silica		3.3	mg/L	SM-4500-Si D		10/12/1994	kmd		41	0.01
Solids, Total Dissolved		251	mg/L	E-160.1		09/29/1994	amr		361	5
Sulfate, Turbidimetric		50	mg/L	E-375.4		10/04/1994	kmd		195	5
Prep, Dissolved Metals, ICP		complete		E-200.7		10/10/1994	dpp	1041		
Prep, Filtration 0.45 u		complete		ASTM D1094		10/10/1994	dpp		27	
Calcium, Dissolved, ICP		62.7	mg/L	E-200.7	10/10/1994	10/10/1994	dpp	1041	175	0.05
Magnesium, Dissolved, ICP		14.6	mg/L	E-200.7	10/10/1994	10/10/1994	dpp	1041	174	0.05
Potassium, Dissolved, ICP		2.2	mg/L	E-200.7	10/10/1994	10/10/1994	dpp	1041	157	0.50
Sodium, Dissolved, ICP		7.6	mg/L	E-200.7	10/10/1994	10/10/1994	dpp	1041	179	1.0

NET
NATIONAL ENVIRONMENTAL TESTING, INC.

Austin Division
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QUALITY CONTROL REPORT BLANKS

John Ward
B-M-A
WCID #1
P.O. BOX 170
Natalia, TX 78059

10/18/1994

NET Job Number: 94.02731

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	Blank Result	Units	Reporting Limit	Date Analyzed	Prep Batch Number	Run Batch Number
Alkalinity, bicarb (CACO3)		<1	mg/L	1	09/30/1994		174
BOD, Five Day		<2	mg/L	2	09/28/1994		418
Chloride		<1	mg/L	1	09/30/1994		235
Conductivity		<1	umhos/cm	1	09/29/1994		126
Fluoride		<0.1	mg/L	0.1	09/30/1994		163
Hardness, Total		<4	mg/L	4	10/11/1994		63
N-Ammonia		<0.01	mg/L	0.01	10/03/1994	45	229
N-Kjeldahl		<0.50	mg/L	0.50	10/06/1994		206
N-Nitrate		<0.1	mg/L	0.1	10/03/1994		5
N-Nitrate/Nitrite		<0.1	mg/L	0.1	10/14/1994		6
N-Nitrite		<0.01	mg/L	0.01	09/28/1994		224
pH		NA	units	0.1	09/28/1994		804
Phosphorus, Total		<0.03	mg/L	0.03	09/29/1994		170
Silica		<0.01	mg/L	0.01	10/12/1994		41
Solids, Total Dissolved		<5	mg/L	5	09/29/1994		361
Sulfate, Turbidimetric		<5	mg/L	5	10/04/1994		195

All parameters should be less than the reporting limit.

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QUALITY CONTROL REPORT
CONTINUING CALIBRATION VERIFICATION STANDARD

John Ward
B-M-A
WCID #1
P.O. BOX 170
Natalia, TX 78059

10/18/1994

NET Job Number: 94.02731

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	CCVS True Concentration	Units	CCVS Concentration Found	CCVS Percent Recovery	Date Analyzed	Run Batch Number
Alkalinity, bicarb (CACO3)		100	mg/L	100	100.0	09/30/1994	174
BOD, Five Day		198	mg/L	202	102.0	09/28/1994	418
Chloride		100	mg/L	98	98.0	09/30/1994	235
Conductivity		1,409	umhos/cm	1,302	92.4	09/29/1994	126
Fluoride		5.0	mg/L	5.0	100.0	09/30/1994	163
Hardness, Total		80	mg/L	80	100.0	10/11/1994	63
N-Ammonia		1.0	mg/L	1.01	101.0	10/03/1994	229
N-Kjeldahl		2.00	mg/L	2.17	108.5	10/06/1994	206
N-Nitrate		1.0	mg/L	1.09	109.0	10/03/1994	5
N-Nitrate/Nitrite		1.0	mg/L	1.09	109.0	10/14/1994	6
N-Nitrite		0.10	mg/L	0.10	100.0	09/28/1994	224
pH		4.0	units	4.0	100.0	09/28/1994	804
Phosphorus, Total		0.50	mg/L	0.48	96.0	09/29/1994	170
Silica		7.5	mg/L	7.4	98.7	10/12/1994	41
Sulfate, Turbidimetric		20	mg/L	20	100.0	10/04/1994	195
Calcium, Dissolved, ICP		100	mg/L	109	109.0	10/10/1994	175
Magnesium, Dissolved, ICP		25.0	mg/L	23.7	94.8	10/10/1994	174
Potassium, Dissolved, ICP		25.0	mg/L	26.5	106.0	10/10/1994	157
Sodium, Dissolved, ICP		100	mg/L	102	102.0	10/10/1994	179

CCVS - Continuing Calibration Verification Standard

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QUALITY CONTROL REPORT
MATRIX SPIKE/MATRIX SPIKE DUPLICATE

John Ward
B-M-A
WCID #1
P.O. BOX 170
Natalia, TX 78059

10/18/1994

NET Job Number: [illegible]94.02731

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	Units	Sample Result	Spike Amount Added	Matrix Spike Result	MS Percent Recovery	Duplicate Spike Amount Added	MSD Result	MSD Percent Recovery	MS/MSD RPD	Date Analyzed	Prep Batch Number	Run Batch Number
Alkalinity, bicarb (CACO3)		mg/L	268	100	368	100.0	100	368	100.0	0.0	09/30/1994		174
Chloride		mg/L	18	100	114	96.0	100	114	96.0	0.0	09/30/1994		235
Fluoride		mg/L	0.3	1.0	1.2	90.0	1.0	1.2	90.0	0.0	09/30/1994		163
Ha[illegible]ss, Total		mg/L	256	80	332	95.0	80	332	95.0	0.0	10/11/1994		63
N-[illegible]nia		mg/L	0.31	1.0	1.2	89.0	1.0	1.2	89.0	0.0	10/03/1994	45	229
N-Ammonia		mg/L	1.4	2.0	3.4	100.0	2.0	3.4	100.0	0.0	10/03/1994	45	229
N-Kjeldahl		mg/L	<0.50	0.50	0.52	104.0	0.50	0.57	114.0	9.2	10/06/1994		206
N-Nitrate		mg/L	0.68	1.0	1.55	87.0	1.0	1.48	80.0	8.4	10/03/1994		5
N-Nitrate/Nitrite		mg/L	50	10	58	80.0	10	59	90.0	11.8	10/14/1994		6
N-Nitrate/Nitrite		mg/L	1.9	1.0	3.1	120.0	1.0	3.0	110.0	8.7	10/14/1994		6
N-Nitrate/Nitrite		mg/L	0.60	1.0	1.55	95.0	1.0	1.43	83.0	13.5	10/03/1994		6
N-Nitrite		mg/L	0.29	0.50	0.77	96.0	0.50	0.76	94.0	2.1	09/28/1994		224
Phosphorus, Total		mg/L	0.17	0.50	0.72	110.0	0.50	0.73	112.0	1.8	09/29/1994		170
Silica		mg/L	9	75	84	100.0	75	77	90.7	9.7	10/12/1994		41
Silica		mg/L	33	75	96	84.0	75	96	84.0	0.0	10/12/1994		41
Sulfate, Turbidimetric		mg/L	875	500	1,500	125.0	500	1,500	125.0	0.0	10/04/1994		195
Sulfate, Turbidimetric		mg/L	50	20	65	75.0	20	65	75.0	0.0	10/04/1994		195
Sulfate, Turbidimetric		mg/L	50	20	65	75.0	20	65	75.0	0.0	10/04/1994		195
Calcium, Dissolved, ICP		mg/L	62.7	100	162	99.3	100	161	98.3	1.0	10/10/1994	1041	175
Magnesium, Dissolved, ICP		mg/L	14.6	100	106	91.4	100	104	89.4	2.2	10/10/1994	1041	174
Potassium, Dissolved, ICP		mg/L	2.2	110	112	99.8	110	113	100.7	0.8	10/10/1994	1041	157
Sodium, Dissolved, ICP		mg/L	7.6	100	107	99.4	100	106	98.4	1.0	10/10/1994	1041	179

NOTE: The Quality Control data in this report reflects the batch in which your sample was prepped and/or analyzed. The sample selected for QA may not necessarily be your sample.

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QUALITY CONTROL REPORT DUPLICATES

John Ward
B-M-A
WCID #1
P.O. BOX 170
Natalia, TX 78059

10/18/1994

NET Job Number: 94.02731

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	Units	Sample Result	Duplicate Sample Result	RPD	Date Analyzed	Prep Batch Number	Run Batch Number
BOD, Five Day		mg/L	180	180	0.0	09/28/1994		418
BOD, Five Day		mg/L	170	170	0.0	09/28/1994		418
BOD, Five Day		mg/L	115	121	5.1	09/28/1994		418
Conductivity		umhos/cm	360	360	0.0	09/29/1994		126
pH		units	7.7	7.7	0.0	09/28/1994		804
pH		units	7.2	7.2	0.0	09/28/1994		804
Solids, Total Dissolved		mg/L	503	502	0.2	09/29/1994		361
Solids, Total Dissolved		mg/L	440	434	1.4	09/29/1994		361

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QUALITY CONTROL REPORT
LABORATORY CONTROL STANDARD

John Ward
B-M-A
WCID #1
P.O. BOX 170
Natalia, TX 78059

10/18/1994

NET Job Number: 94.02731

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	LCS True Concentration	LCS Concentration Found	LCS Percent Recovery	Date Analyzed	Prep Batch Number	Run Batch Number
N-Ammonia		1.0	0.99	99.0	10/03/1994		229
N-Kjeldahl		2.00	2.17	108.5	10/06/1994		206
Phosphorus, Total		0.50	0.50	100.0	09/29/1994		170
Phosphorus, Total		0.50	0.50	100.0	09/29/1994		170
Solids, Total Dissolved		100	97	97.0	09/29/1994		361

LCS - Laboratory Control Standard

For samples with insufficient sample volume, an LCS/LCS duplicate is reported instead of an MS/MSD.

NATIONAL ENVIRONMENTAL TESTING, INC.

CHAIN OF CUSTODY RECORD

COMPANY B-M-A WC+ID #1
ADDRESS P.O. Box 170
PHONE Natalia TX 78059 FAX
phone (210) 665 2132
fax (210) 663-3519
PROJECT NAME/LOCATION SCS Water Quality Study
PROJECT NUMBER
PROJECT MANAGER Douglas Hearn

REPORT TO: Johnny Ward
INVOICE TO:
P.O. NO.
NET QUOTE NO.

SAMPLED BY Douglas Hearn (PRINT NAME) — SIGNATURE Douglas Hearn
(PRINT NAME) — SIGNATURE

						# and Type of Containers					ANALYSES: See Attached										COMMENTS
9/27	9:27	River							6												Copy to Douglas Hearn @ Blackwell
																					add pH & cond as per Doug Hearn 9-27

CONDITION OF SAMPLE: BOTTLES INTACT? YES / NO FIELD FILTERED? YES / NO
COC SEALS PRESENT AND INTACT? YES / NO VOLATILES FREE OF HEADSPACE? YES / NO
TEMPERATURE UPON RECEIPT: On Ice
Bottles supplied by NET? YES / NO

SAMPLE REMAINDER DISPOSAL: RETURN SAMPLE REMAINDER TO CLIENT VIA
I REQUEST NET TO DISPOSE OF ALL SAMPLE REMAINDERS ______ DATE ______

RELINQUISHED BY:	DATE/TIME	RECEIVED BY:	RELINQUISHED BY:	DATE/TIME	RECEIVED FOR NET BY:
Douglas Hearn	9/27/94 5:12				Debby Skogen

METHOD OF SHIPMENT

REMARKS:

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ANALYTICAL RESULTS REPORT
and
QUALITY CONTROL DATA REPORTS

John Ward
B-M-A
WCID #1
P.O. BOX 170
Natalia, TX 78059

10/12/1994

NET Job Number: 94.02732

Page 1

Project Description:
Job Description: SCS Water Quality Study

Enclosed are the Analytical Results and Quality Control Data Reports for the following samples submitted to NET, Inc. - Austin Division for analysis:

Sample Number	Sample Description	Date Taken	Time Taken	Date Received
109785	Ingram	09/27/1994	12:45	09/27/1994
109786	A-5	09/27/1994	13:30	09/27/1994
109787	Siphon 5	09/27/1994	10:53	09/27/1994
109788	FM 2790	09/27/1994	14:20	09/27/1994
109789	Hwy. 90	09/27/1994	10:46	09/27/1994

This Quality Control report is generated on a batch basis. All information contained in this report is for the analytical batch(es) in which your sample(s) were analyzed.

Project Manager

NOTE: Results apply only to the samples analyzed. Reproduction of this report is permitted only in its entirety.

OCEAN GROUP

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ANALYTICAL RESULTS REPORT

John Ward
B-M-A
WCID #1
P.O. BOX 170
Natalia, TX 78059

10/12/1994

NET Job Number: 94.02732
Sample Number: 109785

Project Description:
Job Description: SCS Water Quality Study

Sample Description: Ingram

Parameter	Flag	Result	Units	Analytical Method	Date Prepared	Date Analyzed	Analyst	Prep Batch Number	Run Batch Number	Reporting Limit
Conductivity		380	umhos/cm	E-120.1		09/29/1994	amr		126	1
Oxygen, Dissolved		7.7	mg/L	E-360.1		09/27/1994	ndk		349	1.0
pH		7.4	units	E-150.1		09/28/1994	amr		804	0.1
Solids, Total Suspended		84	mg/L	E-160.2		09/29/1994	amr		341	1
Turbidity		38	NTU	E-180.1		09/28/1994	kmd		47	0.01
Coliform, fecal		400	/100 ml	S-9222D		09/27/1994	cpc		89	0

NET® NATIONAL ENVIRONMENTAL TESTING, INC.

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ANALYTICAL RESULTS REPORT

John Ward
B-M-A
WCID #1
P.O. BOX 170
Natalia, TX 78059

10/12/1994

NET Job Number: 94.02732
Sample Number: 109786

Project Description:
Job Description: SCS Water Quality Study

Sample Description: A-5

Parameter	Flag	Result	Units	Analytical Method	Date Prepared	Date Analyzed	Analyst	Prep Batch Number	Run Batch Number	Reporting Limit
Conductivity		400	umhos/cm	E-120.1		09/29/1994	amr		126	1
Oxygen, Dissolved		8.7	mg/L	E-360.1		09/27/1994	ndk		349	1.0
pH		7.6	units	E-150.1		09/28/1994	amr		804	0.1
Solids, Total Suspended		62	mg/L	E-160.2		09/29/1994	amr		341	1
Turbidity		34	NTU	E-180.1		09/28/1994	kmd		47	0.01
Coliform, fecal		200	/100 ml	S-9222D		09/27/1994	cpc		89	0

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ANALYTICAL RESULTS REPORT

John Ward
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WCID #1
P.O. BOX 170
Natalia, TX 78059

10/12/1994

NET Job Number: 94.02732
Sample Number: 109787

Project Description:
Job Description: SCS Water Quality Study

Sample Description: Siphon 5

Parameter	Flag	Result	Units	Analytical Method	Date Prepared	Date Analyzed	Analyst	Prep Batch Number	Run Batch Number	Reporting Limit
Conductivity		360	umhos/cm	E-120.1		09/29/1994	amr		126	1
Oxygen, Dissolved		8.3	mg/L	E-360.1		09/27/1994	ndk		349	1.0
pH		7.5	units	E-150.1		09/28/1994	amr		804	0.1
Solids, Total Suspended		7	mg/L	E-160.2		09/29/1994	amr		341	1
Turbidity		5.5	NTU	E-180.1		09/28/1994	kmd		47	0.01
Coliform, fecal		144	/100 ml	S-9222D		09/27/1994	cpc		89	0

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ANALYTICAL RESULTS REPORT

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10/12/1994

NET Job Number: 94.02732
Sample Number: 109788

Project Description:
Job Description: SCS Water Quality Study

Sample Description: FM 2790

Parameter	Flag	Result	Units	Analytical Method	Date Prepared	Date Analyzed	Analyst	Prep Batch Number	Run Batch Number	Reporting Limit
Conductivity		410	umhos/cm	E-120.1		09/29/1994	amr		126	1
Oxygen, Dissolved		5.6	mg/L	E-360.1		09/27/1994	ndk		349	1.0
pH		7.3	units	E-150.1		09/28/1994	amr		804	0.1
Solids, Total Suspended		21	mg/L	E-160.2		09/29/1994	amr		341	1
Turbidity		12.9	NTU	E-180.1		09/28/1994	kmd		47	0.01
Coliform, fecal		13,500	/100 ml	S-9222D		09/27/1994	cpc		89	0

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ANALYTICAL RESULTS REPORT

John Ward
B-M-A
WCID #1
P.O. BOX 170
Natalia, TX 78059

10/12/1994

NET Job Number: 94.02732
Sample Number: 109789

Project Description:
Job Description: SCS Water Quality Study

Sample Description: Hwy. 90

Parameter	Flag	Result	Units	Analytical Method	Date Prepared	Date Analyzed	Analyst	Prep Batch Number	Run Batch Number	Reporting Limit
Conductivity		390	umhos/cm	E-120.1		09/29/1994	amr		126	1
Oxygen, Dissolved		8.0	mg/L	E-360.1		09/27/1994	ndk		349	1.0
pH		7.5	units	E-150.1		09/28/1994	amr		804	0.1
Solids, Total Suspended		6	mg/L	E-160.2		09/29/1994	amr		341	1
Turbidity		5.5	NTU	E-180.1		09/28/1994	kmd		47	0.01
Coliform, fecal		128	/100 ml	S-9222D		09/27/1994	cpc		89	0

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QUALITY CONTROL REPORT
BLANKS

John Ward
B-M-A
WCID #1
P.O. BOX 170
Natalia, TX 78059

10/12/1994

NET Job Number: 94.02732

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	Blank Result	Units	Reporting Limit	Date Analyzed	Prep Batch Number	Run Batch Number
Conductivity		<1	umhos/cm	1	09/29/1994		126
pH		NA	units	0.1	09/28/1994		804
Solids, Total Suspended		<1	mg/L	1	09/29/1994		341
Turbidity		<0.01	NTU	0.01	09/28/1994		47

All parameters should be less than the reporting limit.

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QUALITY CONTROL REPORT
CONTINUING CALIBRATION VERIFICATION STANDARD

John Ward
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WCID #1
P.O. BOX 170
Natalia, TX 78059

10/12/1994

NET Job Number: 94.02732

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	CCVS True Concentration	Units	CCVS Concentration Found	CCVS Percent Recovery	Date Analyzed	Run Batch Number
Conductivity		1,409	umhos/cm	1,302	92.4	09/29/1994	126
pH		4.0	units	4.0	100.0	09/28/1994	804
Turbidity		18	NTU	18	100.0	09/28/1994	47

CCVS - Continuing Calibration Verification Standard

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QUALITY CONTROL REPORT DUPLICATES

John Ward
B-M-A
WCID #1
P.O. BOX 170
Natalia, TX 78059

10/12/1994

NET Job Number: 94.02732

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	Units	Sample Result	Duplicate Sample Result	RPD	Date Analyzed	Prep Batch Number	Run Batch Number
Conductivity		umhos/cm	360	360	0.0	09/29/1994		126
pH		units	7.7	7.7	0.0	09/28/1994		804
pH		units	7.2	7.2	0.0	09/28/1994		804
Solids, Total Suspended		mg/L	29	29	0.0	09/29/1994		341
Solids, Total Suspended		mg/L	16	16	0.0	09/29/1994		341
Solids, Total Suspended		mg/L	2	2	0.0	09/29/1994		341
Turbidity		NTU	5.5	5.7	3.6	09/28/1994		47

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QUALITY CONTROL REPORT
LABORATORY CONTROL STANDARD

John Ward
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Natalia, TX 78059

10/12/1994

NET Job Number: 94.02732

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	LCS True Concentration	LCS Concentration Found	LCS Percent Recovery	Date Analyzed	Prep Batch Number	Run Batch Number
Solids, Total Suspended		100	103	103.0	09/29/1994		341

LCS - Laboratory Control Standard

For samples with insufficient sample volume, an LCS/LCS duplicate is reported instead of an MS/MSD.

NET NATIONAL ENVIRONMENTAL TESTING, INC.

CHAIN OF CUSTODY RECORD

COMPANY: B-M-A WC#10 #1

ADDRESS:

PHONE: FAX:

PROJECT NAME/LOCATION: SCS Water Quality Study

PROJECT NUMBER:

PROJECT MANAGER: Douglas Hearn

REPORT TO: Johnny Ward

INVOICE TO:

P.O. NO.

NET QUOTE NO.

SAMPLED BY: Douglas Hearn (PRINT NAME) — SIGNATURE: Douglas Hearn

(PRINT NAME) — SIGNATURE

DATE	TIME	SAMPLE ID/DESCRIPTION	MATRIX	GRAB	COMP	HCl	NaOH	HNO_3	H_2SO_4	OTHER	ANALYSES: See Attached	COMMENTS
9/27	12:45	Ingram							2	[illegible]	✓	Copy to Douglas Hearn
9/27	1:30	A-5								[illegible]	✓	
9/27	10:53	Siphon 5								3	✓	add pH & cond as
9/27	2:20	FM 2790								[illegible]	✓	per Doug Hearn 9-27.
9/27	10:46	Hwy 90								[illegible]	✓	
									DCH			

CONDITION OF SAMPLE: BOTTLES INTACT? YES / NO FIELD FILTERED? YES / NO

COC SEALS PRESENT AND INTACT? YES / NO VOLATILES FREE OF HEADSPACE? YES / NO

TEMPERATURE UPON RECEIPT: on ice

Bottles supplied by NET? YES / NO

SAMPLE REMAINDER DISPOSAL: RETURN SAMPLE REMAINDER TO CLIENT VIA ______

I REQUEST NET TO DISPOSE OF ALL SAMPLE REMAINDERS ______ DATE ______

RELINQUISHED BY:	DATE/TIME	RECEIVED BY:	RELINQUISHED BY:	DATE/TIME	RECEIVED FOR NET BY:
Douglas Hearn	9/27 5:15				Debby Skogen

METHOD OF SHIPMENT:

REMARKS:

PT 1 - ORIGINAL - WHITE PT 2 - NET PROJECT MANAGER - YELLOW PT 3 - CUSTOMER COPY - PINK

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ANALYTICAL RESULTS REPORT and QUALITY CONTROL DATA REPORTS

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733

Page 1

Project Description:
Job Description: SCS Water Quality Study

Enclosed are the Analytical Results and Quality Control Data Reports for the following samples submitted to NET, Inc. - Austin Division for analysis:

Sample Number	Sample Description	Date Taken	Time Taken	Date Received
109790	Chacon	09/27/1994	11:37	09/27/1994
109791	USGS	09/27/1994	10:18	09/27/1994
109792	Pearson	09/27/1994	11:25	09/27/1994
109793	Touchstone	09/27/1994	13:15	09/27/1994

This Quality Control report is generated on a batch basis. All information contained in this report is for the analytical batch(es) in which your sample(s) were analyzed.

Project Manager

NOTE: Results apply only to the samples analyzed. Reproduction of this report is permitted only in its entirety.

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ANALYTICAL RESULTS REPORT

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733
Sample Number: 109790

Project Description:
Job Description: SCS Water Quality Study

Sample Description: Chacon

Parameter	Flag	Result	Units	Analytical Method	Date Prepared	Date Analyzed	Analyst	Prep Batch Number	Run Batch Number	Reporting Limit
Chloride		24	mg/L	E-325.3		09/30/1994	amr		235	1
Chromium, hexavalent		<0.01	mg/L	S-7196		09/28/1994	kmd		413	0.01
Conductivity		380	umhos/cm	E-120.1		09/29/1994	amr		126	1
Prep - Cyanide Distillation		complete		E-335.2		10/04/1994	kmd	242		
Cyanide, total		<0.01	mg/L	E-335.2	10/04/1994	10/04/1994	kmd	242	233	0.01
P[illegible] Ammonia, Aqueous		complete		E-350.2		09/30/1994	amr	45		
N[illegible]ia		<0.01	mg/L	E-350.2	09/30/1994	10/03/1994	amr	45	229	0.01
N-Nitrate		0.62	mg/L	SM-4500 D		10/03/1994	kmd		5	0.1
N-Nitrite, for N-Nitrate only		<0.01	mg/L	E-354.1		09/28/1994	kmd		224	0.01
Oxygen, Dissolved		8.8	mg/L	E-360.1		09/27/1994	ndk		349	1.0
pH		7.8	units	E-150.1		09/28/1994	amr		804	0.1
Prep - Phenols		complete		E-420.1		10/04/1994	kmd	38		
Phenols, colorimetric		<0.01	mg/L	E-420.1	10/04/1994	10/04/1994	kmd	38	227	0.01
Solids, Total Dissolved		259	mg/L	E-160.1		09/29/1994	amr		361	5
Sulfate, Turbidimetric		55	mg/L	E-375.4		10/04/1994	kmd		195	5
Prep, Total Aqueous ICP Metals		complete		E-200.7		10/10/1994	ddc	609		
Arsenic, ICP		<0.005	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	324	0.005
Barium, ICP		0.057	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	597	0.001
Boron, ICP		0.077	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	289	0.010
Cadmium, ICP		<0.001	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	338	0.001
Copper, ICP		0.003	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	194	0.002
Iron, ICP		0.781	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	166	0.005
Lead, ICP		<0.005	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	361	0.005
Manganese, ICP		0.017	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	161	0.001
Selenium, ICP		<0.005	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	286	0.005
Silver, ICP		<0.002	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	304	0.002
Zinc, ICP		0.013	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	190	0.010
Prep, Pesticides; Wastewater		complete		E-608		10/03/1994	dh	69		

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ANALYTICAL RESULTS REPORT

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733
Sample Number: 109790

Project Description:
Job Description: SCS Water Quality Study

Sample Description: Chacon

Parameter	Flag	Result	Units	Analytical Method	Date Prepared	Date Analyzed	Analyst	Prep Batch Number	Run Batch Number	Reporting Limit
PESTICIDES - 608 AQUEOUS					10/03/1994					
Aldrin		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
alpha-BHC		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
beta-BHC		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
delta-BHC		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
gamma-BHC (Lindane)		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Chlordane		<0.20	ug/L	E-608		10/03/1994	dh	69	253	0.20
4,4'-DDD		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
4,4'-DDE		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
4,4'-DDT		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Dieldrin		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endosulfan I		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endosulfan II		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endosulfan sulfate		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endrin		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endrin aldehyde		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Heptachlor		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Heptachlor epoxide		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Toxaphene		<5.0	ug/L	E-608		10/03/1994	dh	69	253	5.0
HERBICIDES E-615 M AQUEOUS										
2,4-D		<1.0	ug/L	E-615M		10/14/1994	dh		7	1.0
2,4,5-T		<0.50	ug/L	E-615M		10/14/1994	dh		7	0.50
2,4,5-TP (Silvex)		<0.50	ug/L	E-615M		10/14/1994	dh		7	0.50
Coliform, fecal		170	/100 ml	S-9222D		09/27/1994	cpc		90	0
Coliform, total		>200	/100 ml	S-9222B		09/27/1994	cpc		18	0

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ANALYTICAL RESULTS REPORT

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733
Sample Number: 109791

Project Description:
Job Description: SCS Water Quality Study

Sample Description: USGS

Parameter	Flag	Result	Units	Analytical Method	Date Prepared	Date Analyzed	Analyst	Prep Batch Number	Run Batch Number	Reporting Limit
Chloride		18	mg/L	E-325.3		09/30/1994	amr		235	1
Chromium, hexavalent		<0.01	mg/L	S-7196		09/28/1994	kmd		413	0.01
Conductivity		380	umhos/cm	E-120.1		09/29/1994	amr		126	1
Prep - Cyanide Distillation		complete		E-335.2		10/04/1994	kmd	242		
Cyanide, total		<0.01	mg/L	E-335.2	10/04/1994	10/04/1994	kmd	242	233	0.01
Pr[illegible] Ammonia, Aqueous		complete		E-350.2		09/30/1994	amr	45		
N-[illegible]nia		0.08	mg/L	E-350.2	09/30/1994	10/03/1994	amr	45	229	0.01
N-Nitrate		1.50	mg/L	SM-4500 D		10/03/1994	kmd		5	0.1
N-Nitrite, for N-Nitrate only		<0.01	mg/L	E-354.1		09/28/1994	kmd		224	0.01
Oxygen, Dissolved		8.8	mg/L	E-360.1		09/27/1994	ndk		349	1.0
pH		7.7	units	E-150.1		09/28/1994	amr		804	0.1
Prep - Phenols		complete		E-420.1		10/04/1994	kmd	38		
Phenols, colorimetric		<0.01	mg/L	E-420.1	10/04/1994	10/04/1994	kmd	38	227	0.01
Solids, Total Dissolved		257	mg/L	E-160.1		09/29/1994	amr		361	5
Sulfate, Turbidimetric		50	mg/L	E-375.4		10/04/1994	kmd		195	5
Prep, Total Aqueous ICP Metals		complete		E-200.7		10/10/1994	ddc	609		
Arsenic, ICP		<0.005	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	324	0.005
Barium, ICP		0.029	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	597	0.001
Boron, ICP		0.067	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	289	0.010
Cadmium, ICP		<0.001	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	338	0.001
Copper, ICP		<0.002	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	194	0.002
Iron, ICP		0.019	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	166	0.005
Lead, ICP		<0.005	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	361	0.005
Manganese, ICP		0.004	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	161	0.001
Selenium, ICP		<0.005	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	286	0.005
Silver, ICP		<0.002	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	304	0.002
Zinc, ICP		<0.010	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	190	0.010
Prep, Pesticides; Wastewater		complete		E-608		10/03/1994	dh	69		

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ANALYTICAL RESULTS REPORT

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733
Sample Number: 109791

Project Description:
Job Description: SCS Water Quality Study

Sample Description: USGS

Parameter	Flag	Result	Units	Analytical Method	Date Prepared	Date Analyzed	Analyst	Prep Batch Number	Run Batch Number	Reporting Limit
PESTICIDES - 608 AQUEOUS					10/03/1994					
Aldrin		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
alpha-BHC		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
beta-BHC		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
delta-BHC		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
ga[illegible] BHC (Lindane)		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Ch[illegible]ane		<0.20	ug/L	E-608		10/03/1994	dh	69	253	0.20
4,4'-DDD		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
4,4'-DDE		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
4,4'-DDT		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Dieldrin		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endosulfan I		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endosulfan II		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endosulfan sulfate		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endrin		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endrin aldehyde		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Heptachlor		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Heptachlor epoxide		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Toxaphene		<5.0	ug/L	E-608		10/03/1994	dh	69	253	5.0
HERBICIDES E-615 M AQUEOUS										
2,4-D		<1.0	ug/L	E-615M		10/14/1994	dh		7	1.0
2,4,5-T		<0.50	ug/L	E-615M		10/14/1994	dh		7	0.50
2,4,5-TP (Silvex)		<0.50	ug/L	E-615M		10/14/1994	dh		7	0.50
Coliform, fecal		0	/100 ml	S-9222D		09/27/1994	cpc		90	0
Coliform, total		69	/100 ml	S-9222B		09/27/1994	cpc		18	0

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ANALYTICAL RESULTS REPORT

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733
Sample Number: 109792

Project Description:
Job Description: SCS Water Quality Study

Sample Description: Pearson

Parameter	Flag	Result	Units	Analytical Method	Date Prepared	Date Analyzed	Analyst	Prep Batch Number	Run Batch Number	Reporting Limit
Chloride		20	mg/L	E-325.3		09/30/1994	amr		235	1
Chromium, hexavalent		<0.01	mg/L	S-7196		09/28/1994	kmd		413	0.01
Conductivity		380	umhos/cm	E-120.1		09/29/1994	amr		126	1
Prep - Cyanide Distillation		complete		E-335.2		10/04/1994	kmd	242		
Cyanide, total		<0.01	mg/L	E-335.2	10/04/1994	10/04/1994	kmd	242	233	0.01
Pr[illegible] Ammonia, Aqueous		complete		E-350.2		09/30/1994	amr	45		
[illegible]ia		0.10	mg/L	E-350.2	09/30/1994	10/03/1994	amr	45	229	0.01
N-Nitrate		0.81	mg/L	SM-4500 D		10/03/1994	kmd		5	0.1
N-Nitrite, for N-Nitrate only		<0.01	mg/L	E-354.1		09/28/1994	kmd		224	0.01
Oxygen, Dissolved		7.7	mg/L	E-360.1		09/27/1994	ndk		349	1.0
pH		7.8	units	E-150.1		09/28/1994	amr		804	0.1
Prep - Phenols		complete		E-420.1		10/04/1994	kmd	38		
Phenols, colorimetric		<0.01	mg/L	E-420.1	10/04/1994	10/04/1994	kmd	38	227	0.01
Solids, Total Dissolved		259	mg/L	E-160.1		09/29/1994	amr		361	5
Sulfate, Turbidimetric		195	mg/L	E-375.4		10/04/1994	kmd		195	5
Prep, Total Aqueous ICP Metals		complete		E-200.7		10/10/1994	ddc	609		
Arsenic, ICP		<0.005	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	324	0.005
Barium, ICP		0.060	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	597	0.001
Boron, ICP		0.078	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	289	0.010
Cadmium, ICP		<0.001	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	338	0.001
Copper, ICP		<0.002	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	194	0.002
ron, ICP		1.79	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	166	0.005
ead, ICP		<0.005	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	361	0.005
anganese, ICP		0.028	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	161	0.001
elenium, ICP		<0.005	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	286	0.005
ilver, ICP		<0.002	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	304	0.002
inc, ICP		0.013	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	190	0.010
ep, Pesticides; Wastewater		complete		E-608		10/03/1994	dh	69		

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ANALYTICAL RESULTS REPORT

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733
Sample Number: 109792

Page 7

Project Description:
Job Description: SCS Water Quality Study

Sample Description: Pearson

Parameter	Flag	Result	Units	Analytical Method	Date Prepared	Date Analyzed	Analyst	Prep Batch Number	Run Batch Number	Reporting Limit
PESTICIDES - 608 AQUEOUS					10/03/1994					
Aldrin		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
alpha-BHC		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
beta-BHC		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
delta-BHC		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
g[illegible]-BHC (Lindane)		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
C[illegible]dane		<0.20	ug/L	E-608		10/03/1994	dh	69	253	0.20
4,4'-DDD		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
4,4'-DDE		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
4,4'-DDT		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Dieldrin		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endosulfan I		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endosulfan II		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endosulfan sulfate		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endrin		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endrin aldehyde		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Heptachlor		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Heptachlor epoxide		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Toxaphene		<5.0	ug/L	E-608		10/03/1994	dh	69	253	5.0
HERBICIDES E-615 M AQUEOUS										
2,4-D		<1.0	ug/L	E-615M		10/14/1994	dh		7	1.0
2,4,5-T		<0.50	ug/L	E-615M		10/14/1994	dh		7	0.50
2,4,5-TP (Silvex)		<0.50	ug/L	E-615M		10/14/1994	dh		7	0.50
Coliform, fecal		400	/100 ml	S-9222D		09/27/1994	cpc		90	0
Coliform, total		400	/100 ml	S-9222B		09/27/1994	cpc		18	0

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ANALYTICAL RESULTS REPORT

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733
Sample Number: 109793

Project Description:
Job Description: SCS Water Quality Study

Sample Description: Touchstone

Parameter	Flag	Result	Units	Analytical Method	Date Prepared	Date Analyzed	Analyst	Prep Batch Number	Run Batch Number	Reporting Limit
hloride		18	mg/L	E-325.3		09/30/1994	amr		235	1
hromium, hexavalent		<0.01	mg/L	S-7196		09/28/1994	kmd		413	0.01
onductivity		360	umhos/cm	E-120.1		09/29/1994	amr		126	1
rep - Cyanide Distillation		complete		E-335.2		10/04/1994	kmd	242		
yanide, total		<0.01	mg/L	E-335.2	10/04/1994	10/04/1994	kmd	242	233	0.01
Pr[illegible] Ammonia, Aqueous		complete		E-350.2		09/30/1994	amr	45		
[illegible]ia		<0.01	mg/L	E-350.2	09/30/1994	10/03/1994	amr	45	229	0.01
-Nitrate		0.68	mg/L	SM-4500 D		10/03/1994	kmd		5	0.1
-Nitrite, for N-Nitrate only		<0.01	mg/L	E-354.1		09/28/1994	kmd		224	0.01
xygen, Dissolved		9.0	mg/L	E-360.1		09/27/1994	ndk		349	1.0
H		7.8	units	E-150.1		09/28/1994	amr		804	0.1
rep - Phenols		complete		E-420.1		10/04/1994	kmd	38		
henols, colorimetric		<0.01	mg/L	E-420.1	10/04/1994	10/04/1994	kmd	38	227	0.01
olids, Total Dissolved		231	mg/L	E-160.1		09/29/1994	amr		361	5
ulfate, Turbidimetric		50	mg/L	E-375.4		10/04/1994	kmd		195	5
rep, Total Aqueous ICP Metals		complete		E-200.7		10/10/1994	ddc	609		
rsenic, ICP		<0.005	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	324	0.005
arium, ICP		0.065	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	597	0.001
oron, ICP		0.060	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	289	0.010
admium, ICP		<0.001	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	338	0.001
opper, ICP		0.003	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	194	0.002
ron, ICP		0.151	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	166	0.005
ead, ICP		<0.005	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	361	0.005
anganese, ICP		0.005	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	161	0.001
elenium, ICP		<0.005	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	286	0.005
ilver, ICP		<0.002	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	304	0.002
nc, ICP		0.022	mg/L	E-200.7	10/10/1994	10/11/1994	dpp	609	190	0.010
ep, Pesticides; Wastewater		complete		E-608		10/03/1994	dh	69		

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ANALYTICAL RESULTS REPORT

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733
Sample Number: 109793

Project Description:
Job Description: SCS Water Quality Study

Sample Description: Touchstone

Parameter	Flag	Result	Units	Analytical Method	Date Prepared	Date Analyzed	Analyst	Prep Batch Number	Run Batch Number	Reporting Limit
PESTICIDES - 608 AQUEOUS					10/03/1994					
Aldrin		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
alpha-BHC		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
beta-BHC		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
delta-BHC		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
g[illegible]BHC (Lindane)		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Ch[illegible]ane		<0.20	ug/L	E-608		10/03/1994	dh	69	253	0.20
4,4'-DDD		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
4,4'-DDE		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
4,4'-DDT		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Dieldrin		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endosulfan I		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endosulfan II		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endosulfan sulfate		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endrin		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Endrin aldehyde		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Heptachlor		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Heptachlor epoxide		<0.10	ug/L	E-608		10/03/1994	dh	69	253	0.10
Toxaphene		<5.0	ug/L	E-608		10/03/1994	dh	69	253	5.0
HERBICIDES E-615 M AQUEOUS										
2,4-D		<1.0	ug/L	E-615M		10/14/1994	dh		7	1.0
2,4,5-T		<0.50	ug/L	E-615M		10/14/1994	dh		7	0.50
2,4,5-TP (Silvex)		<0.50	ug/L	E-615M		10/14/1994	dh		7	0.50
Coliform, fecal		100	/100 ml	S-9222D		09/27/1994	cpc		90	0
Coliform, total		1,700	/100 ml	S-9222B		09/27/1994	cpc		18	0

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QUALITY CONTROL REPORT
BLANKS

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	Blank Result	Units	Reporting Limit	Date Analyzed	Prep Batch Number	Run Batch Number
Chloride		<1	mg/L	1	09/30/1994		235
Chromium, hexavalent		<0.01	mg/L	0.01	09/28/1994		413
Conductivity		<1	umhos/cm	1	09/29/1994		126
Cyanide, total		<0.01	mg/L	0.01	10/04/1994	242	233
N-Ammonia		<0.01	mg/L	0.01	10/03/1994	45	229
N-Nitrate		<0.1	mg/L	0.1	10/03/1994		5
N-Nitrite, for N-Nitrate only		<0.01	mg/L	0.01	09/28/1994		224
pH		NA	units	0.1	09/28/1994		804
Phenols, colorimetric		<0.01	mg/L	0.01	10/04/1994	38	227
Solids, Total Dissolved		<5	mg/L	5	09/29/1994		361
Sulfate, Turbidimetric		<5	mg/L	5	10/04/1994		195
Arsenic, ICP		<0.005	mg/L	0.005	10/11/1994	609	324
Barium, ICP		<0.001	mg/L	0.001	10/11/1994	609	597
Boron, ICP		<0.010	mg/L	0.010	10/11/1994	609	289
Cadmium, ICP		<0.001	mg/L	0.001	10/11/1994	609	338
Copper, ICP		<0.002	mg/L	0.002	10/11/1994	609	194
Iron, ICP		<0.005	mg/L	0.005	10/11/1994	609	166
Lead, ICP		<0.005	mg/L	0.005	10/11/1994	609	361
Manganese, ICP		<0.001	mg/L	0.001	10/11/1994	609	161
Selenium, ICP		<0.005	mg/L	0.005	10/11/1994	609	286
Silver, ICP		<0.002	mg/L	0.002	10/11/1994	609	304
Zinc, ICP		<0.010	mg/L	0.010	10/11/1994	609	190
PESTICIDES - 608 AQUEOUS							
Aldrin		<0.10	ug/L	0.10	10/03/1994	69	253
alpha-BHC		<0.10	ug/L	0.10	10/03/1994	69	253
beta-BHC		<0.10	ug/L	0.10	10/03/1994	69	253
delta-BHC		<0.10	ug/L	0.10	10/03/1994	69	253
gamma-BHC (Lindane)		<0.10	ug/L	0.10	10/03/1994	69	253

All parameters should be less than the reporting limit.

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QUALITY CONTROL REPORT
BLANKS

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	Blank Result	Units	Reporting Limit	Date Analyzed	Prep Batch Number	Run Batch Number
Chlordane		<0.20	ug/L	0.20	10/03/1994	69	253
4,4'-DDD		<0.10	ug/L	0.10	10/03/1994	69	253
4,4'-DDE		<0.10	ug/L	0.10	10/03/1994	69	253
4,4'-DDT		<0.10	ug/L	0.10	10/03/1994	69	253
Dieldrin		<0.10	ug/L	0.10	10/03/1994	69	253
Endosulfan I		<0.10	ug/L	0.10	10/03/1994	69	253
ndosulfan II		<0.10	ug/L	0.10	10/03/1994	69	253
dosulfan sulfate		<0.10	ug/L	0.10	10/03/1994	69	253
Endrin		<0.10	ug/L	0.10	10/03/1994	69	253
Endrin aldehyde		<0.10	ug/L	0.10	10/03/1994	69	253
Heptachlor		<0.10	ug/L	0.10	10/03/1994	69	253
Heptachlor epoxide		<0.10	ug/L	0.10	10/03/1994	69	253
Toxaphene		<5.0	ug/L	5.0	10/03/1994	69	253
HERBICIDES E-615 M AQUEOUS							
2,4-D		<1.0	ug/L	1.0	10/14/1994		7
2,4,5-T		<0.50	ug/L	0.50	10/14/1994		7
2,4,5-TP (Silvex)		<0.50	ug/L	0.50	10/14/1994		7

All parameters should be less than the reporting limit.

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QUALITY CONTROL REPORT
CONTINUING CALIBRATION VERIFICATION STANDARD

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	CCVS True Concentration	Units	CCVS Concentration Found	CCVS Percent Recovery	Date Analyzed	Run Batch Number
Chloride		100	mg/L	98	98.0	09/30/1994	235
Chromium, hexavalent		0.15	mg/L	0.15	100.0	09/28/1994	413
Conductivity		1,409	umhos/cm	1,302	92.4	09/29/1994	126
Cyanide, total		0.50	mg/L	0.52	104.0	10/04/1994	233
N-Ammonia		1.0	mg/L	1.01	101.0	10/03/1994	229
N-Nitrate		1.0	mg/L	1.09	109.0	10/03/1994	5
N-Nitrite, for N Nitrate only		0.10	mg/L	0.10	100.0	09/28/1994	224
pH		4.0	units	4.0	100.0	09/28/1994	804
Phenols, colorimetric		0.06	mg/L	0.06	100.0	10/04/1994	227
Sulfate, Turbidimetric		20	mg/L	20	100.0	10/04/1994	195
Arsenic, ICP		0.500	mg/L	0.504	100.8	10/11/1994	324
Barium, ICP		0.500	mg/L	0.478	95.6	10/11/1994	597
Boron, ICP		0.500	mg/L	0.500	100.0	10/11/1994	289
Cadmium, ICP		0.500	mg/L	0.490	98.0	10/11/1994	338
Copper, ICP		0.500	mg/L	0.496	99.2	10/11/1994	194
Iron, ICP		0.500	mg/L	0.502	100.4	10/11/1994	166
Lead, ICP		0.500	mg/L	0.490	98.0	10/11/1994	361
Manganese, ICP		0.500	mg/L	0.493	98.6	10/11/1994	161
Selenium, ICP		0.500	mg/L	0.502	100.4	10/11/1994	286
Silver, ICP		0.500	mg/L	0.499	99.8	10/11/1994	304
Zinc, ICP		0.500	mg/L	0.499	99.8	10/11/1994	190

CCVS - Continuing Calibration Verification Standard

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QUALITY CONTROL REPORT
MATRIX SPIKE/MATRIX SPIKE DUPLICATE

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	Units	Sample Result	Spike Amount Added	Matrix Spike Result	MS Percent Recovery	Duplicate Spike Amount Added	MSD Result	MSD Percent Recovery	MS/MSD RPD	Date Analyzed	Prep Batch Number	Run Batch Number
Chloride		mg/L	18	100	114	96.0	100	114	96.0	0.0	09/30/1994		235
Chromium, hexavalent		mg/L	<0.01	0.15	0.14	93.3	0.15	0.14	93.3	0.0	09/28/1994		413
Chromium, hexavalent		mg/L	<0.01	0.15	0.15	100.0	0.15	0.14	93.3	6.8	09/28/1994		413
N [illegible]onia		mg/L	0.31	1.0	1.2	89.0	1.0	1.2	89.0	0.0	10/03/1994	45	229
N [illegible]nia		mg/L	1.4	2.0	3.4	100.0	2.0	3.4	100.0	0.0	10/03/1994	45	229
N-Nitrate		mg/L	0.68	1.0	1.55	87.0	1.0	1.48	80.0	8.4	10/03/1994		5
N-Nitrite, for N-Nitrate only		mg/L	0.29	0.50	0.77	96.0	0.50	0.76	94.0	2.1	09/28/1994		224
Phenols, colorimetric		mg/L	<0.01	0.06	0.05	83.3	0.06	0.05	83.3	0.0	10/04/1994	38	227
Sulfate, Turbidimetric		mg/L	875	500	1,500	125.0	500	1,500	125.0	0.0	10/04/1994		195
Sulfate, Turbidimetric		mg/L	50	20	65	75.0	20	65	75.0	0.0	10/04/1994		195
Sulfate, Turbidimetric		mg/L	50	20	65	75.0	20	65	75.0	0.0	10/04/1994		195
Arsenic, ICP		mg/L	<0.005	0.500	0.470	94.0	0.500	0.477	95.4	1.5	10/11/1994	609	324
Arsenic, ICP		mg/L	0.172	0.500	0.673	100.2	0.500	0.644	94.4	5.9	10/11/1994	609	324
Barium, ICP		mg/L	0.057	0.500	0.531	94.8	0.500	0.537	96.0	1.3	10/11/1994	609	597
Barium, ICP		mg/L	0.144	0.500	0.572	85.6	0.500	0.569	85.0	0.7	10/11/1994	609	597
Boron, ICP		mg/L	0.077	0.500	0.546	93.8	0.500	0.552	95.0	1.3	10/11/1994	609	289
Boron, ICP		mg/L	0.694	0.500	1.21	103.2	0.500	1.20	101.2	2.0	10/11/1994	609	289
Cadmium, ICP		mg/L	<0.001	0.500	0.456	91.2	0.500	0.461	92.2	1.1	10/11/1994	609	338
Cadmium, ICP		mg/L	<0.001	0.500	0.451	90.2	0.500	0.420	84.0	7.1	10/11/1994	609	338
Copper, ICP		mg/L	0.003	0.500	0.477	94.8	0.500	0.484	96.2	1.5	10/11/1994	609	194
Copper, ICP		mg/L	0.005	0.500	0.516	102.2	0.500	0.463	91.6	10.8	10/11/1994	609	194
Iron, ICP		mg/L	0.781	0.500	1.19	81.8	0.500	1.22	87.8	7.1	10/11/1994	609	166

NOTE: The Quality Control data in this report reflects the batch in which your sample was prepped and/or analyzed. The sample selected for QA may not necessarily be your sample.

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QUALITY CONTROL REPORT
MATRIX SPIKE/MATRIX SPIKE DUPLICATE

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	Units	Sample Result	Spike Amount Added	Matrix Spike Result	MS Percent Recovery	Duplicate Spike Amount Added	MSD Result	MSD Percent Recovery	MS/MSD RPD	Date Analyzed	Prep Batch Number	Run Batch Number
ron, ICP		mg/L	0.355	0.500	0.869	102.8	0.500	0.855	100.0	2.8	10/11/1994	609	166
ead, ICP		mg/L	<0.005	0.500	0.456	91.2	0.500	0.462	92.4	1.3	10/11/1994	609	361
ead, ICP		mg/L	<0.005	0.500	0.451	90.2	0.500	0.419	83.8	7.4	10/11/1994	609	361
an[illegible]se, ICP		mg/L	0.017	0.500	0.492	95.0	0.500	0.499	96.4	1.5	10/11/1994	609	161
an[illegible]e, ICP		mg/L	0.159	0.500	0.647	97.6	0.500	0.618	91.8	6.1	10/11/1994	609	161
elenium, ICP		mg/L	<0.005	0.500	0.458	91.6	0.500	0.465	93.0	1.5	10/11/1994	609	286
elenium, ICP		mg/L	0.200	0.500	0.695	99.0	0.500	0.664	92.8	6.5	10/11/1994	609	286
ilver, ICP		mg/L	<0.002	0.500	0.474	94.8	0.500	0.479	95.8	1.0	10/11/1994	609	304
ilver, ICP		mg/L	<0.002	0.500	0.456	91.2	0.500	0.456	91.2	0.0	10/11/1994	609	304
inc, ICP		mg/L	0.013	0.500	0.467	90.8	0.500	0.475	92.4	1.7	10/11/1994	609	190
inc, ICP		mg/L	0.049	0.500	0.526	95.4	0.500	0.496	89.4	6.5	10/11/1994	609	190

NOTE: The Quality Control data in this report reflects the batch in which your sample was prepped and/or analyzed. The sample selected for QA may not necessarily be your sample.

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QUALITY CONTROL REPORT
DUPLICATES

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	Units	Sample Result	Duplicate Sample Result	RPD	Date Analyzed	Prep Batch Number	Run Batch Number
Conductivity		umhos/cm	360	360	0.0	09/29/1994		126
pH		units	7.7	7.7	0.0	09/28/1994		804
pH		units	7.2	7.2	0.0	09/28/1994		804
Solids, Total Dissolved		mg/L	503	502	0.2	09/29/1994		361
Solids, Total Dissolved		mg/L	440	434	1.4	09/29/1994		361

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QUALITY CONTROL REPORT
LABORATORY CONTROL STANDARD

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733

Project Description:
Job Description: SCS Water Quality Study

Parameter	Flag	LCS True Concentration	LCS Concentration Found	LCS Percent Recovery	Date Analyzed	Prep Batch Number	Run Batch Number
Cyanide, total		0.50	0.52	104.0	10/04/1994	242	233
Cyanide, total		0.50	0.52	104.0	10/04/1994	242	233
N-Ammonia		1.0	0.99	99.0	10/03/1994		229
Phenols, colorimetric		0.06	0.06	100.0	10/04/1994	38	227
Solids, Total Dissolved		100	97	97.0	09/29/1994		361
senic, ICP		0.500	0.509	101.8	10/11/1994	609	324
ium, ICP		0.500	0.529	105.8	10/11/1994	609	597
Boron, ICP		0.500	0.504	100.8	10/11/1994	609	289
Cadmium, ICP		0.500	0.509	101.8	10/11/1994	609	338
Copper, ICP		0.500	0.523	104.6	10/11/1994	609	194
Iron, ICP		0.500	0.556	111.2	10/11/1994	609	166
Lead, ICP		0.500	0.509	101.8	10/11/1994	609	361
Manganese, ICP		0.500	0.528	105.6	10/11/1994	609	161
Selenium, ICP		0.500	0.507	101.4	10/11/1994	609	286
Silver, ICP		0.500	0.518	103.6	10/11/1994	609	304
Zinc, ICP		0.500	0.511	102.2	10/11/1994	609	190

LCS - Laboratory Control Standard

For samples with insufficient sample volume, an LCS/LCS duplicate is reported instead of an MS/MSD.

NET® NATIONAL ENVIRONMENTAL TESTING, INC.

Austin Division
2621 Ridgepoint Drive
Suite 130
Austin, TX 78754
Tel: (512) 928-8905
Fax: (512) 928-3208

QUALITY CONTROL REPORT
LABORATORY CONTROL STANDARD

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733

Project Description:
Job Description: SCS Water Quality Study

Parameter	Date Analyzed	Percent Recovery
PESTICIDES - EPA 608 AQUEOUS		
Alpha - BHC	10/07/1994	68.6
Lindane	10/07/1994	74.0
Beta - BHC	10/07/1994	75.6
Heptachlor	10/07/1994	67.0
Delta - BHC	10/07/1994	76.4
Aldrin	10/07/1994	56.3
Heptachlor epoxide	10/07/1994	68.1
Endosulfan I	10/07/1994	74.3
4,4' - DDE	10/07/1994	70.4
Dieldrin	10/07/1994	78.5
Endrin	10/07/1994	80.0
4,4' - DDD	10/07/1994	71.8
Endosulfan II	10/07/1994	81.8
4,4' - DDT	10/07/1994	80.8
Endrin aldehyde	10/07/1994	68.3
Methoxychlor	10/07/1994	76.5
Endosulfan sulfate	10/07/1994	76.2
Chlordane	10/07/1994	NA
Toxaphene	10/07/1994	NA
PCB - 1016	10/07/1994	NA
PCB - 1221	10/07/1994	NA
PCB - 1232	10/07/1994	NA
PCB - 1242	10/07/1994	NA
PCB - 1248	10/07/1994	NA
PCB - 1254	10/07/1994	NA
PCB - 1260	10/07/1994	NA

LCS - Laboratory Control Standard

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LABORATORY CONTROL STANDARD

John Ward
BEXAR-MEDINA-ATASOSA
Water Cntrl & Improvement
District #1
Natalia, TX 78059

11/04/1994

NET Job Number: 94.02733

Project Description:
Job Description: SCS Water Quality Study

Parameter	Date Analyzed	Percent Recovery
HERBICIDES - EPA 615 AQUEOUS		
Dalapon	10/13/1994	115
Dicamba	10/13/1994	77.4
MCPP	10/13/1994	73.9
MCPA	10/13/1994	76.0
Dichlorprop	10/13/1994	85.8
2,4 - D	10/13/1994	81.8
2,4,5 - TP	10/13/1994	79.7
2,4,5 - T	10/13/1994	91.9
2,4 - DB	10/13/1994	86.9
Dinoseb	10/13/1994	98.5

LCS - Laboratory Control Standard

For samples with insufficient sample volume, an LCS/LCS duplicate is reported instead of an MS/MSD.

OCEAN GROUP

NATIONAL ENVIRONMENTAL TESTING, INC.

CHAIN OF CUSTODY RECORD

COMPANY B-M-A WC&ID #1
ADDRESS
PHONE ____ FAX ____
PROJECT NAME/LOCATION SCS Water Quality Study
PROJECT NUMBER
PROJECT MANAGER Douglas Hearn

REPORT TO: Johnny Ward
INVOICE TO:
P.O. NO.
NET QUOTE NO.

SAMPLED BY
Douglas Hearn
(PRINT NAME) — SIGNATURE: Douglas H[signature]
(PRINT NAME) — SIGNATURE

			# and Type of Containers	ANALYSES: See Attached List	COMMENTS
9/27	11:37	Chacon	10	↓	Copy to Douglas Hearn
9/27	10:18	USGS	↓	↓	
9/27	11:25	Pearson	↓	↓	
9/27	1:15	Touchstone	↓	↓	add pH and [illegible] as per Doug Hearn
~~9/27~~					

CONDITION OF SAMPLE: BOTTLES INTACT? YES / NO
FIELD FILTERED? YES / NO
COC SEALS PRESENT AND INTACT? YES / NO
VOLATILES FREE OF HEADSPACE? YES / NO
TEMPERATURE UPON RECEIPT: on ice
Bottles supplied by NET? YES / NO

SAMPLE REMAINDER DISPOSAL: RETURN SAMPLE REMAINDER TO CLIENT VIA ____
I REQUEST NET TO DISPOSE OF ALL SAMPLE REMAINDERS ____ DATE ____

RELINQUISHED BY:	DATE/TIME	RECEIVED BY:	RELINQUISHED BY:	DATE/TIME	RECEIVED FOR NET BY:
Douglas H[signature]	9/27/94 5:24				Debby Sledge[signature]

METHOD OF SHIPMENT

REMARKS:

PT 1 - ORIGINAL - WHITE PT 2 - NET PROJECT MANAGER - YELLOW PT 3 - CUSTOMER COPY - PINK

WEED CONTROL

Aquatic Weeds

Aquatic weeds are objectionable in both canals and bathing areas. They cause blockages at structures in the canal system (trash racks, culverts, bridge piping, checks, etc.), become entwined around the legs and arms of bathers which interferes with swimming, and provide harborage for snails.

Vegetation that grows and remains below the water surface does not generally cause difficulty. Decaying and emergent aquatic vegetation, as well as decaying leaves, brush, weeds, grasses, and debris in the water can cause tastes and odors in water supplies. The discharge of organic wastes from wastewater treatment plants, storm sewers, and drainage from lawns, pastures, and fertilized fields contains nitrogen and phosphorus, which promote algal and weed growths. The contribution of phosphorus from sewage treatment plants can be relatively small compared to that from surface runoff. Unfortunately little can be done to permanently prevent the entrance of wastes and drainage or destroy growths of rooted plants, although certain chemical, mechanical, and biological methods can provide temporary control.

Reasonably good temporary control of rooted aquatic plants may be obtained by physically removing the growths by dredging or with wire, chain drags, or rakes, and by cutting. Filling of marshy areas and deepening the edges of reservoirs, lakes, and ponds to a depth of 2 ft or more will prevent or reduce plant growths. Weeds that float to the surface should be removed before they decay.

Where it is possible to drain or lower the water level 6 ft to expose the affected areas of the reservoir for about one month, drying of weeds and roots, clearing and removal, direct burning, or oiling of the vegetation, peat, and so forth with a light oil such as kerosene and thorough burning is of great value. Drying out of roots and burning and removal of the ash is effective for a number of years. Flooding 3 ft or more above normal is also effective where possible.

As a last resort, aquatic weeds may be controlled by chemical means. Tastes and odors may result if the water is used for drinking purposes; the chemical may kill fish and persist in the bottom mud, and it may be hazardous to the applicator. The treatment must be repeated annually or more often, and heavy algal blooms may be stimulated, particularly if the plant destroyed is allowed to remain in the water and return its nutrients to the water. Chemical use should be restricted and permitted only after careful review of the toxicity to humans and fish, the hazards involved, and the purpose to be served. Copper sulfate should not be used for the control of aquatic weeds, since the concentration required to destroy the vegetation will assuredly kill any fish present in the water.

One of the simplest ways of controlling the growth of aquatic weeds, where possible, is lowering the water level sufficiently to cause the plants to dry out. If this is followed by burning and removal of the remaining debris, reasonably good control will result. The physical cutting and removal of the weeds is also temporarily effective. Where aquatic weeds grow above the water surface chemical control by the use of weed killers is possible.

Sodium arsenite as As_2O_3 at a rate of 4 to 7.5 mg/l has been very effective to control submerged rooted or anchored aquatic weeds, but its use is no longer advised due to it being is very toxic to man and dangerous to the applicator. Other chemicals such as Endothall, Acrolein, Diquat, and 2,4-D granules or pellets may be used if approved by the proper control authority. Diquat, 2,4-D low-volatile esters, Silvex, or Amitrole-T may be permitted for floating weeds. The manufacturer's directions should be carefully followed, and when the water is located on a water supply watershed permission must first be obtained from the water supply officials.

A major problem to overcome in the treatment of aquatic vegetation in flowing water is the development of herbicides and methods of application that will ensure the desired contact time. While constant rate or slug applications have proven to be effective, most of the chemical is wasted.

The health, agriculture, and conservation departments should also be consulted because some of the chemicals available are toxic to humans and fish. In many instances knowledge regarding persistence and effect on the ecology may be limited. A permit to apply chemicals to public waters is usually required. Only approved chemicals should be used and only when necessary. The correct use of aquatic herbicides is essential to achieve the desired weed control without causing undue public concern.

Biological Control of Aquatic Weeds by Fish in Irrigation Channels

Tilapie zillii is not a panacea for weed control, but can aid in the reduction of aquatic weeds. Equal or better control can be obtained for equal or less cost when compared to mechanical control techniques. Sometimes, integrated control techniques must be applied. The effectiveness of Tilapie zillii is limited by its feeding preference and its temperature requirements.

In areas such as southern California, where there are over 5,000 miles of irrigation canals and drainage ditches. These service over 600,000 acres of cropland and open throughout the year. In these systems the ensuing aquatic weed problems great. Chemicals cannot be used for weed control because they are expensive, dilution due to flow, and the canal water provides part of the potable water supply. Mechanical control costs are about 1/2 million dollars annually. Biological control techniques have offered an opportunity to reduce these costs. By this approach, herbivorous fish which graze on the vegetation are introduced into the waters.

While the limitations of the Tilapie zillii could be overcome by a good management scheme based on an annual stocking program, biological means of control are not well suited to BMA's canal system since flow in the canals is shut off numerous times in a given year.

Conclusion

Until the District can either line or pipe the entire system, control of vegetation in and along the canals will continue to be a major maintenance problem and expense. The timely application of herbicides in conjunction with mechanical removal is the only cost effective means available at this time. Historically, BMA has utilized excavators to remove aquatic vegetation which has led to an increase in seepage from the canals due to the removal of the clay liner. In lieu of buckets, the District should consider using drag chains or rakes to prevent the loss of any more liner.

DIQUAT

Primarily used as a contact herbicide for submersed and free-floating aquatic weeds. Only provides short-term top kill on emergent plants such as cattails. A surfactant or spreader should be added to the diquat solution when treating free-floating or emergent weeds. The chemical binds to suspended soil particles; therefore, do not use in or dilute in muddy water. Note 14 day water use restrictions.

Weedtrine-D
Rate: 1-4 lb. ai/surface A
2.5-10 gal./surface A
Condition of Application: Apply when weeds are actively growing but before weed growth has reached the water surface.
Weeds: **Aquatic weeds:**

bladderwort	elodea	salvinia
cattails	naiad	waterhyacinth
coontail	pennywort	waterlettuce
duckweed	pondweeds	

Remarks: Refer to label for specific rates to control weeds listed. Do not use treated water for animal consumption, drinking, spraying, irrigation, or domestic purposes for 14 days, or swimming for 24 hours after treatment.

GLYPHOSATE

Used strictly for emergent and floating plant control. Surfactant must be added to Rodeo to insure foliage penetration. Broad spectrum activity. Only restriction is within one-half mile of potable water intakes.

Rodeo
Rate: Boom equipment:
1-5 lb. ai/A
1.5-7.5 pt./A
Handgun equipment:
0.75%-1.5% solution
Condition of Application: Apply to foliage of emerged weeds. Apply at early growth stages of annual weeds and when perennial weeds are approaching maturity.
Weeds: **Aquatic weeds:**

alligatorweed	maidencane	spatterdock
cattail	paragrass	torpedograss
giant cutgrass	phragmites	willow

Remarks: Always use 0.5% by volume nonionic surfactant. Apply in 3-20 gal. water/A. Rate dependent upon weed species to be controlled. Effective on emerged and floating plants as well as ditchbanks or shoreline aquatic weeds. Not effective on plants which are either completely submerged or have most of their foliage under water. Can be used in and around all bodies of water which may be flowing, nonflowing, or transient. Do not apply within one-half mile upstream of potable water intakes. Do not apply in estuaries.

Slow Release Algimycin — see copper complex

Weedar — see 2,4-D

Weedtrine-D — see diquat

Weedtrine-II — see 2,4-D

MOVING WATER
(Irrigation, Drainage Canals, Bayous)

Aquathol K — see endothall

COPPER COMPLEXES

Copper sulfate and various chelated copper compounds that are used primarily for algae control. Some of the chelates can also be used for hydrilla and southern naiad control. Copper sulfate is widely used but may not be effective in hard water; the chelates are formulated to provide longer lasting effect in hard water. Copper sulfate and chelates are the only compounds for which there are no restrictions on water use after treatment, with the exception that they should not be used in trout-bearing waters. When used for filamentous algae, good distribution and contact with the mats is essential for optimal control.

Cutrine-Plus Liquid (mixed copper-ethanolamine complexes)
Rate: 1 qt./cfs water flow/hour for 3 hours.
Calculated Concentration in Water: 1 ppm ai.
Condition of Application: Apply when algae begins to interfere with normal delivery of water (clogging at headgates, suction screens, weed screens, and siphon tubes).
Weeds: **Algae:**

chara	filamentous	nitella

Remarks: Follow all label directions. Treat when there is sufficient water flow to allow dispersion of chemical. Apply early in the morning. Chemical should be introduced at points of turbulence-creating structures such as weirs. Cleared for use in potable water up to 1 ppm copper.

Triangle Brand Copper Sulfate (copper sulfate)
Rate: Slug application: 0.5-2 lb. copper sulfate/cfs water flow/30 miles of length; repeat in 2 weeks. Continuous application: 0.1-0.2 lb. copper sulfate/hour/cfs water flow for 12 hours of each 24 hours.
Condition of Application: Apply as growth develops. Feed may be solution or crystal.
Weeds: **Algae:**

chara	filamentous	nitella

Remarks: May be toxic to fish in soft water. Do not exceed 4 ppm in potable water.

Cutrine-Plus — see copper complex

2,4-D - PHENOXY HERBICIDES

Granular ester formulations are labeled for use on submersed weeds and are particularly effective on Eurasian watermilfoil. Liquid amine formulations are effective for water hyacinth control. Caution should be used when applying liquid ester formulations because they can cause a fish kill. Note restrictions on water use.

Esteron 99 Concentrate (2,4-D LV ester)
See 2,4-D (2,4-D LV ester)
Rate: 1.25-2.25 lb. ai/A
2.5-4.5 pt. 99C/A
Condition of Application: Apply when leaves are fully developed above waterline and plants are actively growing.
Weeds: **Aquatic weeds:**

alligatorweed	pennywort	waterplantain
arrowhead	waterhyacinth	waterprimrose
bulrush	waterlily	willow
duckweed		

Remarks: Apply in 50-100 gal. water. Spray to wet foliage thoroughly. Perennial and other hard to control weeds may require a repeat application to give adequate control. Do not apply to more than one-third to one-half of a lake or pond in any one month because excessive decaying vegetation may deplete oxygen content of water and kill fish. Consult your State Conservation Department or Game and Fish Commission to determine the best time and rate of application under local conditions.

Weedar 64 (2,4-D amine)
Rate: 2-4 lb. ai/A
2-4 qt. 64/A
Condition of Application: Spray when waterhyacinths are actively growing.
Weeds: Waterhyacinth.
Remarks: To be applied by federal, state, or local public agency personnel trained in aquatic weed control, or by licensed commercial applicators under contract to the above agencies.

ENDOTHALL

Contact herbicide used for submersed weeds (Aquathol) or algae and submersed weeds (Hydrothol). Fish are particularly sensitive to the liquid formulation of Hydrothol, and open water should be left untreated to provide an escape for them. Aquathol is safe for fish, and the liquid formulation is often tank-mixed with copper chelates to provide both algae and submersed weed control. Water use restrictions vary from 24 hours to 25 days depending on use and dosage applied.

Aquathol K
Rate: 2-9.7 lb. ae/A ft.
0.6-3.2 gal. K/A ft.
Calculated Concentration in Water: 1-5 ppm dipotassium salt.

NOTICE The information on these pages is for preliminary planning — not a guide for use. Be sure to follow manufacturer's directions, notwithstanding information contained here.

Condition of Application: Apply after water has warmed and weed growth is visible.
Weeds: Aquatic weeds:

bassweed	hydrilla	pondweeds
burreed	milfoil	(Potamogeton spp.)
coontail	naiad	waterstargrass

Remarks: No injury to fish. Do not use treated water for irrigation, agricultural sprays, livestock, or domestic purposes for at least 7 to 25 days after treatment. Fish may be used for food or feed 3 days after treatment. May be used for swimming 24 hours after treatment.

Hydrothol 191 Liquid or Granular
Rate: 2.8-13.5 lb. ae/A ft.
1.4-6.75 gal. Liquid/A ft.
55-270 lb. Granular/A ft.
Calculated Concentration in Water: 1-5 ppm.
Condition of Application: Refer to label.
Weeds: **Algae control:**

coontail	Najas spp.	pondweeds
elodea		

Remarks: Do not use treated water for irrigation, agricultural sprays, livestock, or domestic purposes for at least 7 to 25 days after treatment. Do not treat more than one-tenth of area at one time with doses in excess of 1 ppm. Fish may be used for food or feed 3 days after treatment. If growth is heavy, treat in strips. Fish may be killed by dosages in excess of 0.3 ppm.

Esteron 99 Concentrate — see 2,4-D

GLYPHOSATE

Used strictly for emergent and floating plant control. Surfactant must be added to Rodeo to insure foliage penetration. Broad spectrum activity. Only restriction is within one-half mile of potable water intakes.

Rodeo
Rate: Boom equipment:
1-5 lb. ai
1.5-7.5 pt./A
Handgun equipment:
0.75%-1.5% solution
Condition of Application: Apply to foliage of emerged weeds. Apply at early growth stages of annual weeds and when perennial weeds are approaching maturity.
Weeds: **Aquatic weeds:**

alligatorweed	maidencane	spatterdock
cattail	paragrass	torpedograss
giant cutgrass	phragmites	willow

Remarks: Always use 0.5% by volume nonionic surfactant. Apply in 3-20 gal. water/A. Rate dependent upon weed species to be controlled as specified on the label. Effective on emerged and floating plants as well as ditchbanks or shoreline aquatic weeds. Not effective on plants which are either completely submerged or have most of their foliage under water. Can be used in and around all bodies of water which may be flowing, nonflowing, or transient. Do not apply within one-half mile upstream of potable water intakes. Do not apply in estuaries.

Hydrothol — see endothall

Rodeo — see glyphosate

SEE 2,4-D — see 2,4-D

SONAR

Primarily used for submersed flowering plant control. Can be applied before or soon after weeds emerge. Slow-acting; effects on plants may not be seen for 30 to 90 days after treatment. However, in some cases, treatment will provide more than one year's control. Must be used as a whole pond treatment.

Sonar A.S., 5P or SRP (fluridone)
Rate: 2 lb. ai/surface A
4 pt. A.S./surface A
40 lb. 5P, SRP/surface A
Condition of Application: Apply prior to initiation of weed growth or when weeds begin actively growing. Under optimum conditions, 30 to 90 days are required before the desired level of aquatic weed management is achieved.
Weeds: **Floating weeds:**
common duckweed
(A.S. only)
Emersed weeds:

spatterdock	waterlily

Submersed weeds:

bladderwort	egeria (Brazilian elodea)	naiad
common coontail	fanwort (Cabomba)	pondweed (except Illinois pondweed)
common elodea	hydrilla	watermilfoil

Shoreline grasses:
paragrass
Vascular aquatic weeds-suppression:

alligatorweed	giant cutgrass	southern watergrass
American lotus	Illinois pondweed	spikerush
cattail	parrotfeather	torpedograss
common watermeal	reed canarygrass	waterpurslane
creeping waterprimrose	smartweed	watershield

Remarks: To achieve satisfactory control, water flow must be restricted for a minimum of 7 days to prevent dilution of Sonar. Use an application pattern that will provide uniform distribution and avoid concentration of the herbicide. Trees and shrubs growing in treated water may be injured. Do not apply in tidewater or brackish water. Do not apply in lakes, ponds, or other bodies of water where crayfish farming is performed. Do not apply this product through any type of irrigation system.

Triangle Brand Copper Sulfate — see copper complex

Weedar — see 2,4-D

MOVING WATER
(Ditchbanks)

COPPER COMPLEXES

Copper sulfate and various chelated copper compounds that are used primarily for algae control. Some of the chelates can also be used for hydrilla and southern naiad control. Copper sulfate is widely used but may not be effective in hard water; the chelates are formulated to provide longer lasting effect in hard water. Copper sulfate and chelates are the only compounds for which there are no restrictions on water use after treatment, with the exception that they should not be used in trout-bearing waters. When used for filamentous algae, good distribution and contact with the mats is essential for optimal control.

Algimycin PLL-C (chelated copper complex)
Rate: 0.42 lb. ai/A ft.
1 gal. PLL-C/A ft.
Calculated Concentration in Water: 0.155 ppm copper equiv.
Condition of Application: Apply when algae first appear and as needed thereafter.
Weeds: **Algae:**

filamentous	planktonic

Remarks: Follow label directions. Treat on calm day when water temperature is 60°F or over. For spot treatment use 2-3 gal./A ft.

Slow Release Algimycin PLL-C (chelated copper complex)
Rate: 1-2 lb. ai/surface A
20-40 lb. PLL-C/surface A
Condition of Application: Apply when algae first appear and repeat as needed.
Weeds: Algae especially chara and nitella.
Remarks: Follow label directions. Use liquid Algimycin PLL-C for surface treatment. Scatter pellets on bottom for long-lasting effect on bottom growing algae.

2,4-D - PHENOXY HERBICIDES

Granular ester formulations are labeled for use on submersed weeds and are particularly effective on Eurasian watermilfoil. Liquid amine formulations are effective for water hyacinth control. Caution should be used when applying liquid ester formulations because they can cause a fish kill. Note restrictions on water use.

'PP-preplant • PPI-preplant incorporated • PRE-preemergence • POST-postemergence • SEQ-sequential
ai-active ingredient DF-dry flowable E/EC-emulsifiable concentrate F/FL-flowable G-granule L/LC-liquid W/WP-wettable powder

Weedar 64 (2,4-D amine)
Rate: 1-2 lb. ai/A
2-4 pt. 64/A
Condition of Application: Apply when weeds are young and growing vigorously.
Weeds: Annual and perennial broadleaf weeds and woody brush.
Remarks: Read and observe precautions and directions on label.
State Restrictions: For use on irrigation canal ditchbanks in Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, New Mexico, Nevada, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, Wyoming.

Rate: 2-4 lb. ai/A
4-8 pt. 64/A
Condition of Application: Spray when waterhyacinths are actively growing.
Weeds: Waterhyacinth.
Remarks: To be applied by federal, state, or local public agency personnel trained in aquatic weed control, or by licensed commercial applicators under contract to the above agencies.

DIQUAT

Primarily used as a contact herbicide for submersed and free-floating aquatic weeds. Only provides short-term top kill on emergent plants such as cattails. A surfactant or spreader should be added to the diquat solution when treating free-floating or emergent weeds. The chemical binds to suspended soil particles; therefore, do not use in or dilute in muddy water. Note 14 day water use restrictions.

Weedtrine-D (diquat)
Rate: 0.5-2 lb. ai/surface A
1.25-5 gal./surface A
Condition of Application: Apply before flowering and repeat as necessary to control regrowth.
Weeds: Aquatic weeds: cattail.
Remarks: Dilute with sufficient water and add nonionic surfactant to spray solution prior to application. Wet foliage thoroughly and avoid drift onto desirable plants.

GLYPHOSATE

Used strictly for emergent and floating plant control. Surfactant must be added to Rodeo to insure foliage penetration. Broad spectrum activity.

Rodeo
Rate: Boom equipment:
1-5 lb. ai/A
1.5-7.5 pt./A
Handgun equipment:
0.75%-1.5% solution
Condition of Application: Apply to foliage of emerged weeds. Apply at early growth stages of annual weeds and when perennial weeds are approaching maturity.
Weeds: **Aquatic weeds:**

alligatorweed	maidencane	spatterdock
cattail	paragrass	torpedograss
giant cutgrass	phragmites	willow

Remarks: Always use 0.5% by volume nonionic surfactant. Apply in 3-20 gal. water/A. Rate dependent upon weed species to be controlled. Effective on emerged and floating plants as well as ditchbanks or shoreline aquatic weeds. Not effective on plants which are either completely submerged or have most of their foliage under water. Can be used in and around all bodies of water which may be flowing, nonflowing, or transient. Do not apply within one-half mile upstream of potable water intakes. Do not apply in estuaries.

Slow Release Algimycin PLL-C — see Copper complex

Weedar — see 2,4-D

Weedtrine D — see diquat

QUIESCENT OR SLOW-MOVING WATER

Algimycin PLL-C — see Copper complex

Aquathol K — see endothall

COPPER COMPLEXES

Copper sulfate and various chelated copper compounds that are used primarily for algae control. Some of the chelates can also be used for hydrilla and southern naiad control. Copper sulfate is widely used but may not be effective in hard water; the chelates are formulated to provide longer lasting effect in hard water. Copper sulfate and chelates are the only compounds for which there are no restrictions on water use after treatment, with the exception that they should not be used in trout-bearing waters. When used for filamentous algae, good distribution and contact with the mats is essential for optimal control.

Algimycin PLL-C (chelated copper complex)
Rate: 0.42 lb. ai/A ft.
1 gal. PLL-C/A ft.
Calculated Concentration in Water: 0.155 ppm copper equiv.
Condition of Application: Apply when algae first appear and repeat as needed.
Weeds: **Algae:**
filamentous planktonic
Remarks: Follow label directions. Treat on calm day when water temperature is 60°F or over. For spot treatment, use 2-3 gal./A ft.

Cutrine-Plus Granular (mixed copper-ethanolamine complexes)
Rate: 2.22 lb. ai/surface A
60 lb. G/surface A
Calculated Concentration in Water: 0.4 ppm within bottom 2 ft. water.
Condition of Application: Apply when algae first appears and repeat as needed.
Weeds: **Algae:**
bottom-growing chara nitella
filamentous algae
Remarks: Treated waters can be used for swimming, fishing, irrigating, or domestic use immediately after treatment. Can be used for spot treatment where localized infestations exist. Heavy infestations should be treated in sections to avoid fish suffocation.

Cutrine-Plus Liquid (mixed copper-ethanolamine complexes)
Rate: 0.54-2.72 lb. ai/A ft.
0.6-3 gal./A ft.
Calculated Concentration in Water: 0.2-1 ppm ai.
Condition of Application: Apply when algae or hydrilla first appears and repeat as needed. For optimum effectiveness, treat under sunny conditions when water temperatures are 60°F or higher.
Weeds: **Algae:**
chara filamentous planktonic
Aquatic weeds: Hydrilla verticillata.
Remarks: Approved for use in crop and noncrop irrigation systems, potable water reservoirs, ponds, lakes, and fish hatcheries. No restrictions or waiting periods on use of treated water. Heavy infestations should be treated in sections to avoid fish suffocation.

Komeen (copper-ethylenediamine complex)
Rate: 4.8-12.8 lb. ai
6-16 gal./surface A
Calculated Concentrations in Water: 0.03-0.04 ppm.
Conditions of Application: Apply when weeds are actively growing and in a manner which will deposit the herbicide on leaf surfaces.
Weeds: **Aquatic weeds:**
egeria (Brazilian elodea) Hydrilla verticillata southern naiad
Remarks: Water may be used for fishing, swimming, irrigation, or domestic use. Refer to label for further use directions.

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K-Tea (copper-triethanolamine complex)
Rate: 0.54-8.16 lb. ai/surface A
0.66-10.2 gal./surface A
Calculated Concentration in Water: 0.2-1 ppm Cu.
Conditions of Application: Apply as soon as first signs of algae appear. If hydrilla is present, apply in bright sunlight.
Weeds: **Free floating algae:**

planktonic:	filamentous:	Hydrilla verticillata
anabaena	chara	
aphanizomenon	chlorella	
dictyosphaerium	cladophora	
euglena	hydrodictyon	
microcystis	oedogonium	
	phormidium	
	spirogyra	

Remarks: Treat one-third to one-half of the water area in a single operation and wait 10 to 14 days between treatments. Refer to label for precautions and limitations.

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Slow Release Algimycin PLL-C (chelated copper complex)
Rate: 1-2 lb. ai/surface A
20-40 lb. PLL-C/surface A
Condition of Application: Apply when algae first appear and repeat as needed.
Weeds: **Algae:**
bottom-growing algae chara nitella
Remarks: Follow label directions. Use liquid Algimycin PLL-C for surface treatment. Scatter pellets on bottom for long-lasting effect on bottom-growing algae.

Cutrine-Plus — see copper complex

2,4-D - PHENOXY HERBICIDES

Granular ester formulations are labeled for use on submersed weeds and are particularly effective on Eurasian watermilfoil. Liquid amine formulations are effective for water hyacinth control. Caution should be used when applying liquid ester formulations because they can cause a fish kill. Note restrictions on water use.

Weedtrine II (2,4-D isooctyl ester)
Rate: 28-56 lb. ai/surface A
100-200 lb./surface A
Condition of Application: Application should be made on smooth surface infested with weeds so granules settle to the bottom around roots and stems.
Weeds: **Aquatic weeds:**
bulrush, coontail, spatterdock, waterlily, watermilfoil
Remarks: Consult your Fish and Game Department or water control agency prior to application. Do not contaminate water in irrigation ditches or for domestic purposes.

DIQUAT

Primarily used as a contact herbicide for submersed and free-floating aquatic weeds. Only provides short-term top kill on emergent plants such as cattails. A surfactant or spreader should be added to the diquat solution when treating free-floating or emergent weeds. The chemical binds to suspended soil particles; therefore, do not use in or dilute in muddy water. Note 14 day water use restrictions.

Valent Diquat Herbicide-H/A
Rate: 2 lb. ai/100 gal. water
1 gal./100 gal. water
Condition of Application: For top kill. Apply before flowering for best results.
Weeds: Cattails.
Remarks: Repeat treatment as necessary to control regrowth.

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Rate: 2-4 lb. ai/surface A
1-2 gal./surface A
Condition of Application: For best results, apply before weed growth reaches surface of water.
Weeds: **Submersed weeds:**
bladderwort, coontail, elodea, naiad, pondweed*, watermilfoil
Algae (0.5-1.5 ppm)
Spirogyra spp., Pithophora spp.
Except P. robbinsii, P. richardsonii in Minnesota
Remarks: Add 1 pt. Valent X-77 Spreader (nonionic) surfactant. Dense weed areas should be treated one part at a time with 14 days between to avoid oxygen depletion with its resultant fish kill. Apply by injecting a diluted (10-20 to 1) solution beneath water surface or by pouring directly from container while moving over surface of water. Do not apply to muddy water. Do not use treated water for animal consumption, spraying, or irrigation within 14 days after treatment.

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Rate: 1-1.5 lb. ai/surface A
0.5-0.75 gal./surface A
Duckweed:
2 lb. ai/surface A
1 gal./surface A
Condition of Application: 0.5 gal. rate used early in season, 0.75 gal. rate used as season progresses and growth thickens.
Weeds: **Floating weeds:**
duckweed, pennywort, salvinia, waterhyacinth, waterlettuce
Remarks: Apply as overall spray, wetting foliage thoroughly. Do not apply to muddy water. For aerial application to waterlettuce, use 7.5 gal. water/A + 1 pt. Valent X-77 Spreader/100 gal. spray solution. Do not use treated water for animal consumption, crop spraying, or irrigation within 14 days after treatment. Application use only by the Corps of Engineers or other federal or state public agencies, or contractors or licensees under their direct control on slow-moving or quiescent waters.

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Rate: 3-4 lb. ai/surface A
1.5-2 gal./surface A
Condition of Application: For best results, apply in spring and summer when weeds are growing rapidly. Timing is enhanced by routine survey of plant development.
Weeds: **Submersed weeds:**
coontail, elodea, hydrilla, naiad, narrowleaf pondweed, watermilfoil
Remarks: Apply as a spray mix with water if necessary to get uniform coverage of treated areas. Thickening agents such as Nalquatic may be added to spray solution to avoid underwater drifts and aid placement on the target plants. Some areas may require a later repeat application if treated early in the spring. Do not apply to muddy water or silt covered plants. Refer to label for directions, restrictions, precautions, and worker safety rules.
State Restrictions: SLN-Alabama, Tennessee.

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Rate: 4 lb. ai/surface A
2 gal./surface A
Weeds: **Submersed weeds:**
bladderwort, coontail, elodea, hydrilla, naiad, pondweeds (except P. robbinsii), watermilfoil

Rate: 1-1.5 lb. ai/surface A
0.5-0.75 gal./surface A in 150 gal. water
Weeds: **Floating weeds:**
salvinia, waterhyacinth, waterlettuce

Rate: 2-4 lb. ai/surface A
1-2 gal./surface A in 50-150 gal. water
Weeds: Floating weeds: duckweed.

Rate: 2 lb. ai/surface A
1 gal./surface A in 100 gal. water
Weeds: Marginal weeds: cattails, pennywort.
Remarks: Add 1 pt. Valent X-77 Spreader (nonionic). Repeat treatments will be necessary to control regrowth. For best results, apply before flowering. Do not use treated water for animal consumption, drinking purposes, overhead irrigation or spraying within 14 days after treatment unless an approved analysis shows that the water does not contain more than 0.01 ppm Diquat ion. Do not use dirty or muddy water for Diquat dilution as Diquat will be inactivated. Refer to label for directions, restrictions, precautions, and worker safety rules.
State Restrictions: SLN-Florida.

Weedtrine-D
Rate: 1-4 lb. ai/surface A
2.5-10 gal./surface A
Condition of Application: Apply when weeds are actively growing but before weed growth has reached water surface.
Weeds: **Aquatic weeds:**
bladderwort, cattails, coontail, duckweed, elodea, naiad, pennywort, pondweeds, salvinia, waterhyacinth, waterlettuce
Remarks: Refer to label for specific label rates to control weeds listed. Do not use treated water for drinking, irrigating, spraying, animal consumption, or domestic purposes for 14 days, or swimming for 24 hours after treatment.

DIQUAT TANK MIX

(active ingredient per acre)

PRODUCT	TIMING/REMARKS
Valent Diquat 20 lb. + **Komeen** 16 lb.	SLN-Florida: Hydrilla.

GLYPHOSATE

Used strictly for emergent and floating plant control. Surfactant must be added to Rodeo to insure foliage penetration. Broad spectrum activity. Only restriction is within one-half mile of potable water intakes.

Rodeo
Rate: Boom equipment:
1-5 lb. ai/A
1.5-7.5 pt./A
Handgun equipment:
0.75%-1.5% solution

PP-preplant • PPI-preplant incorporated • PRE-preemergence • POST-postemergence • SEQ-sequential
ai-active ingredient DF-dry flowable E/EC-emulsifiable concentrate F/FL-flowable G-granule L/LC-liquid W/WP-wettable powder

Condition of Application: Apply to foliage of emerged weeds. Apply at early growth stages of annual weeds and when perennial weeds are approaching maturity.

Weeds: **Aquatic weeds:**

alligatorweed	maidencane	spatterdock
cattail	paragrass	torpedograss
giant cutgrass	phragmites	willow

Remarks: Always use 0.5% by volume nonionic surfactant. Apply in 3-20 gal. water/A. Rate dependent upon weed species to be controlled. Effective on emerged and floating plants as well as ditchbanks or shoreline aquatic weeds. Not effective on plants which are either completely submerged or have most of their foliage under water. Can be used in and around all bodies of water which may be flowing, nonflowing, or transient. Do not apply within one-half mile upstream of potable water intakes. Do not apply in estuaries.

Komeen — see copper complex

K-Tea — see copper complex

Rodeo — see glyphosate

Slow Release Algimycin — see copper complex

Weedar — see 2,4-D

Weedtrine II — see 2,4-D

NOTICE The information on these pages is for preliminary planning — not a guide for use. Be sure to follow manufacturer's directions, notwithstanding information contained here.

NONCROPLAND

ACCESS (Premix)

Restricted Use Pesticide.

Access Herbicide (1 lb./gal. picloram & 2 lb./gal. triclopyr)

Rate: Conventional basal bark treatment: 1-2 gal./100 gal. spray mixture; low volume: 20-30 gal./100 gal. spray mixture

Weeds: **Woody plants:**

ash	hickory	oceanspray
aspen	locust	pine
birch	maple	poplar
cherry	multiflora rose	sassafras
elm	oak	tanoak
hackberry		

Remarks: Apply in enough oil to make 100 gal. spray mixture at any time, including the winter months, except when snow or water prevent spraying to the ground line. Best control will be obtained when applications are made during the late dormant or active growing season. Apply to stems with basal diameter less than 6". For conventional basal bark treatment, thoroughly wet to basal part of brush and tree stems (including the root collar) and spray until runoff is noticeable. For low volume basal bark treatment, spray the basal parts of brush and tree stems in a manner which thoroughly wets the lower stem (including the root collar) but not to the point of runoff. For thinline basal bark treatment, apply undiluted in a thin stream to form a narrow band which completely encircles the lower stem of brush and tree species. Refer to label for precautions.

Areas of Application: Electrical power lines, pipelines, roadside, and railroad rights-of-way; storage sites, fence rows, and other noncrop areas.

AMITROLE

Restricted Use Pesticide.

Amitrol T
AT-Liquid

Rate: 2-4 lb. ai/A
1-2 gal./A

Weeds: **Annual broadleaf weeds:**

Canada thistle	milkweed	volunteer alfalfa
dock	pigweed	whitetop (hoary cress)
horsenettle	poison ivy	wild barley
horsetail rush	poison oak	wild chrysanthemum
kochia	sowthistle	wild hemp (marijuana)
leafy spurge (Western States)	sunflower	

Annual grasses:

annual bluegrass	foxtail	reed canarygrass*
barnyardgrass	nutsedge	ripgutgrass*
bermudagrass	quackgrass (couchgrass)	ryegrass
cheatgrass		witchgrass

Woody plants:

ash	honeysuckle	salmonberry
bigleaf maple	kudzu	sumac
blackberry	locust	wild cherry

** Suppression*

Remarks: Apply in 40-100 gal. water. A second treatment may be needed to control weeds not thoroughly sprayed or coming from dormant seeds or old roots. Apply when regrowth is young and growing actively. Do not spray or allow drift to edible crops or water for irrigation, drinking, or domestic purposes.

Areas of Application: Railroads, roadsides, fence rows, and hardwood nurseries.

Amizol (90WP)
AT-90 (90WP)

Rate: 1.8-9 lb. ai/A
2-10 lb. 90WP/A

Weeds: **Broadleaf weeds:**

alfalfa	hempnettle	purslane
Canada thistle	jimsonweed	ragweed
carpetweed	knotweed	shepherdspurse
catchfly	kochia	smartweed
chickweed	lambsquarters	sowthistle
chrysanthemum weed (mugwort)	mustard	stinkweed
cocklebur	nightshade	white cockle
dandelion	pigweed	wild buckwheat
groundsel	plantain	yellow rocket
	poison ivy	

Grasses:

bluegrass	foxtail	velvetgrass
crabgrass	goosegrass	wild oat
downy brome (cheat)	quackgrass	witchgrass

Remarks: Apply in 100 gal. water when most weeds are 3"-10" tall. Of used in combinations for improved kill of deep-rooted perennials and ra knockdown of existing vegetation.

Areas of Application: Roadsides, ditchbanks, fence rows, industrial are public utilities, railroads.

ARSENAL

Broad-spectrum systemic herbicide with residual activity.

Arsenal (imazapyr)

Rate: Annual grasses, broadleaves:
0.5-1 lb. ae/A
2-4 pt./A
Perennial grasses, broadleaves, vines, brambles:
0.5-1.5 lb. ae/A
2-6 pt./A
Deciduous trees:
1-1.5 lb. ae/A
4-6 pt./A

Weeds: **Broadleaf weeds:**

broom snakeweed	horseweed	rush skeletonweed
bull thistle	Indian mustard	Russian thistle
burdock	Japanese bamboo	Russian knapweed*
camphorweed	kochia	saltbush
Canada thistle	lambsquarters	silverleaf nightshade
Carolina geranium	lespedeza	smartweed
carpetweed	little mallow	sorrel
clover	milkweed	sowthistle
cocklebur	minerslettuce	stinging nettle
common chickweed	mullein	sunflower
common ragweed	nettleleaf goosefoot	sweet clover
dandelion	oxeye daisy	tansymustard
desert camelthorn	pepperweed	Texas thistle
diffuse knapweed	pigweed	western ragweed
dock	plantain	wild carrot
dogfennel	pokeweed	wild lettuce
filaree	primrose	wild parsnip
fleabane	puncturevine	wild turnip
giant ragweed	purple loosestrife	woollyleaf bursage
goldenrod	purslane	yellow starthistle
hoary vervain		yellow woodsorrel

Grasses:

annual bluegrass	feathertop	quackgrass
bahiagrass	fescue	reed canarygrass
beardgrass	foxtail	saltgrass
bermudagrass	goosegrass	sand dropseed
big bluestem	guineagrass	sandbur
broadleaf signalgrass	Italian ryegrass	smooth brome
Canada bluegrass	johnsongrass	timothy
cattail	Kentucky bluegrass	torpedograss
cheat	lovegrass	vaseygrass
cogongrass	orchardgrass	Virginia creeper
crabgrass	paragrass	wild barley
dallisgrass	phragmites	wild oat
downy brome	prairie cordgrass	wirestem muhly
fall panicum	prairie threeawn	witchgrass

Vines and brambles:

blackberry	kudzu	trumpetcreeper
dewberry	Macartney rose	Virginia creeper
field bindweed	morningglory	wild buckwheat
greenbriar	multiflora rose	wild grape
hedge bindweed	poison ivy	wild rose
honeysuckle	redvine	

Woody brush and trees:

American beech	hawthorn	rubber rabbitbrush
ash	hickory	Russian olive
baldcypress	maple	saltcedar
bigleaf maple	mulberry	sassafras
blackgum	oak	sourwood
boxelder	persimmon	sumac
cherry	poplar	sweetgum
chinaberry	privet	willow
Chinese tallow-tree	red alder	yellow poplar
dogwood	red maple	

PP-preplant • PPI-preplant incorporated • PRE-preemergence • POST-postemergence • SEQ-sequential
ai-active ingredient DF-dry flowable E/EC-emulsifiable concentrate F/FL-flowable G-granule L/LC-liquid W/WP-wettable powder

Remarks: Arsenal is readily absorbed by both the roots and foliage providing both preemergent and postemergent control of weeds. Postemergence application is the recommended method, particularly for the control of perennials. The excellent soil residual activity provides preemergent control of newly germinating weeds for several months after application. Although the compound is translocated quickly, kill of treated plants is slow. Biotypes of kochia have been identified that are not adequately controlled with Arsenal. Use of Arsenal in combination with other registered herbicides that have a different mode of action is recommended for controlling these biotypes. Control of kudzu requires a minimum 75 gal./A total solution and may require multiple applications.
Areas of Application: Railroad, utility, and pipeline rights-of-way; utility plant sites; petroleum tank farms; pumping installations; fence rows; nonirrigation ditchbanks; and storage areas.

Arsenal 0.5 Granule (Imazapyr)
Rate: 1 lb. ai/A
200 lb. 0.5G/A
Weeds: Same control as for Arsenal. Vines, brambles, woody brush and trees and the following broadleaf weeds which are not listed on current label:

broom snakeweed	Japanese bamboo	rush skeletonweed
bull thistle	kochia	Russian knapweed
burdock	lespedeza	Russian thistle
desert camelthorn	puncturevine	saltbush
diffuse knapweed	purple loosestrife	stinging nettle
goldenrod		

Grasses:

cogongrass	phragmites	saltgrass
feathertop	reed canarygrass	Virginia creeper

Remarks: Apply any time during the growing season before weeds have emerged. Treated plants stop growing soon after spray application. Biotypes of kochia have been identified that are not adequately controlled with Arsenal. Use of Arsenal in combination with other registered herbicides that have a different mode of action is recommended for controlling these biotypes.
Areas of Application: Railroad, utility, pipeline, and highway rights-of-way, petroleum tank farms, pumping installations, fence rows, storage areas.

Arsenal Applicators Concentrate (Imazapyr)
Rate: 0.375-1.25 lb. ai/A
0.75-2.5 pt. AS/A
Weeds: Same as for Arsenal.
Remarks: Rate varies by species of conifer being managed and by purpose of application (site preparation, herbaceous weed control, conifer release). Arsenal is readily absorbed by both the roots and foliage providing both preemergent and postemergent control of weeds. Applications can be made during the growing season after leaves have attained full flush up to color change in late summer or early fall. Some minor growth inhibition may be observed when release treatments are made during period of active conifer growth. Although the compound is translocated quickly, kill of treated plants is slow. The degree of control on blackberries is species dependent. Control of kudzu requires a minimum of 75 gal./A total solution and may require multiple applications.
Areas of Application: Forest roads, forestry site preparation, conifer release from woody and herbaceous competition, non-irrigation ditchbanks and the establishment and maintenance of wildlife openings.

Ansar 6.6 — see MSMA

ASULOX

Asulox 3.34 WS (asulam)
Rate: 3.34-6.68 lb. ai/A
1-2 gal. 3.34 WS/A
Weeds: **Grasses:**

crabgrass	paragrass	western bracken
johnsongrass		

Remarks: Apply postemergence.
Areas of Application: Boundary fences; ditchbanks; fence rows; highway, roadside, pipeline, railroad, and utility rights-of-way; lumberyards; storage areas; industrial plant sites; warehouse lots.

ATRAZINE

Restricted Use Pesticide due to groundwater concerns.

AAtrex 4L or Nine-0
Atratol 4LC or 90
Drexel Atrazine 4L or 90
Rate: 4.8-10 lb. ai/A
4.8-10 qt. 4L, 4LC/A
3.8-8 qt. 5L/A
6-12.5 lb. 80/A
5.3-11.1 lb. Nine-0, 90/A

Weeds: **Annual broadleaf weeds:**

lambsquarters	ragweed	turkey mullein
puncturevine		

Grasses:

barnyardgrass	crabgrass	foxtail
cheatgrass		

Rate: 10-20 lb. ai/A
10-20 qt. 4L, 4LC/A
8-16 qt. 5L/A
12.5-25 lb. 80/A
11.1-22.2 lb. Nine-0, 90/A
Weeds: **Annual and many perennial broadleaf weeds such as:**

burdock	dogfennel	purpletop
Canada thistle	plantain	redtop

Grasses:

bluegrass	quackgrass	smooth brome
orchardgrass		

Rate: 20-40 lb. ai/A
20-40 qt. 4L/A
16-32 qt. 5L/A
25-50 lb. 80/A
22-44 lb. Nine-0, 90/A
Weeds: Hard-to-kill biennial and perennial weeds such as bull thistle and sowthistle.
Remarks: Apply these rates for longer residual control in areas of high rainfall and a long growing season. Apply before or soon after weeds begin growth. Postemergence applications should be made when weeds are young and actively growing. Use the higher rates on heavy clay and muck soils. Use sufficient water to assure thorough coverage. Use at least 1 gal. water/qt. or lb. of product, more if practical. Do not exceed 10 lb. ai/A per year. Do not allow livestock to graze treated areas or illegal residues may result.
Areas of Application: Noncrop areas such as utility, highway, pipeline, and railroad rights-of-way, petroleum tank farms, lumberyards, storage areas, industrial plant sites, and around buildings.

ATRAZINE TANK MIXES

(active ingredient per acre)

PRODUCT	TIMING/REMARKS
Atratol 90 4-10 lb. + **Arsenal** 0.5-1.5 lb.	For use only in states where registered.
Atratol 90 4-10 lb. + **Karmex** 4-10 lb.	For use only in states where registered.
Atratol 90 2.6-10 lb. + **Princep** 2.6-10 lb.	For use only in states where registered.

BANVEL HERBICIDE

Banvel Herbicide (DMA salt of dicamba)
Rate: Cut surface treatments: 1 part Banvel with 1 to 3 parts water. Use the lower dilution when treating hard-to-control species.
Weeds: **Woody brush and trees such as:**

ash	cedar	serviceberry
aspen	elm	sycamore
basswood	hickory	

Remarks: Frill or girdle treatments should be overlapping or continuous. 2,4-D may be added for more rapid foliar effects.
Areas of Application: Forest and noncrop areas including fence rows and rights-of-way.

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Rate: Annuals:
0.25-0.75 lb. ai/A
0.5-1.5 pt./A
Biennials:
0.25-1.5 lb. ai/A
0.5-3 pt./A
Perennials:
0.5-6 lb. ai/A
1-12 pt./A
Weeds: **Annual, biennial, and perennial broadleaf weeds including:**

burdock	kochia	Russian thistle
Canada thistle	leafy spurge	tansy ragwort
field bindweed	pigweed	

Remarks: Apply in 5-600 gal. diluted spray/A with ground equipment; 3-40 gal. diluted spray/A by air. Apply when weeds are actively growing and when biennials are in the rosette stage. Retreatment may be made as needed, but do not exceed 8 lb. ai (2 gal.)/A during a growing season.
Areas of Application: Noncrop areas such as fence rows, roadways, wasteland, and rights-of-way.

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Rate 0.5-8 lb. ai/A
1-16 pt./A
Weeds: **Many woody brush and vine species including:**

ash	fringed sagebrush	multiflora rose
aspen	honeysuckle	sumac
blackberry	huisache	tarbush
blackgum	kudzu	trumpetcreeper
creosotebush	Macartney rose	willow
dewberry	mesquite	yaupon
eastern persimmon		

Remarks: Apply any time after leaf development. Retreatment may be made as needed, but do not exceed 8 lb. ai (2 gal.)/A during a growing season.
Areas of Application: Noncrop areas such as fence rows, roadways, wasteland, and rights-of-way.

BANVEL

Banvel CST (dicamba)
Rate: Product requires no dilution or mixing. Apply to freshly cut surface. Frill, girdle, or stump treatments: spray or paint freshly cut surface until wet.
Weeds: **Woody brush and trees such as:**

ash	cedar	hickory
aspen	dogwood	serviceberry
basswood	elm	sycamore

Remarks: Frill or girdle treatments should be overlapping or continuous.
Areas of Application: Forest and noncrop areas including fence rows, drainage ditchbanks, and rights-of-way.

BROMAX

Bromax 4G (bromacil)
Rate: 2.4-4.8 lb. ai/A
60-120 lb. 4G/A
Weeds: **Broadleaf weeds:**

lambsquarters	puncturevine	turkey mullein
pigweed	ragweed	

Grasses:

bromegrass	crabgrass	ryegrass
cheatgrass	foxtail	wild oat

Rate: 5.6-9.6 lb. ai/A
140-240 lb. 4G/A
Weeds: **Broadleaf weeds:**

aster	dogfennel	purpletop
broomsedge	goldenrod	redtop
dandelion	plantain	

Grasses:

bahiagrass	quackgrass	wild carrot
bluegrass	smooth brome	

Brush (broadcast treatment):

oak	sweetgum	willow
pine		

Rate: 12-24 lb. ai/A
300-600 lb. 4G/A
Weeds: **Difficult-to-control broadleaf weeds:**

bouncingbet	brackenfern	dogbane

Difficult-to-control grasses:

bermudagrass	johnsongrass	saltgrass
dallisgrass	nutgrass	vaseygrass

Brush:

American elm	hackberry	winged elm
cottonwood	sumac	

Rate: 1.25-2.5 oz. product/stem 2"-4" in basal diameter
Weeds: **Brush:**

cottonwood	poplar	wild cherry
hackberry	redbud	willow
maple	sweetgum	winged elm
oak		

Remarks: Apply in spring or summer as a broadcast or basal (spot) treatment. Length of control depends on type of soil and rainfall conditions. Best results are obtained if applied when or shortly before plant growth starts. Rain or thorough watering after application will cause material to move to root zone and thus speed up control. Do not apply when ground is frozen. Do not apply or allow to drift onto desirable vegetation. Do not apply to brush standing in water or use on rights-of-way or other sites where marketable timber or other desirable trees or shrubs are immediately adjacent to the treated area. Refer to label before use. Use the higher rates on absorptive soils (those high in organic matter or carbon).
Areas of Application: Rights-of-way, industrial plants, lumberyards, tank farms, storage areas, around buried cable closures, transformer pads, and other noncrop areas.

Bromax 4L (bromacil)
Rate: 2.5-5 lb. ai/A
2.5-5 qt. 4L/A
Weeds: **Broadleaf weeds:**

lambsquarters	puncturevine	turkey mullein
pigweed	ragweed	

Grasses:

bromegrass	foxtail	ryegrass
cheatgrass	orchardgrass	wild oat
crabgrass		

Rate: 6-10 lb. ai/A
1.5-2.5 gal. 4L/A
Weeds: **Broadleaf weeds:**

aster	dogfennel	purpletop
broomsedge	goldenrod	redtop
dandelion	plantain	

Grasses:

bahiagrass	quackgrass	wild carrot
bluegrass	smooth brome	

Rate: 12-24 lb. ai/A
3-6 gal. 4L/A
Weeds: **Difficult-to-control broadleaf weeds:**

bouncingbet	dogbane	horsetail
brackenfern		

Difficult-to-control grasses:

bermudagrass	johnsongrass	saltgrass
dallisgrass	nutgrass	vaseygrass

Brush-broadcast treatment:

American elm	hackberry	winged elm
cottonwood	sumac	

Rate: 4.8-10 lb. ai/A
1.2-2.5 gal. 4L/A
Weeds: **Brush:**

oak	sweetgum	willow
pine		

Rate: Basal (spot) treatment-diluted: mix 0.5 gal. product in 5 gal. water; apply 1-2 fl. oz./stem 2"-4" in basal diameter, wet base of stem to runoff. Basal (spot) treatment-undiluted: apply with an exact delivery handgun applicator at the rates of 2.5-5 milliliters/stem 2"-4" in basal diameter
Weeds: **Woody plants-diluted treatment:**

cottonwood	poplar	wild cherry
hackberry	redbud	willow
maple	sweetgum	winged elm
oak		

Woody plants-undiluted treatment:

American elm	oak	sweetgum
cottonwood	poplar	wild cherry
maple	sumac	willow

Remarks: Apply in spring or summer as a broadcast or basal (spot) treatment. Length of control depends on type of soil and rainfall conditions. Best results are obtained if applied at or shortly before plant growth begins. Rain or thorough watering after application will cause the material to move to the root zone and thus speed up control. Do not apply when ground is frozen. Do not apply or allow to drift onto desirable vegetation. Do not apply to brush standing in water, or use in rights-of-way or other sites where marketable timber or other desirable trees or shrubs are immediately adjacent to the treated area. Refer to label before use. For brush control, use the higher rates on absorptive soils (those high in organic matter or carbon). Direct delivery of solution at the base of the brush (root collar area). When treating large stems and more than one delivery of solution is needed per stem, apply on the opposite side of the stem.
Areas of Application: Rights-of-way, industrial plants, lumberyards, tank farms, storage areas, and other noncrop areas.

Bueno 6 — see MSMA

Casoron — see dichlobenil

CHOPPER

Chopper (2EC) (imazapyr)
Rate: 0.125-0.188 lb. ai/1 gal. solution
8-12 fl. oz. 2EC/1 gal. solution
Weeds: **Broadleaf weeds:**

ash	hickory	oak
cherry	maple	poplar
dogwood	mulberry	prickly wild rose
hawthorn	multiflora rose	privet

PP-preplant • PPI-preplant incorporated • PRE-preemergence • POST-postemergence • SEQ-sequential
ai-active ingredient DF-dry flowable E/EC-emulsifiable concentrate F/FL-flowable G-granule L/LC-liquid W/WP-wettable powder

red maple	sumac	willow
sassafras	sweetgum	

Remarks: Chopper may be applied in one gal. water, diesel oil or penetrating oil such as Cide-Kick, Cide-Kick II, or Arborchem Basal Oil. Use water as a diluent only when temperatures are sufficient to prevent freezing.
Chopper applications may be made as cut stump, tree injections, frill or girdle or as low volume basal bark treatments. Do not use on food or feed crops. Do not apply on ditches used to transport irrigation water. Do not use on lawns, driveways, tennis courts, or similar areas.
Areas of application: For control of brush in noncropland areas such as railroad, utility, and pipeline rights-of-way, utility plant sites, petroleum tank farms, pumping installations, fence rows, storage areas, nonirrigation ditchbanks, and other similar areas.
State Restrictions: Not for use in California.

Chopper RTU (imazapyr)
Rate: Apply undiluted as basal or cut stump treatment.
Weeds: **Broadleaf weeds:**

ash	live oak	sassafras
aspen	maple	sumac
Autumn olive	multiflora rose	sweetgum
bigleaf maple	persimmon	tulip poplar
black cherry	red alder	turkey oak
boxelder	red oak	water oak
cottonwood	Russian olive	white oak
hickory	saltcedar	willow
laurel oak		

Remarks: For brush with 4" DBH stems, throughly wet the lower 12"-18" of the stem bark. For stems greater than 4" DBH, spray or brush undiluted solution onto the cambium area of the freshly cut stump surface and the bark of the cut stump.
Areas of application: For control of brush in noncropland areas such as railroad, utility, and pipeline rights-of-way, utility plant sites, petroleum tank farms, pumping installations, fence rows, storage areas, nonirrigation ditchbanks, and other similar areas.
State Restrictions: Not for use in California.

CLOPYRALID

Transline
Rate: 0.1-0.5 lb. ae/A
0.25-1.33 pt./A
Weeds: **Annual and perennial broadleaf weeds such as:**

buckwheat	knapweeds	sunflower
chamomile	ragweed	thistles
clover	smartweed	vetch

Remarks: Apply broadcast or as spot treatment. Best results are achieved when applied to actively growing weeds. Do not apply in drought situations. Do not apply by aircraft. Do not apply to soils having a rapid to very rapid permeability, where a shallow aquifer exists, or to soils containing sinkholes over limestone bedrock or fractured surfaces.
Areas of Application: Rights-of-way, industrial sites, and noncrop areas.

COTTON-AIDE

Cotton-Aide HC (cacodylic acid)
Rate: 3.25 lb. ai/A
1 gal. HC/A
Weeds: Nonselective general weed control.
Remarks: Apply in 65-80 gal. water/A. Spray undesirable vegetation to runoff. Use with additional surfactant or crop oil concentrate to enhance weed control in arid regions. Do not apply through any type of irrigation system.
Areas of Application: Noncrop areas such as rights-of-way, equipment yards, fence rows, and drainage ditchbanks.

CROSSBOW (Premix)

Crossbow (1 lb./gal. triclopyr & 2 lb./gal. 2,4-D)
Rate: High volume applications through handguns, apply as a foliar wetting spray containing 1-1.5 gal. product/100 gal. total spray. Broadcast treatment: 1.5-4 gal. product in sufficient water to deliver 15-30 gal. spray/A with ground equipment.
Weeds: **Woody plants:**

alder	ceanothus	pine
ash	cherry (except black)	poison ivy
aspen	elderberry	poison oak
birch	elm	Russian olive
black locust	hazel	sassafras
blackberry	honeysuckle	Scotch broom
boneset	maple	sumac
buckbrush*	multiflora rose	sweetgum
sycamore	tanoak	willow
tamarack	white oak	

** Suppression*

Remarks: Use the lower rates for more sensitive species such as blackberry and willow and the higher rates and spray volumes for more tolerant species such as ash, oaks and maples.
Areas of Application: Fence rows, non-irrigation ditchbanks, roadsides, noncrop areas, industrial sites.

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Rate: Broadcast treatment: 2-4 qt. product/A
Weeds: **Broadleaf weeds:**

annual fleabane	dandelion	oxalis
bedstraw	dogfennel*	plantain
broadleaf plantain	field pennycress	pokeweed
bull thistle	goldenrod*	redroot pigweed
burdock	hemp sesbania	sunflower
buttercup	horsenettle*	tall ironweed
Canada thistle (top growth)	horseweed (marestail)	tansy ragwort
	kochia*	vetch
clover	marshelder	wild carrot (Queen Anne's lace)
cocklebur	milkweed*	
common lambsquarters	mouseear chickweed	wild mustard
common ragweed	musk thistle	wild violet
curly dock		

** Suppression*

Remarks: Apply in sufficient water needed for uniform coverage.
Areas of Application: Fence rows, roadsides, noncrop areas, industrial sites.

2,4-D - PHENOXY HERBICIDES

2,4-D and 2,4-D-type compounds selectively control broadleaf weeds with little or no control of grasses. 2,4-D drift can injure adjacent crops either by drift of spray or by volitalization (the spray turns into a vapor). Ester formulations are most volatile and the amines least volatile. Ester formulations can vaporize at temperatures as low as 70°F and moved by wind to harm sensitive plants. Vaporization increases as air temperatures rise.

Annual and perennial broadleaf weeds controlled by 2,4-D including:

alfalfa	dogbane	mugwort artemisia
annual chickweed	dwarf mallow	mustard
annual sowthistle	European bindweed	nettles
annual yellow sweetclover	falseflax	orange hawkweed
	fanweed	pennycress
aster	fiddleneck	pennywort
Austrian fieldcress	field bindweed (creeping jenny)	peppergrass
beggarticks		pepperweed (except perennial)
bitterweed	flixweed	
black medic	flower-of-an-hour	perennial sowthistle
blackeyedsusan	frenchweed	plantain
blue lettuce	galinsoga	poison ivy
broomweed	giant ragweed	poorjoe
buckhorn plantain	goatsbeard	prickly lettuce
bull thistle	goldenrod	primrose
burdock	goosefoot	puncturevine
Canada thistle	gooseweed	ragweed
carpetweed	ground ivy	rough fleabane
catchweed bedstraw	groundsel	rushes
catnip	gumweed	Russian thistle
chickweed	hairy galinsoga	Scotch thistle
chicory	healall	shepherdspurse
cinquefoil	hedge bindweed	slender aster
clover	hemlock	sneezeweed
cockle	hemp	snow-on-the-mountain
cocklebur	henbit	sour dock
coffeebean	hoary cress	spanishneedles
coffeeweed	horsenettle	spikerush
common artemisia	ironweed	spiny sowthistle
common broomweed	ivyleaf morningglory	spurge
common burdock	Jerusalem artichoke	St. Johnswort
common cocklebur	jewelweed	starthistle
common eveningprimrose	jim hill mustard	stinging nettle
	jimsonweed	sumac
common lambsquarters	knapweed	sunflower
common morningglory	knotweed	tall buttercup
common ragweed	lambsquarters	tansy mustard
common salsify	leafy spurge	tansy ragwort
common sowthistle	locoweed	tanweed
curly dock	mallow	Texas croton
curly indigo	manyflowered aster	toadflax
daisy fleabane	marestail	tumbling pigweed
dandelion	marshelder	velvetleaf
dayflower	mexicanweed	Venice mallow
devilsclaw	milkweed	vervain
dock	morningglory	vetch

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western ironweed	wild onion	woolly croton
western ragweed	wild parsnip	woolly morningglory
western salsify	wild radish	wormwood
whitetop	wild sweet potato	yankeeweed
wild carrot	wild turnip	yarrow
wild cucumber	willow	yellow rocket
wild garlic	wintercress	yellow starthistle
wild lettuce	witchweed	

Decamine 4D (2,4-D amine)
Rate: General weed control:
0.9-1.8 lb. ai/A
1-2 qt./A
Woody plant control:
3.6-5.4 lb. ai/A
4-6 qt./A
Remarks: Apply in 100 gal. water in the spring and early summer. Thoroughly wet all parts of the plant to point of runoff. Do not treat during periods of severe drought. Refer to label for further use directions.
Areas of Application: Waste areas or noncrop areas such as powerlines and highway rights-of-way, vacant lots, fence rows, roadsides, and around buildings.

Esteron 99 Concentrate
Hi-Dep (2,4-D mixed amine)
Weed Rhap A-4D or LV-4D (2,4-D amine or ester)
Rate: 1-3 lb. ai/A
2-6 pt./A
Remarks: By air, apply not less than 2 qt. total spray solution/A; by ground equipment, mix with water to spray 1-10 gal. total spray solution. Do not use on dichondra or other herbaceous ground covers. Do not use on creeping grasses such as bent except for spot treating nor on freshly seeded turf until grass is well established. Do not use on alfalfa, clover, or other legumes. Reseeding of lawns should be delayed following treatment. With spring application, reseed in the fall. With fall application, reseed in the spring. Legumes are usually damaged or killed. Deep rooted perennial weeds such as bindweed and Canada thistle may require repeated applications.
Areas of application: Golf courses, cemeteries, parks, airfields, roadsides, vacant lots, drainage ditchbanks.

SEE 2,4-D (2,4-D LV ester)
Rate: 2-3 lb. ai/A
4-6 pt./A
Remarks: Apply in 100 gal. water/A. Higher volumes of up to 400 gal./A are necessary where the brush is very dense and over 6 ft. to 8 ft. high. Hard-to-control species may require retreatment next season.
Areas of Application: Airfields, roadsides, vacant lots, drainage ditchbanks, fence rows, industrial sites, and other noncrop areas.

Weedar 64 (2,4-D amine)
Weedone LV4 (2,4-D butoxyethyl ester)
Rate: 1-4 lb. ai/A
2-8 pt. 64 or LV4/A
Remarks: Apply when annuals are young and growing vigorously; when biennials and perennials are actively growing and near the bud stage but before flowering, and when woody species are in full leaf and growing actively.
Areas of Application: For use on fence rows, roadsides, drainage ditchbanks, highway rights-of-way.

Weedone 638 (2,4-D ester + acid)
Rate: 1-3 lb. ai/A
1.33-4 qt. 638/A
Weeds: **Many broadleaf weeds including:**

camelthorn	hoary cress	nutgrass
Canada thistle	leafy spurge	Russian knapweed
field bindweed	lotus	tansy ragwort

Remarks: Apply in 150-300 gal. total spray volume when temperatures are lower than 80°F-85°F.
Areas of Application: For use on roadsides, fence rows, and drainage ditchbanks.

Weedone 2,4-DP (dichlorprop butoxyethanol ester)
Rate: 0.5-12 lb. ai/A
0.5-12 qt./A
Weeds: **Woody brush:**

black locust	hickory	sassafras
boxelder	maple	sumac
cherry	oak	sweetgum
chinquapin	persimmon	wax myrtle
conifer	sandsage	

Remarks: Apply in oil and water. Refer to label for techniques and rates.
Areas of Application: Utility rights-of-way, highways, railroads, drainage ditchbanks, and firebreaks; also pine release.

2,4-D COMBINATIONS

Acme Brush Killer 875 (2,4-D & MCPP & dicamba)
Acme Super Brush Killer (2,4-D & 2,4-DP & dicamba)
Rate: High volume:
0.5-1 gal. product/100 gal. water at 100 to 300 gal./A
Weeds: **Broadleaf weeds:**

bedstraw	kochia	ragweed
bindweed	lambsquarters	sheep sorrel
black medic	leafy spurge	shepherdspurse
buckhorn	lespedeza	smartweed
burdock	mallow	speedwell
chickweed	morningglory	spurge
chicory	mustard	sunflower
clover	nettles	thistles
cocklebur	oxalis	trumpetvine
dandelion	peppergrass	velvetleaf
dock	pigweed	wild carrot
ground ivy	plantain	wild garlic
healall	poison ivy	wild lettuce
henbit	poison oak	wild onion
jimsonweed	purslane	yarrow
knotweed		

Brush:

ash	cottonwood	oak
aspen	dogwood	pine
birch	elm	shortleaf pine
black cherry	gooseberry	spruce
black locust	honey locust	sumac
brambles	honeysuckle	sycamore
buckbrush	kudzu	wild plum
cedar	maple	willow
cherry	multiflora rose	

Remarks: Apply when plants come into full leaf (spring) to the time plants begin to go dormant. Best results are obtained when weeds are young and actively growing. Avoid spray drift to sensitive crops.
Areas of Application: Roadsides, rights-of-way, drainage ditchbanks, railroads, firebreaks, forests, fencerows, industrial sites, and other similar noncrop areas.

Envert 171 (2,4-D & 2,4-DP ester)
Rate: 6.75-22.5 lb. ai/A
3-10 gal. 171/A
Weeds: **Mixed woody brush including:**

blackgum	locust	sassafras
conifers	oak	sumac
elm	red maple	

Remarks: For creating an invert emulsion or conventional spray. Use the higher rate on dense and tall (25 ft.-30 ft.) brush or where conifers are to be controlled. Apply through helicopter mounted Spra-Disk or through ground mechanical invert system such as the Wanner sprayer.
Areas of Application: For use on utility rights-of-way, roadsides, drainage ditchbanks, and similar areas.

Weedone CB (2,4-D & 2,4-DP)
Rate: 2-10 lb. ai/A
1-5 gal. CB/A
Weeds: Over 100 species of woody plants such as:

ailanthus	oak	red maple
blackgum	osageorange	sassafras
cherry	pine	sumac
hickory	poison ivy	sweetgum

Remarks: Weedone CB is a ready-to-apply formulation of 2,4-D & dichlorprop plus a penetrant for use as a basal or stump treatment for controlling unwanted woody plants. Rate varies depending on amount and size of brush in the treated area. Do not dilute with water. May be applied any time of year whether plants are actively growing or dormant. Weedone CB can be tank mixed with triclopyr, picloram, or dicamba. Do not graze meat or dairy animals on treated areas.
Areas of Application: For controlling woody plants in forest management programs and on fence rows, roadsides, drainage ditchbanks, railroads, utility rights-of-way, and other noncrop areas.

Weedone 170 (2,4-D & 2,4-DP ester)
Weedone DPC Amine (2,4-D & 2,4-DP amine)
Rate: Foliage spray:
1-1.5 gal./A in 100 gal. water
Basal bark application:
3-4 gal./100 gal. oil
Weeds: Most brush species including solid stands of oak or elm.
Remarks: Apply after foliage is fully developed. Refer to label for various techniques and rates.
Areas of Application: Fence rows, highways, utility and railroad rights-of-way, and drainage ditchbanks.

PP-preplant • PPI-preplant incorporated • PRE-preemergence • POST-postemergence • SEQ-sequential
ai-active ingredient DF-dry flowable E/EC-emulsifiable concentrate F/FL-flowable G-granule L/LC-liquid W/WP-wettable powder

2,4-D TANK MIXES
(active ingredient per acre)

PRODUCT	TIMING/REMARKS
Hi-Dep 1-2 lb. + **Tordon** 0.5 lb.	Industrial noncropland sites: control of leafy spurge in CO, ID, MT, MN, NE, ND, SD, WA, WY.
Hi-Dep 1 lb. + **Banvel** 2 lb.	Same as for Hi-Dep + Tordon.
Hi-Dep 2 lb. + **Tordon** 0.25 lb. + **Banvel** 1 lb.	Same as for Hi-Dep + Tordon.

Daconate — see MSMA

Dal-E-Rad — see MSMA

DICHLOBENIL

Nonselective in action and may destroy all types of vegetation.

Casoron 10G
Norosac 10G
Rate: 12-20 lb. ai/A
120-200 lb. 10G/A
Weeds: **Broadleaf weeds:**

artemisia	gisekia	rosarypea
camphorweed	groundsel	Russian knapweed
Canada thistle	henbit	Russian thistle
carpetweed	horsetail	sheep sorrel
chickweed	jerusalemoak goosefoot	shepherdspurse
citronmelon	knotweed	smartweed
coffeeweed	lambsquarters	spanishneedles
cudweed	leafy spurge	spurge
curly dock	maypop	teaweed
dandelion	milkweed vine	wild artichoke
dogfennel	minerslettuce	wild aster
eveningprimrose	pineappleweed	wild carrot
falsedandelion (catsear)	plantain	wild mustard
	purslane	wild radish
fiddleneck	ragweed	yellow rocket
Florida purslane (pusley)	red deadnettle	yellow woodsorrel
	redroot pigweed	

Grasses:

annual bluegrass	foxtail	Texas panicum (hurrahgrass)
bluegrass	natalgrass	
bull thistle	old witchgrass	timothy
crabgrass	orchardgrass	wild barley
fescue	peppergrass	

Remarks: Apply during season of lowest temperatures (November 1-March 1 in most areas or to April 1 on the northern tier of states). Do not apply if air temperature is expected to rise above 70°F within the following week. Apply only to areas where complete plant control is desired. The treated area may be totally or partially nonproductive for one or more years.
Areas of Application: Electric substations (equipment sales and storage areas), lumberyards (above ground pipes and tanks), nonsurface roadways (railroad and highway rights-of-way), petroleum installations (around buildings, along fence rows), fuel storage tanks and under asphalt.

DIQUAT

Valent Diquat Herbicide-H/A
Rate: 0.5-1 lb. ai
1-2 qt./A + 8-16 oz. Valent X-77 Spreader (nonionic)/100 gal. water
or 4 tsp. H/A + 0.5 tsp. Valent X-77 Spreader (nonionic)/1 gal. water
Weeds: For control of undesirable broadleaf and grassy weeds.
Remarks: Apply for full coverage and thorough weed contact. Apply to young weeds since control decreases as weeds mature. Retreatment may be necessary to control grasses and established weeds. Avoid spray contact with foliage of food crops or ornamental plants. Do not apply this product through any type of irrigation system.
Areas of Application: Rights-of-way, including railroad, highways, roads, dividers and medians, pipelines, public utility lines, including pumping stations, transformer stations and substations. Around electric utilities, commercials buildings, manufacturing plants, storage yards, railyards, fence lines and parkways, edges and nonflooded portions of ponds, lakes and ditches. Also around ornamental gardens, walkways, patios, beneath greenhouse benches, along driveways, and around golf courses.

DIURON

Direx 4L or 80W
Drexel Diuron 4L or 80W
Rate: 4-32 lb. ai/A
1-8 gal. 4L/A
5-60 lb. 80W/A
Weeds: **Broadleaf weeds:**

horsenettle	ragweed	thistle
morningglory		

Grasses:

guineagrass	pangolagrass	quackgrass
johnsongrass		

Remarks: Refer to label for detailed use in irrigation ditches. Higher rates for use on perennial grass and herbaceous weeds. Deep-rooted perennials may require retreatment. Do not use in the presence of valuable plants. Use only where bare ground is not objectionable.
Areas of Application: Utility, highway, pipeline, and railroad rights-of-way, around farm buildings, and other noncrop areas.

Karmex DF
Rate: 4-12 lb. ai/A
5-15 lb. DF/A
Weeds: Annual weeds.
Remarks: Add 1 qt. surfactant/100 gal. spray mixture for established weeds. Refer to label for detailed use in irrigation ditches.
Areas of Application: Railroad, highway, utility, pipeline, petroleum tank farms, lumberyards, storage areas, industrial plant sites, around farm buildings, irrigation and drainage ditches during noncrop season.

Drexar 530 — see MSMA

DSMA

Drexel DSMA Liquid or Slurry (DSMA + surfactant)
Helena Liquid DSMA (DSMA + surfactant)
Rate: 3.6-7.2 lb. ai/A
1-2 gal. Liquid/A
0.5-1 gal. Slurry/A
Weeds: **Broadleaf weeds:**

cocklebur	puncturevine	ragweed

Grasses:

dallisgrass	nutsedge	sandbur
johnsongrass		

Remarks: No additional surfactant needed. Spray unwanted vegetation thoroughly to just short of runoff. If regrowth occurs, reapply as required.
Areas of application: Drainage ditchbanks, rights-of-way, storage yards, and similar noncrop areas.

DSMA Liquid (DSMA + surfactant)
Rate: 3.6 lb. ai/A
1 gal./A
Weeds: **Grasses:**

barnyardgrass	goosegrass	nutsedge
cocklebur	johnsongrass	smooth crabgrass
dallisgrass	large crabgrass	

Remarks: Apply in 40 gal water when weeds are small and conditions favor active growth of weeds. Spray to point of runoff. Adequate coverage and complete wetting of foliage is important for effective control. Repeat applications may be necessary if regrowth occurs.
Areas of Application: Drainage ditchbanks, fence rows, rights-of-way, storage yards, and similar noncrop areas.

Envert — see 2,4-D Premix

ESCORT

Escort (60DF) (metsulfuron methyl)
Rate: 0.2-1.2 oz. ai/A
0.3-2 oz. 60DF/A
Weeds: **Broadleaf weeds:**

aster	Canada thistle*	field bindweed*
bahiagrass	chicory	flixweed
bitter sneezeweed	common chickweed	goldenrod
blackberry	common mullein	gumweed
blackeyed susan	common yarrow	henbit
broom snakeweed	crown vetch	kudzu (3-4 oz.)
broomweed	curly dock	marestail
buckhorn plantain	dandelion	multiflora rose
bull thistle	dogfennel	plantain

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Russian thistle	treacle mustard	wild lettuce
scouringrush	tumble mustard	woodsorrel
sweet clover	white clover	yankeeweed
tansymustard	wild carrot	

* *Suppression*

Remarks: Nonselective control. May be used at low rates to selectively control annual broadleaf weeds in rough turf and native perennial rangeland grasses. Kochia, Russian thistle and prickly lettuce may be resistant (biotypes) and tank mix combinations or sequential treatments of other registered herbicides are recommended. Refer to label for application restrictions. Apply uniformly with ground equipment using minimum of 10 gal. spray solution/A. Apply any time except when ground is frozen. Do not use on bahiagrass as severe injury will result. There are no grazing restrictions for up to 0.75 oz. 60DF/A.

Areas of Application: Airports, highways, roadsides, utility, pipeline, and railroad rights-of-way, petroleum tank farms, plant sites, and other noncrop areas.

State Restrictions: Use restricted to railroad rights-of-way in Montana, North Dakota, and South Dakota. Not for use in California and Alamosa, Costilla, Conejos, Rio Grande and Saguache counties of Colorado.

Esteron 99 Concentrate — see 2,4-D

EVIK

Evik 80W (ametryn)
Rate: 1-2 lb. ai/A
1.25-2.5 lb. 80W/A
Weeds: **Broadleaf weeds:**

Florida pusley	ragweed	velvetleaf
lambsquarters	smartweed	wild mustard
morningglory		

Grasses:

barnyardgrass	goosegrass	signalgrass (brachiaria)
crabgrass	green foxtail	Texas panicum
fall panicum	nutsedge	(Texas millet)
giant foxtail	shattercane	yellow foxtail

Remarks: Apply in 20 gal. water to emerged actively growing weeds. Add 2 qt. surfactant/100 gal. spray. Do not plant desirable plants in treated area for one year.

Areas of Application: Industrial sites, railroad rights-of-way, lumberyards, petroleum tank farms, etc.

FENOXAPROP

Horizon 1EC
Rate: 0.15-0.25 lb. ai/A
1.2-2 pt. 1EC/A
Weed: **Grasses:**

barnyardgrass	johnsongrass	silver crabgrass
foxtail	panicum	smooth crabgrass
goosegrass	roughstalk bluegrass	wild oat
hairy crabgrass		

Remarks: Rainfall within one hour may cause a reduction in grass control. Fescue and ryegrass may be overseeded immediately, other grass species should be overseeded after a 21-day waiting period.

Areas of application: Highway rights-of-way.

State Restrictions: Not for use in California and Hawaii.

FUSILADE 2000

Fusilade 2000 (fluazifop-P-butyl)
Rate: 0.25-0.375 lb. ai/A
2-3 pt. 2000/A
Weeds: **Annual and perennial grasses:**

barnyardgrass	johnsongrass	Texas panicum
bermudagrass	(rhizome, seedling)	torpedograss
broadleaf signalgrass	junglerice	tropical crabgrass
fall panicum	kikuyugrass	volunteer cereals
field sandbur	large crabgrass	(barley, corn, milo,
giant foxtail	quackgrass	oats, rye, wheat)
goosegrass	red rice	wild oat
green foxtail	shattercane	wild proso millet
guineagrass	smooth crabgrass	wirestem muhly
Italian ryegrass	sorghum-almum	witchgrass
itchgrass	southern crabgrass	woolly cupgrass
	southern sandbur	yellow foxtail

Remarks: Apply to actively growing grasses. Add either a crop oil concentrate at 1% or nonionic surfactant at 0.25% of the finished spray volume. Rainfast in one hour. Refer to label for complete use directions.

Areas of Application: Nonfood areas.

GALLERY

Gallery 75DF (isoxaben)
Rate: 0.5-1 lb. ai/A
0.66-1.33 lb. 75DF/A
Weeds: **Broadleaf weeds:**

bittercress	cudweed	prostrate spurge
black mustard	dogfennel	redmaids rockpurslane
black nightshade	green tansymustard	redstem filaree
blackleaved fleabane	hairy galinsoga	shepherdspurse
bracted plantain	henbit	sibara
buckhorn plantain	horseweed (marestail)	slender plantain
Carolina geranium	ladysthumb	southern brassbuttons
coast fiddleneck	lambsquarters	spotted spurge
common chickweed	London rocket	thymeleaf speedwell
common groundsel	mouseear chickweed	velvetleaf
common purslane	pennywort	white clover
common ragweed	pigweed	whitestem filaree
common sowthistle	pineappleweed	wild celery
(annual)	prickly lettuce	wild mustard
creeping woodsorrel	prostrate knotweed	yellow woodsorrel

Grasses (suppression):

annual bluegrass	barnyardgrass	foxtail
annual ryegrass	crabgrass	goosegrass
(Italian)	dandelion (from seed)	mallow

Remarks: Apply in late summer to early fall, or in early spring, prior to germination of target weeds. Apply in 10-200 gal. water carrier/A. Do not apply this product through any type of irrigation system.

Areas of Application: Industrial sites, utility substations, highway guard rails, sign posts and delineators.

Garlon — see triclopyr

GLYPHOSATE

Jury
Rattler
Roundup
Rate: Handgun and high volume: mix 4-8 qt. in 100 gal. clean water and apply to foliage of vegetation to be controlled. Boom equipment: 2-5 qt./A in 20-30 gal. clean water as broadcast spray. Aerial Application: apply recommended rates per weed species in 5-15 gal. water/A on rights-of-way only.
Weeds: **Broadleaf weeds:**

Canada thistle	field bindweed	milkweed
common mullein	hemp dogbane	

Grasses:

bermudagrass	johnsongrass	vaseygrass
dallisgrass	paragrass	wirestem muhly
fescue	quackgrass	

Woody brush species:

alder	honeysuckle	oak
blackberry	kudzu	trumpetcreeper
dewberry	maple	willow
elderberry	multiflora rose	

Remarks: Provides top kill plus destruction of underground plant parts including rootstocks, rhizomes, etc. Apply to foliage of actively growing weeds and grasses at recommended growth stage. Not a residual herbicide, therefore, follow with a label-approved program for effective annual and perennial seedling weed control. Do not mix with other herbicides. Do not allow spray or spray drift to contact desirable plants. Do not mow or till prior to treatment. Do not apply if rainfall is imminent.

Areas of Application: Railroad, highway, pipeline, powerline and telephone line rights-of-way (labeled for aerial applications only), petroleum tank farms and pumping installations, lumberyards, parking areas, industrial plant sites, roadsides, storage areas, fence rows, schools, parks, golf courses, other public areas, airports, and similar industrial or noncrop areas.rights-of-way only.

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Rate: Hand sprayer: mix 2 oz. (4 Tbs.)/gal. water for control of annual weeds; mix 3 oz. (6 Tbs.)/gal. water for perennial weeds.
Weeds: Same as above.
Remarks: If spraying areas adjacent to desirable plants, use a shield made of cardboard, sheet metal, or plyboard while spraying to help prevent spray from contacting foliage of desirable plants.
Areas of Application: Around farmstead building foundations, along and in fences, shelterbelts, and for general nonselective farmstead weed control.

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Rate: 2 qt. product broadcast spray or 1% solution with handheld equipment.
Weeds: Multiflora rose.
Remarks: Apply when canes are actively growing and at or beyond early to full bloom stage of growth.

Gramoxone Extra — see paraquat

HELENA WEED BLAST (Premix)

ına Weed Blast-4G (2% bromacil & 2% diuron)
Rate: 8-16 lb. ai/A
200-400 lb. 4G/A
0.5-1 lb. 4G/100 sq. ft.
Weeds: For control of annual and most perennial weeds and grasses.
Remarks: Applications made early in the season have been found to give results superior to applications at a later date. Repeat spot treatments may be required when deep rooted perennial weeds are present. Read and follow all label directions.
Areas of application: Railroad rights-of-way, industrial areas.

Hi-Dep — see 2,4-D

Horizon — see fenoxaprop

HYVAR

Hyvar X or DF (80%) (bromacil)
Rate: 2.4-4.8 lb. ai/A
3-6 lb. 80%/A
Weeds: **Annual broadleaf weeds:**

lambsquarters	ragweed	turkey mullein
puncturevine		

Annual grasses:

cheat	downy brome	ryegrass
crabgrass	foxtail	wild oat

Rate: 5.6-9.6 lb. ai/A
7-15 lb. 80%/A
Weeds: **Perennial broadleaf weeds:**

dandelion	goldenrod	purpletop
dogfennel	plantain	wild carrot

Perennial grasses:

bahiagrass	broomsedge	quackgrass
bermudagrass	johnsongrass	smooth brome
bluegrass	natalgrass (redtop)	

Remarks: Controls many annual and perennial weeds, noncorrosive, nonvolatile, nonflammable. Refer to label for registered tank mixes.
Areas of Application: Railroad, highway, pipeline rights-of-way; petroleum tank farms, lumberyards, storage areas, and industrial plant sites.

Hyvar X-L (bromacil)
Rate: 3-6 lb. ai/A
1.5-3 gal. X-L/A
Weeds: **Broadleaf weeds:**

lambsquarters	ragweed	
puncturevine	turkey mullein	

Grasses:

bromegrass	foxtail	ryegrass
cheatgrass	orchardgrass	wild oat
crabgrass		

Rate: 6-12 lb. ai/A
3-6 gal. X-L/A
Weeds: **Broadleaf weeds:**

aster	goldenrod	purpletop
dandelion	plantain	wild carrot
dogfennel		

Grasses:

bahiagrass	broomsedge	redtop
bluegrass	quackgrass	smooth brome

Rate: 12-24 lb. ai/A
6-12 gal. X-L/A
Weeds: **Broadleaf weeds:**

brackenfern	dogbane	horsetail
bouncingbet		

Grasses:

bermudagrass	johnsongrass	saltgrass
dallisgrass	nutsedge	vaseygrass

Areas of Application: Railroad, highway, pipeline rights-of-way; petroleum tank farms, lumberyards, storage areas, and industrial plant sites.

Rate: 4.5-10 lb. ai/A
2.25-5 gal. X-L/A
Weeds: **Brush:**

oak	sweetgum	willow
ine		

Rate: 12-24 lb. ai/A
6-12 gal. X-L/A
Weeds: **Brush:**

American elm	hackberry	winged elm
cottonwood	sumac	

Remarks: Use higher rates on absorptive soils (high in organic matter and carbon). For basal (soil) treatment, apply Hyvar X-L undiluted with exact delivery handgun at 5-10 milliliters/stem 2"-4" in basal diameter. Direct spot treatment at base of brush (root collar area). When treating large stems and more than one delivery of solution is needed/stem, apply on opposite side of stem. For diluted spot treatment, mix 1 gal. product/A in 5 gal. water and apply 1-2 fl. oz./stem 2"-4" in basal diameter; wet base of stem to runoff.
Areas of Application: Railroad, highway, pipeline rights-of-way; petroleum tank farms, lumberyards, storage areas, and industrial plant sites.

Jury — glyphosate

Karmex — see diuron

KRENITE S

Krenite S (fosamine)
Rate: 6-24 lb. ai/A
1.5-6 gal./A
Weeds: **Brush/herbaceous plants:**

American elder	hickory*	sweetgum
basswood*	leafy spurge*	sycamore
bigleaf maple*	loblolly pine	thimbleberry
birch	multiflora rose	tuliptree* (yellow poplar)
black cherry*	persimmon*	
black locust	pin cherry	tree-of-heaven
blackberry	quaking aspen	vine maple
blackgum*	red alder	Virginia pine
brackenfern	red maple*	water oak
chokecherry*	red oak	white ash*
eastern cottonwood	salmonberry	white oak
eastern white pine	sassafras*	wild grape
elm*	slippery elm	wild plum
field bindweed*	sourwood*	willow*
hawthorn*	sumac	winged elm*

* *Suppression*

Remarks: Water soluble liquid to be diluted with water and applied as a foliar spray for control and/or growth suppression of many woody species. It is applied to brush in summer or early fall, either by air or ground equipment. Susceptible treated plants fail to refoliate the following spring. For control of only a portion of a plant, as in trimming, direct spray to thoroughly cover only the section of the plant to be killed. For field bindweed, apply after plants begin to bloom. Do not apply through any type of irrigation system.
Areas of Application: Railroads, pipeline, utility and highway rights-of-way; reforestation areas, drainage ditchbanks, storage areas, industrial plant sites, and similar areas.
State Restrictions: Not for sale or use in Arizona or California.

KROVAR PREMIXES

Krovar I DF (40% bromacil & 40% diuron)
Rate: Annuals:
3.2-4.8 lb. ai/A
4-6 lb. DF/A
Perennials:
6.6-14.4 lb. ai/A
7-18 lb. DF/A
Hard-to-kill perennials:
15.2-24 lb. ai/A
19-30 lb. DF/A
Weeds: **Broadleaf weeds:**

annual nightshade	fleabane	purslane
annual sowthistle	Florida pusley	ragweed
bouncingbet (hard-to-kill)	groundsel	sandspur
	horseweed	shepherdspurse
chickweed	lambsquarters	spanishneedles
dogbane (hard-to-kill)	pigweed	wild lettuce
	pineappleweed	wild mustard
filaree	puncturevine	

Grasses (hard-to-kill):

barnyardgrass	foxtail	natalgrass
bermudagrass	johnsongrass (seedling)	nutsedge
crabgrass	junglerice	saltgrass

Remarks: Apply in 40-100 gal. water preemergence or in early stages of weed growth. Use higher levels on absorptive soils. Refer to label for registered tank mixes.

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Areas of Application: Railroad, highway, pipeline rights-of-way; tank farms, lumberyards, industrial sites, storage areas.

Krovar II DF (53% bromacil & 27% diuron)
Rate: Annuals:
1.6-4 lb. ai/A
2-5 lb. DF/A
Extended control of annuals; partial control of perennials:
4.8-11.2 lb. ai/A
6-14 lb. DF/A
Hard-to-kill perennials
12-18 lb. ai/A
15-23 lb. DF/A
Weeds: **Bermudagrass (hard-to-kill) and the following annual broadleaf weeds:**

annual nightshade	dogbane (hard-to-kill)	pigweed
annual sowthistle	Florida pusley	purslane
bouncingbet (hard-to-kill)	lambsquarters	ragweed
		spanishneedles

Remarks: Apply in 40-100 gal. water just before weed emergence or in early stages of weed growth.
Areas of Application: Roadsides, storage areas, and plant sites.

LINURON

Drexel Linuron 4L
Linex 4L or 50DF
Lorox 4L or DF
Rate: 1-3 lb. ai/A
2-6 pt. 4L/A
2-6 lb. DF, 50DF/A
Weeds: **Broadleaf weeds:**

carpetweed	galinsoga	pigweed
chickweed	lambsquarters	purslane
common ragweed	mustard	smartweed
Florida pusley	nettleleaf goosefoot	wild radish

Grasses:

barnyardgrass	crabgrass	foxtail
canarygrass	fall panicum	goosegrass

Remarks: Apply in 40-100 gal. water. For established weeds, add 2 qt. surfactant/100 gal. spray mixture and apply as a thorough coverage spray during periods when daily temperatures exceed 70°F and before weed growth exceeds 8" in height. For best results, apply shortly before weed growth begins or at early seedling stage of growth. Do not reenter treated areas for 24 hr. following application unless protective clothing is worn.
Areas of Application: Roadsides and fence rows.

MONCIDE (Premix)

Moncide (3 lb./gal. MSMA & 1.25 lb./gal. cacodylic acid)
Rate: 4.25-8.5 lb. ai/A
1-2 gal./A
Weeds: **Nonselective general broadleaf weed control:**

chickweed	lambsquarters	puncturevine
common plantain	pigweed	wild mustard
common ragweed	prostrate spurge	

Grasses:

crabgrass	sandbur	yellow foxtail
giant foxtail	wild oat	

Top kill of perennial grasses such as:

bermudagrass	johnsongrass	nutsedge
dallisgrass		

Remarks: Apply in 40-100 gal. water. If regrowth occurs, retreatment may be necessary. Best results are obtained on young actively growing weeds at air temperatures above 70°F. Use with additional surfactant or crop oil concentrate to enhance weed control in arid regions. Do not apply through any type of irrigation system.
Areas of Application: Drainage ditchbanks, rights-of-way, fence rows, storage yards, along highways, utility lines, pipe lines, around power plants and buildings, and on similar noncrop areas.

MONTAR

Montar (cacodylic acid)
Rate: 7.71 lb. ai/A
3.11 gal./A
Weeds: Nonselective general weed control.
Remarks: Not for use in vegetable gardens. Apply to unwanted vegetation to runoff. Reapply if regrowth occurs. Use with additional surfactant or crop oil concentrate to enhance weed control in arid regions. Do not apply through any type of irrigation system.

Areas of Application: Apply on drainage ditchbanks, rights-of-way, along sidewalks, driveways, and fences, around buildings, ornamentals, and similar noncrop areas.

MSMA

Ansar 6.6 (MSMA)
Helena MSMA (MSMA)
Rate: 2.5 lb. ai/50 gal. water
3 pt. 6.6/50 gal. water
Weeds: **Broadleaf weeds:**

chickweed	cocklebur

Grasses:

barnyardgrass	johnsongrass	sandbur
dallisgrass	large crabgrass	smooth crabgrass
goosegrass	nutsedge	

Remarks: Add 3-4 pt. suitable nonionic surfactant. Spray unwanted vegetation thoroughly to point of runoff. Adequate coverage and complete wetting of foliage is important for effective control. If regrowth occurs, reapply as required.
Areas of application: Drainage ditchbanks, rights-of-way, storage yards, and similar noncrop areas.

Bueno 6 (MSMA + surfactant)
Daconate 6 (MSMA + surfactant)
Rate: 1.875-2 lb. ai/40 gal. water
2.5-2.66 pt./40 gal. water
Weeds: **Broadleaf weeds:**

chickweed	pigweed	puncturevine
cocklebur		

Grasses:

barnyardgrass	dallisgrass	nutsedge
brachiaria	goosegrass	sandbur
crabgrass	johnsongrass	

Remarks: Apply when weeds are small and conditions favor active growth of weeds. Spray to point of runoff. Adequate coverage and complete wetting of foliage is important for effective control. Repeat applications may be necessary if regrowth occurs.
Areas of Application: Drainage ditchbanks, fence rows, rights-of-way, storage yards, and similar noncrop areas.

Helena MSMA Plus (MSMA + surfactant)
Rate: 2 lb. ai/40 gal. water
4 pt./40 gal. water
Weeds: **Grasses:**

goosegrass	nutsedge	watergrass
johnsongrass		

Remarks: Spray unwanted vegetation thoroughly to just short of runoff. If regrowth occurs, reapply as required.
Areas of application: Drainage ditchbanks, rights-of-way, storage yards, and similar noncrop areas.

Dal-E-Rad 120 (MSMA)
Weed-Hoe 120 (MSMA)
Rate: 2 lb. ai/40 gal. water
2.5 pt. 120/40 gal. water
Weeds: **Broadleaf weeds:**

chickweed	woodsorrel

Grasses:

goosegrass	johnsongrass	yellow foxtail
green foxtail	nutsedge	

Remarks: Apply when weeds are actively growing. Add 2 pt. surfactant.
Areas of Application: Drainage ditchbanks, rights-of-way, storage yards, and similar noncrop areas.

Drexar 530 (MSMA + surfactant)
Drexel MSMA 4 Plus or 6 Plus (MSMA + surfactant)
Rate: 2-5 lb. ai/100 gal. water
4-10 pt. 530, 4 Plus/100 gal. water
6-12 pt. 600, 6 Plus/100 gal. water
Weeds: Broadleaf weeds and grasses including johnsongrass and nutsedge.
Remarks: Spray unwanted vegetation thoroughly to just short of runoff. If regrowth occurs, reapply as required.
Areas of Application: Noncrop areas such as drainage ditchbanks, rights-of-way, fence rows, storage yards.

Drexel MSMA 6.6 (MSMA)
Rate: 2.5-5 lb. ai/100 gal. water
3-6 pt. 6.6/100 gal. water
Weeds: **Grasses:**

barnyardgrass	johnsongrass	nutsedge

Remarks: Add a surfactant to spray solution for best results. Spray unwanted vegetation thoroughly to just short of runoff. If regrowth occurs, reapply as required.

PP-preplant • PPI-preplant incorporated • PRE-preemergence • POST-postemergence • SEQ-sequential
ai-active ingredient DF-dry flowable E/EC-emulsifiable concentrate F/FL-flowable G-granule L/LC-liquid W/WP-wettable powder

Areas of Application: Noncrop areas such as drainage ditchbanks, rights-of-way, fence rows, storage yards.

Helena MSMA Plus H.C. (MSMA + surfactant)
Weed-Hoe 108 (MSMA + surfactant)
Rate: 4.5-9 lb. ai/100 gal. water
6-12 pt./100 gal. water
Weeds: **Broadleaf weeds:**
cocklebur, puncturevine
Grasses:
barnyardgrass, johnsongrass, ragweed, dallisgrass, nutsedge, sandbur
Remarks: Spray unwanted vegetation at a rate of about 50 gal. spray solution/A. If regrowth occurs, reapply as required.
Areas of application: Drainage ditchbanks, rights-of-way, fence rows, storage yards, and similar areas.

Norosac — see dichlobenil listing

OUST

Oust (sulfometuron methyl)
Rate: Arid areas:
1-1.5 oz. ai/A
1.33-2 oz./A
Weeds: **Broadleaf weeds:**
annual sowthistle, common speedwell, seaside heliotrope, black mustard, common yarrow, spreading orach, buckhorn plantain, curly dock, sunflower, burclover, prickly coontail, western ragweed, chickweed, prickly lettuce, whitestem filaree, common mallow
Grasses:
annual bluegrass, Italian ryegrass, ripgut brome, barnyardgrass, jointed goatgrass, seashore saltgrass, cheat, red brome, signalgrass, foxtail barley, reed canarygrass, yellow foxtail, foxtail fescue

Rate: 2.25-3.8 oz. ai/A
3-5 oz./A
Weeds: **Broadleaf weeds:**
annual sowthistle, hoary cress, Russian thistle, bouncingbet, kochia, sunflower, burclover, little mallow, sweet clover, Carolina geranium, mustard, tansy ragwort, common chickweed, oxeye daisy, tansymustard, common dandelion, pepperweed, tumble mustard, common speedwell, pigweed, vetch, common yarrow, prickly lettuce, wild carrot, crimson clover, purple starthistle, wild oat, dogfennel, ragweed, yellow rocket
Grasses (up to 6"-12" in height):
alta fescue, fescue, red fescue, annual bluegrass, foxtail (except green), reed canarygrass, annual ryegrass, ripgut brome, annual sprangletop, indiangrass, ryegrass, bahiagrass, Italian ryegrass, smooth brome, barley, Kentucky bluegrass, sprangletop, barnyardgrass, little barley, volunteer wheat, downy brome, red brome

Rate: 4.5-9 oz. ai/A
6-12 oz./A
Weeds: **Broadleaf weeds:**
bedstraw, groundsel, musk thistle, Canada thistle, hemlock, poison ivy, curly dock, honeysuckle, redstem filaree, dewberry, horsetail, spanishneedles, fiddleneck, Jerusalem artichoke, turkey mullein, fleabane, kudzu, Virginia pepperweed, goldenrod, mayweed, wild blackberry
Grasses:
johnsongrass, yellow nutsedge
Remarks: Oust may be applied preemergence or postemergence to weeds. Best results are obtained if application is made before or during early stages of weed growth. Requires extreme care in use near crops. Refer to label for application restrictions.
Areas of Application: Noncrop areas such as railroad, roadsides, utility and pipeline rights-of-way, utility plant sites, petroleum tank farms, pumping installations, fence rows, storage areas, airports, lumberyards, and other similar areas.

PARAQUAT

Restricted Use Pesticide.

Gramoxone Extra
Rate: 0.625-0.94 lb. ai/A
2-3 pt./A
Weeds: **Broadleaf weeds:**
burclover, nettle, red clover, chickweed, pigweed, shepherdspurse, filaree, plantain, thistle, groundsel, puncturevine, wild mustard, morningglory*, purslane, wild radish
Grasses:
bermudagrass*, cheatgrass, johnsongrass*, bluegrass, crabgrass, wild oat
** Top kill*
Remarks: Apply in 50 gal. water with ground equipment. Always add an approved nonionic surfactant or an approved crop oil concentrate as per label directions. Repeat as necessary. Avoid contact with foliage of ornamentals or desired plants. Do not use around home gardens, schools, recreation parks, or playgrounds. Do not apply this product through any type of irrigation system.
Areas of Application: Public airports, electric transformer stations and substations, pipeline pumping stations, around commercial buildings, storage yards and other installations, fence lines, and similar noncrop areas.

Pathfinder — see triclopyr

PATHWAY (Premix)

Pathway (3% picloram & 11.2% 2,4-D)
Rate: Apply undiluted to injector wounds, frills, or girdles, or freshly cut stumps or stubs of individual stems.
Weeds: **Woody plants:**
ailanthus, dogwood, maple, alder, Douglas-fir, oak, aspen, elm, pecan, balsam fir, green ash, persimmon, birch, gum, serviceberry, cedar, hickory, sourwood, cherry, hornbeam, sweetbay
Remarks: Ready-to-use product. Apply to cut surface of woody plants.
Areas of Application: Forests and noncrop areas such as fence rows, rights-of-way, and industrial sites.

PRAMITOL

Pramitol 25E
Rate: 10-15 lb. ai/A
5-7.5 gal. 25E/A
Weeds: **Annual and susceptible perennial weeds such as:**
goldenrod, oatgrass, puncturevine, goosegrass, plantain, quackgrass

Rate: 40-60 lb. ai/A
20-30 gal. 25E/A
Weeds: **Hard-to-kill perennial weeds and grasses such as:**
bindweed, johnsongrass, wild carrot
Remarks: Apply before weeds emerge or up to 3 months after emergence. Apply to ground before laying asphalt, or may be mixed with cutback asphalts. Use only in areas where complete control of all vegetation is desired and not on land to be cropped, or near adjacent desirable trees, shrubs, or plants because injury may occur.
Areas of Application: Noncrop areas such as utility, highway, pipeline and railroad rights-of-way; fence lines; petroleum tank farms, lumberyards, storage areas, industrial plant sites and around buildings.

PRAMITOL 5PS (Premix)

Pramitol 5PS (5% prometon & 0.75% simazine & 90% chlorate-borate)
Rate: 218-872 lb. 5PS/A
or 0.5-2 lb. 5PS/100 sq. ft.
Weeds: For control of most annual and perennial broadleaf weeds and grasses.
Remarks: The high rate should be used in areas having a long growing season or high rainfall. The higher rates will also provide longer residual control.
Areas of Application: Noncrop areas such as utility, highway, pipeline and railroad rights-of-way; fence lines; petroleum tank farms, lumberyards, storage areas, industrial plant sites, around buildings.

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Rattler — see glyphosate

Redeem — see triclopyr

Remedy — see triclopyr

Roundup — see glyphosate

SEE 2,4-D — see 2,4-D

SIMAZAT (Premix)

Restricted Use Pesticide due to groundwater concerns.

Simazat 4L (2 lb./gal. simazine & 2 lb./gal. atrazine)
Rate: 4.33-10 lb. ai/A
4.33-10 qt. 4L/A
Weeds: Most annual broadleaf and grass weeds.
Remarks: Apply before or soon after weeds begin growth. Postemergence application should be made when weeds are young and actively growing. Use high rates for heavy clay and muck soils. For hard-to-kill annual and many perennial broadleaf and grass weeds, broadcast 10-20 qt. 4L/A; hard-to-kill biennial and perennial weeds, such as bull thistle, broadcast 20-40 qt. 4L/A.
Areas of Application: For use on fence rows, utility poles, industrial sites, highway medians and shoulders, railroad rights-of-way, lumberyards, petroleum tank farms, and noncrop areas on farms.

SIMAZINE

Drexel Simazine 4L, 80W or 90DF
Princep 4L, 80W, Caliber 90 or 4G
Rate: 4.8-18 lb. ai/A
4.8-17.6 qt. 4L/A
250-450 lb. 4G/A
6-22.5 lb. 80W/A
5.3-20 lb. 90, 90DF/A
Weeds: **Broadleaf weeds:**

annual morningglory	flora's paintbrush	redmaids
burclover	groundsel	Russian thistle
carelessweed	henbit	shepherdspurse
carpetweed	knawel (German moss)	smartweed
common chickweed	nightshade	spanishneedles
common lambsquarters	pepperweed	speedwell
common purslane	pigweed	tansymustard
fiddleneck	pineappleweed	turkey mullein
filaree	prickly lettuce	wild mustard
fireweed	puncturevine	yellowflower pepperweed
Florida pusley	ragweed	

Grasses:

annual bluegrass	downy brome (cheatgrass)	quackgrass
annual ryegrass	fall panicum	rattail fescue
barnyardgrass (watergrass)	foxtail	redtop
burdock	goosegrass	signalgrass (brachiaria)
Canada thistle	junglerice	silver hairgrass
crabgrass	orchardgrass	smooth brome
dogfennel	plantain	wild oat
	purpletop	witchgrass

Remarks: Use higher rate for perennials or for longer residual. Apply before weeds emerge.
Areas of Application: All noncultivated areas such as rights-of-way.

SIMAZINE TANK MIXES

(active ingredient per acre)

PRODUCT

Princep 4-16 lb.
+ **Oust** 2.25-9 oz.

Princep 4.8-18 lb.
+ **Roundup** 1-5 lb.

SODIUM TCA WEED KILLER

Sodium TCA Weed Killer Liquid Concentrate (sodium TCA)
Rate: 9.52-114.24 lb. ai/A
2-24 gal./A
Weeds: **Grasses:**

bermudagrass	Japanese chess	phragmites
crabgrass	johnsongrass	quackgrass
foxtail	paragrass	

Remarks: Rate varies depending on soil type and control desired; refer to label. Also for grass suppression and seedling grasses. Do not use more than 25 gal. product/A. Do not allow animals to graze on treated areas for at least 24 hours after treatment.
Areas of Application: Noncultivated areas.

SPIKE

Spike 20P, 40P, 80W or 5G (tebuthiuron)
Rate: 1-6 lb. ai/A
5-30 lb. 20P/A
2.5-15 lb. 40P/A
1.25-7.5 lb. 80W/A
20-120 lb. 5G/A
Weeds: Control over 125 grass and weed species and 110 woody species including hard-to-contol species such as maple, oak, white ash and willow.
Remarks: Rate varies depending on weed species, treatment, and geographic location. Degree and duration of control may vary with amount of chemical applied, soil type, and other conditions. Spike will injure or control other herbaceous vegetation in treated area, therefore, do not apply where such injury cannot be tolerated. Do not apply on field crops. Do not apply on or near desirable trees or other plants, or on areas where their roots may extend, or in locations where the chemical may be washed into contact with their roots.
Areas of Application: Noncrop areas such as railroad and utility rights-of-way, wildlife openings, industrial sites, pipelines, fence rows, firebreaks, ditchbanks, and along highways.

SPIKE TREFLAN 6G (Premix)

Spike Treflan 6G (2% tebuthiuron & 4% trifluralin)
Rate: 0.6-12 lb. ai/A
10-200 lb./A
Weeds: Control over 125 grass and weed species and 110 woody species including hard-to-contol species such as maple, oak, white ash and willow.
Remarks: Rate varies depending on weed species, treatment, and geographic location. Degree and duration of control may vary with amount of chemical applied, soil type, and other conditions. Spike will injure or control other herbaceous vegetation in treated area, therefore, do not apply where such injury cannot be tolerated. Do not apply on field crops. Do not apply on or near desirable trees or other plants, or on areas where their roots may extend, or in locations where the chemical may be washed into contact with their roots.
Areas of Application: Noncrop areas such as railroad and utility rights-of-way, wildlife openings, industrial sites, pipelines, fence rows, firebreaks, ditchbanks, and along highways.

STINGER

Stinger (clopyralid)
Rate: 0.1-0.2 lb. ae/A
0.25-0.5 pt./A
Weeds: **Annual and perennial broadleaf weeds:**

annual sowthistle*	ladysthumb	spotted knapweed
Canada thistle	mayweed (dogfennel)	volunteer alfalfa
cocklebur	musk thistle	volunteer soybeans
common ragweed	perennial sowthistle*	volunteer sunflower
common sunflower	ragweed	wild buckwheat
common vetch	scentless chamomile (false)	wild sunflower
diffuse knapweed		
green smartweed		

* *Suppression*

Remarks: Rate varies depending on type of ground equipment. Apply in 2-5 gal. water. Apply when weeds are 1"-3" tall. Apply 0.5 pt./A when weeds are 3"-6" tall, under dry conditions, or where Canada thistle or knapweeds are the primary pest. To improve spectrum of activity or to increase activity against taller weeds, Stinger may be tank mixed with 0.5-2 lb. ae/A of 2,4-D amine or low volatile ester. Do not apply by aircraft. Do not apply this product through any type of irrigation system.
Areas of Application: Noncrop areas including fence rows, around farm buildings, and equipment pathways.

STOMP

Stomp or Stomp WDG (60%) (pendimethalin)
Rate: 2-4 lb. ai/A
4-8 pt./A
3.3-6.6 lb. WDG/A

Weeds: **Broadleaf weeds:**

carpetweed	hop clover	pigweed
common chickweed	knotweed	puncturevine
cudweed	kochia	purslane
fiddleneck	lambsquarters	shepherdspurse
filaree	London rocket	spurge
Florida pusley	mousear chickweed	velvetleaf
henbit	Pa. smartweed	yellow woodsorrel

Grasses:

barnyardgrass	foxtail	Mexican sprangletop
bluegrass	goosegrass	red sprangletop
browntop panicum	itchgrass	signalgrass
crabgrass	johnsongrass	Texas panicum
crowfootgrass	junglerice	witchgrass
fall panicum	large crabgrass	woolly cupgrass
field sandbur	lovegrass	

Remarks: Stomp will not control mature weeds; areas should be free of established weeds at the time of treatment. Stomp may be used in conjunction with herbicides registered for postemergence use. Follow the most restrictive precautions, directions and limitations that appear on all labels. Stomp is most effective in controlling weeds when adequate rainfall is received within 30 days after application.

Areas of application: May be used on or around railroads, utility and pipeline rights-of-way, highway guardrails, delineators and sign posts, utility substations, petroleum tank farms, pumping installations, fence rows, storage areas, windbreaks, and shelterbelts.

TELAR

Telar (DG) (chlorsulfuron)

Rate: 0.19-0.75 oz. ai/A
0.25-1 oz. DG/A

Weeds: Selective in industrial turf:

bahiagrass	fescue	wheatgrass
bluegrass	smooth brome	

Rate: 0.19-2.25 oz. ai/A
0.25-3 oz. DG/A

Weeds: Nonselective:

annual ryegrass	corn spurry	prostrate pigweed
annual sowthistle	cowcockle	puncturevine
aster	curly dock	red clover
bedstraw	dandelion	redroot pigweed
black mustard	dyers woad	Russian knapweed
blue mustard	fiddleneck (tarweed)	Scotch thistle
bouncingbet	field pennycress	scouringrush
bull thistle	flixweed*	shepherdspurse
bur beakchervil	filaree	smooth pigweed
burclover	foxtail	sweetclover*
buttercup	goldenrod	tansymustard
Canada thistle*	groundsel	treacle mustard
common chickweed	hempnettle	tumble mustard (jim hill)
common cinquefoil	henbit	turkey mullein*
common lambsquarters	horsetail	white clover
common mallow	London rocket	whitetop (hoary cress)
common mullein	mayweed	wild carrot
common ragweed*	minerslettuce	wild garlic
common sunflower	musk thistle	wild onion
common speedwell*	pepperweed	wild mustard
common tansy	pineappleweed	wild parsnip
common yarrow	poison hemlock	yellow starthistle
conical catchfly	prostrate knotweed*	

Remarks: Do not apply this product through any type of irrigation system. Do not use on food or feed crops. Refer to label for further use directions and precautions.

Areas of Application: Airports, highways, roadsides, utility, pipeline, and railroad rights-of-way, petroleum tank farms, plant sites, and other noncrop areas.

State Restrictions: Use restricted to railroad rights-of-way in Montana, North Dakota, and South Dakota. Not for use in California and Alamosa, Costilla, Conejos, Rio Grande, and Saguache counties of Colorado.

TORDON

Restricted Use Pesticide.

Tordon 22K (picloram)

Rate: 1 lb. ae/A
0.5 gal. 22K/A

Weeds: Controls annual and deep-rooted perennial weeds.

Remarks: Carefully follow label.

Areas of Application: Areas such as fence rows, roadsides or other rights-of-way and around farm buildings.

Transline — see clopyralid

TRICLOPYR

Garlon 3A

Rate: 1-9 lb. ae/A
1.33-12 qt. 3A/A

Weeds: **Annual and perennial broadleaf weeds:**

bindweed	dandelion	smartweed
burdock	field bindweed	tansy ragwort
Canada thistle	lambsquarters	vetch
chicory	plantain	wild lettuce
curly dock	ragweed	

Woody plants:

alder	Douglas-fir	poplar
arrowwood	elderberry	red maple
ash	elm	sassafras
aspen	hawthorn	Scotch broom
beech	hazel	sumac
birch	hornbeam	sweetbay magnolia
blackberry	locust	sweetgum
blackgum	madrone	sycamore
Brazilian pepper	mulberry	tanoak
cascara	oaks	thimbleberry
chinquapin	persimmon	tulip poplar
chokecherry	pin cherry	wax myrtle
cottonwood	pine	western hemlock
dogwood	poison oak	willow

Remarks: Foliar spray: apply when weeds and brush are actively growing. Use lower rates for weed control and higher rates for hard-to-control brush and for applications made in late summer or during drought conditions (refer to label for use directions for broadcast and directed sprays). Cut surface treatments: apply either undiluted or diluted in a 1:1 ratio with water. Apply using the tree injector method, with frill or girdle method, or as a cut stump treatment. Apply at any season except during period of heavy sap flow of certain species such as maples.

Areas of Application: Use for forest management applications, on noncrop sites including industrial manufacturing and storage sites, rights-of-way, fence rows, nonirrigation ditchbanks, wildlife openings, and around farm buildings.

Garlon 4

Rate: 1-8 lb. ae/A
1-8 qt./A

Weeds: Same as for Garlon 3A plus:

black medic	ground ivy	wild carrot
clover	mustard	wild violet
goldenrod	oxalis	

Remarks: Foliar spray: same as for Garlon 3. For basal bark treatments, apply to stem with basal diameters less than 6" at any time, including the winter months, except when snow or ice prevent spraying to the ground line. Conventional basal bark treatment: mix 1-5 gal. product in enough oil to make 100 gal. spray mixture and spray the basal parts of brush and tree trunks until thoroughly wet and runoff at ground is noticeable. Low volume basal bark treatment: mix 20-30 gal. product in enough oil to make 100 gal. spray mixture and spray the basal parts of brush and tree trunk in a manner which throughly wets the lower stems and root collar area, but not to the point of runoff. Thinline basal bark treatment: apply undiluted in a thin stream to form a narrow band which completely encircles the lower stem of brush and tree species.

Areas of Application: Same as for Garlon 3A.

Pathfinder

Rate: Apply undiluted to woody plant stems less than 6".

Weeds: Over 80 woody plant species including:

alder	Douglas-fir	poplar
arrowwood	elderberry	red maple
ash	elm	sassafras
aspen	hawthorn	Scotch broom
beech	hazel	sumac
birch	hornbeam	sweetbay magnolia
blackberry	locust	sweetgum
blackgum	madrone	sycamore
Brazilian pepper	mulberry	tanoak
cascara	oaks	thimbleberry
chinquapin	persimmon	tulip poplar
chokecherry	pin cherry	wax myrtle
cottonwood	pine	western hemlock
dogwood	poison oak	willow

Remarks: Ready-to-use product. Spray to runoff around the entire circumference of the lower 12"-15" for a low volume basal treatment. For cut stump treatment, wet the area adjacent to the cambium and bark around the entire circumference and sides of freshly cut stumps.

NOTICE The information on these pages is for preliminary planning — not a guide for use. Be sure to follow manufacturer's directions, notwithstanding information contained here.

Areas of Application: Rights-of-way, forests, industrial sites, nonirrigation ditchbanks, wildlife openings.

Redeem

Rate: Broadcast: 6-9 lb. ae/A; 2-3 gal./A — High-volume leaf stem treatment: 2-4 oz./3 gal. solution

Weeds: **Woody plants-easy to control:**

alder	cascara	mulberry
arrowwood	ceanothus	poplar
aspen	chinquapin	sassafras
beech	common persimmon	Scotch broom
birch	cottonwood	sycamore
black locust	dogwood	wax myrtle
blackberry	elderberry	western hemlock
Brazilian pepper	gallberry	

Woody plants-hard to control:

ash	elm (except winged)	oak (except post, blackjack, black oak)
blackgum	hazel	poison oak
cherry (except black)	madrone	sweetgum
chokecherry	maple (mountain, sugar, red, striped)	willow
Douglas-fir		

Remarks: Use of a nonionic surfactant such as Ortho X-77, Triton AG-98, or Tronic is recommended. May be tank mixed with 2,4-D. Refer to label for further use directions and precautions. Do not apply this product through any type of irrigation system.

Areas of Application: Roadsides, fence rows, non-irrigation ditchbanks.

Remedy

Rate: Foliar-broadcast: 1 lb. ae/A; 2 pt./A — High-volume leaf stem treatment: 1-3 lb. ae/A; 2-6 pt./A

Weeds: **Annual and perennial broadleaf weeds:**

black medic	curly dock	plantain
burdock	dandelion	vetch
chicory	lambsquarters	wild carrot
cinquefoil	lespedeza	wild violet
clover	mustard	yarrow

Mesquite and woody plants such as:

alder	cottonwood	oak (except black, blackjack, post, shinnery)
ash	dogwood	poison oak
aspen	elderberry	poplar
beech	elm (except winged)	sassafras
birch	hawthorn	sumac
blackberry	locust	wax myrtle
blackbrush	maple (except bigleaf and vine)	wild roses
cascara	mulberry	willow
ceanothus		
cherry		

Remarks: For foliar broadcast treatment, apply in enough water to make a minimum 10 gal. total spray/A. For HV leaf-stem treatment, apply in water to make 100 gal. spray mixture/A. May be tank mixed with 2,4-D. Refer to label for further use directions and precautions. Do not apply this product through any type of irrigation system.

Areas of Application: Roadsides, fence rows, non-irrigation ditchbanks.

Trimec — see 2,4-D listings

VANTAGE

Restricted Use Pesticide due to groundwater concerns.

Vantage (sethoxydim)

Rate: 0.2-0.5 lb. ai/A
1.5-3.75 pt./A
0.8-1.4 fl. oz./1000 sq. ft.

Weeds: Annual and perennial grasses.

Remarks: Do not apply through any type of irrigation system.

Areas of Application: Rights-of-way, roadsides and other paved areas, along fence and hedgerows, public buildings, recreation areas, industrial sites, storage years, airports, electric transformer stations, pipeline pumping stations, sewage disposal areas, and general indoor/outdoor sites.

State Restrictions: Registration pending in California.

VEGEMEC (Premix)

Vegemec Vegetation Killer (3.6% prometon & 1% 2,4-D)

Rate: 1 pt. product/100 sq. ft.

Weeds: **Grasses and broadleaf weeds such as:**

Canada thistle, johnsongrass, milkweed

Remarks: Nonselective. Do not apply on lawns. Pre- and postemergence, apply any time of year. Do not replant within a year of application.

VELPAR

Velpar (90WP) or Velpar L (hexazinone)

Rate: 1.8-4.5 lb. ai/A
2-5 lb. WP/A
2-5 lb. ai/A
1-2.5 gal. L/A

Weeds: **Broadleaf weeds** (short term control-up to 3 months):

bindweed	fiddleneck	oxalis
bouncingbet*	filaree	pigweed
burdock	fleabane	purslane
cocklebur	goatsbeard vine	smartweed
crown vetch	goldenrod	trumpet creeper*
curly dock*	lespedeza	wild oat*
dandelion	milkweed*	wild parsnip
dogbane*	mustard	wild starthistle

Grasses (short term control-up to 3 months):

barnyardgrass	crabgrass	paragrass
bromegrass	nutsedge*	quackgrass
buffalograss*	orchardgrass*	ryegrass

Rate: 5.4-10.8 lb. ai/A
6-12 lb. WP/A
6-12 lb. ai/A
3-6 gal. L/A

Weeds: **Broadleaf weeds** (season long control):

broomsedge	dogfennel*	prickly lettuce
camphorweed	heath aster	ragweed
Canada thistle*	honeysuckle	spanishneedles
chickweed	lantana	wild blackberry*
clover	marestail	wild carrot
dewberry	plantain	

Grasses (season long control):

bahiagrass*	fescue*	natalgrass
bermudagrass*	fingergrass	smutgrass
bluegrass	foxtail	vaseygrass
broomsedge	guineagrass	

* *Suppression*

Remarks: Apply as a postemergent spray during active growth.

Areas of Application: Railroad, highway, utility and pipeline rights-of-way; petroleum tank farms, storage areas, industrial plant sites, drainage ditchbanks, and similar areas.

Weed Rhap — see 2,4-D

Weedar — see 2,4-D

Weed-E-Rad — see DSMA

Weed-Hoe — see MSMA

WEEDMASTER (Premix)

Weedmaster (1 lb./gal. DMA salt of dicamba & 2.87 lb./gal. 2,4-D)

Rate: 0.25-2 lb. ai/A
0.5-4 pt./A

Weeds: **Broadleaf weeds and woody plants:**

annual fleabane	common lambsquarters	poison ivy
annual mustard	curly dock	poorjoe
black knapweed	dogfennel	privet
broomweed	eastern persimmon	redroot pigweed
buckeye	elderberry	Russian knapweed
buffalobur	field bindweed	silverleaf nightshade
burdock	field pennycress	southern dewberry
buttercup	hairy honeysuckle	spotted beebalm
Carolina horsenettle	henbit	spotted knapweed
chicory	knotweed	tall morningglory
common chickweed	kochia	Texas groundsel
common cocklebur	late eupatorium	Virginia pepperweed
common dandelion	Missouri goldenrod	woolly croton
common goldenweed	plains coreopsis	

Remarks: Apply when weeds are actively growing. Adjuvants or other spray additives (emulsifiers, surfactants, wetting agents, drift control agents, or penetrants) may be used for wetting, penetration, or drift control. If spray additives are used, follow all restrictions and precautions on label.

Areas of Application: Noncrop areas such as fence rows, roadways, wastelands, and around farm buildings.

Weedone — see 2,4-D

PROPOSED IMPROVEMENTS
BMA WCID #1

DESCRIPTION	UNIT	QUANTITY	UN. PRICE	COST
SIPHON AT FLUME 6 SITE				
LABOR AND EQUIPMENT	LF	700	$60	$42,000
PIPE	LF	700	$165	$115,500
BEDDING	LF	700	$12	$8,400
GRASSING	AC	1	$1,900	$1,900
MISC. SITEWORK	LS	1	$10,000	$10,000
Subtotal				$177,800
Engineering				$17,780
10% Contingency				$17,780
TOTAL ESTIMATED CONSTRUCTION COST				$213,360
SIPHON AT FLUME 11 SITE				
LABOR AND EQUIPMENT	LF	1,650	$55	$90,750
PIPE	LF	1,650	$165	$272,250
BEDDING	LF	1,650	$12	$19,800
GRASSING	AC	3	$1,900	$5,700
MISC. SITEWORK	LS	1	$10,000	$10,000
Subtotal				$398,500
Engineering				$39,850
10% Contingency				$39,850
TOTAL ESTIMATED CONSTRUCTION COST				$478,200
MAIN CANAL LINING				
EARTHWORK	LF	89,760	$5	$448,800
CONCRETE LINING	LF	89,760	$75	$6,732,000
CROSSINGS	EA	10	$6,000	$60,000
GRASSING	AC	10	$1,900	$19,000
MISC. SITEWORK	LS	1	$25,000	$25,000
Subtotal				$7,284,800
Engineering				$437,088
10% Contingency				$728,480
TOTAL ESTIMATED CONSTRUCTION COST				$8,450,368
MAIN CANAL PIPING NEAR CASTROVILLE WWTP				
LABOR AND EQUIPMENT	LF	21,120	$100	$2,112,000
9 X 6 BOX	LF	21,120	$210	$4,435,200
BEDDING	LF	21,120	$10	$211,200
GRASSING	AC	20	$1,900	$38,000
MISC. SITEWORK	LS	0	$10,000	$0
Subtotal				$6,796,400
Engineering				$407,784
10% Contingency				$679,640
TOTAL ESTIMATED CONSTRUCTION COST				$7,883,824
MAIN CANAL CONTROL AND OVERFLOW STRUCTURES				
LAND	AC	2	$1,000	$2,000
STRUCTURE, GATES, & OVERFLO	LF	5	$35,000	$175,000
GRASSING	AC	4	$1,900	$7,600
MISC. SITEWORK	LS	5	$10,000	$50,000
Subtotal				$234,600
Engineering				$18,768
10% Contingency				$23,460
TOTAL ESTIMATED CONSTRUCTION COST				$276,828

PROPOSED IMPROVEMENTS
BMA WCID #1

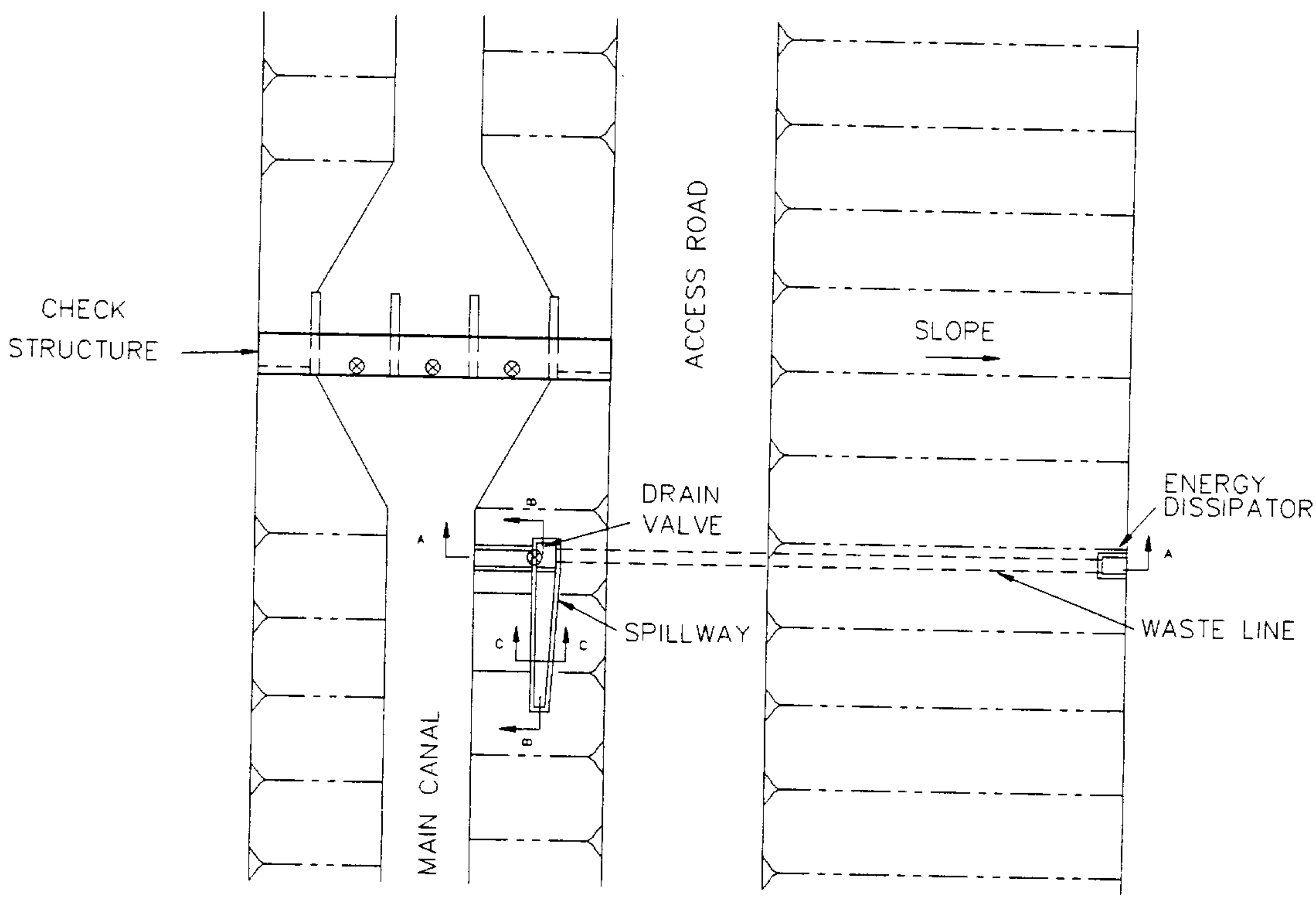
DESCRIPTION	UNIT	QUANTITY	UN. PRICE	COST
A-1 CANAL LINING				
EARTHWORK	LF	36,000	$4	$144,000
CONCRETE LINING	LF	36,000	$65	$2,340,000
CROSSINGS	EA	5	$6,000	$30,000
GRASSING	AC	0	$1,900	$0
MISC. SITEWORK	LS	1	$15,000	$15,000
Subtotal				$2,529,000
Engineering				$151,740
10% Contingency				$252,900
TOTAL ESTIMATED CONSTRUCTION COST				$2,933,640
D-1 PIPING				
LAND	AC	0	$1,000	$0
48" PIPING	LF	42,000	$85	$3,570,000
CONTROL STRUCTURE	LF	50	$500	$25,000
GRASSING	AC	28	$1,900	$53,200
Subtotal				$3,648,200
Engineering				$218,892
10% Contingency				$364,820
TOTAL ESTIMATED CONSTRUCTION COST				$4,231,912
D-2 PIPING				
48" PIPING	LF	42,000	$85	$3,570,000
36" PIPING	LF	8,000	$60	$480,000
24" PIPING	LF	8,000	$40	$320,000
18" PIPING	LF	8,000	$30	$240,000
GRASSING	AC	45	$1,900	$85,500
CONTROL STRUCTURE	LS	125	$500	$62,500
Subtotal				$4,758,000
Engineering				$380,640
10% Contingency				$475,800
TOTAL ESTIMATED CONSTRUCTION COST				$5,614,440
B CANAL LINING				
EARTHWORK	LF	24,000	$4	$96,000
CONCRETE LINING	LF	24,000	$60	$1,440,000
CROSSINGS	EA	5	$6,000	$30,000
GRASSING	AC	0	$1,900	$0
MISC. SITEWORK	LS	1	$10,000	$10,000
Subtotal				$1,576,000
Engineering				$94,560
10% Contingency				$157,600
TOTAL ESTIMATED CONSTRUCTION COST				$1,828,160
NATALIA PIPING				
36" PIPING	LF	16,000	$60	$960,000
CONTROL STRUCTURE	LF	10	$500	$5,000
GRASSING	AC	11	$1,900	$20,900
Subtotal				$985,900
Engineering				$59,154
10% Contingency				$98,590
TOTAL ESTIMATED CONSTRUCTION COST				$1,143,644

PROPOSED IMPROVEMENTS
BMA WCID #1

DESCRIPTION	UNIT	QUANTITY	UN. PRICE	COST
CHACON RESERVOIR SILT REMOVAL				
EXCAVATION	CY	315,000	$4	$1,260,000
HAUL OFF AND DISPOSAL	CY	315,000	$5	$1,575,000
GRASSING	AC	2	$1,900	$3,800
Subtotal				$2,838,800
Engineering				$170,328
10% Contingency				$283,880
TOTAL ESTIMATED CONSTRUCTION COST				$3,293,008
EXPAND PEARSON LAKE				
LAND	AC	10	$1,000	$10,000
EXCAVATION	CY	194,000	$2	$388,000
HAUL OFF AND DISPOSAL	CY	194,000	$4	$776,000
GRASSING	AC	3	$1,900	$5,700
CONTROL STRUCTURE	LS	1	$20,000	$20,000
Subtotal				$1,199,700
Engineering				$71,982
10% Contingency				$119,970
TOTAL ESTIMATED CONSTRUCTION COST				$1,391,652
EXPAND JUNGMAN LAKE				
LAND	AC	5	$1,000	$5,000
EXCAVATION	CY	89,760	$3	$269,280
GRASSING	AC	10	$1,900	$19,000
CONTROL STRUCTURE	LS	1	$15,000	$15,000
Subtotal				$308,280
Engineering				$30,828
10% Contingency				$30,828
TOTAL ESTIMATED CONSTRUCTION COST				$369,936
NEW RESERVOIR AT BEXAR CO. LINE ON A-1				
LAND	AC	10	$1,000	$10,000
LEVEE (Material from Pearson Lake)	CY	17,000	$4	$68,000
GRASSING	AC	10	$1,900	$19,000
CONTROL STRUCTURE	LS	1	$10,000	$10,000
Subtotal				$107,000
Engineering				$16,050
10% Contingency				$10,700
TOTAL ESTIMATED CONSTRUCTION COST				$133,750
NEW RESERVOIR SOUTH OF IH-35 ON D-2				
LAND	AC	9	$1,000	$9,000
LEVEE	CY	16,000	$4	$64,000
HDPE LINER	SY	34,000	$1	$34,000
PROTECTIVE COVER	CY	11,500	$3	$34,500
GRASSING	AC	9	$1,900	$17,100
CONTROL STRUCTURE	LS	1	$10,000	$10,000
Subtotal				$168,600
Engineering				$25,290
10% Contingency				$16,860
TOTAL ESTIMATED CONSTRUCTION COST				$210,750

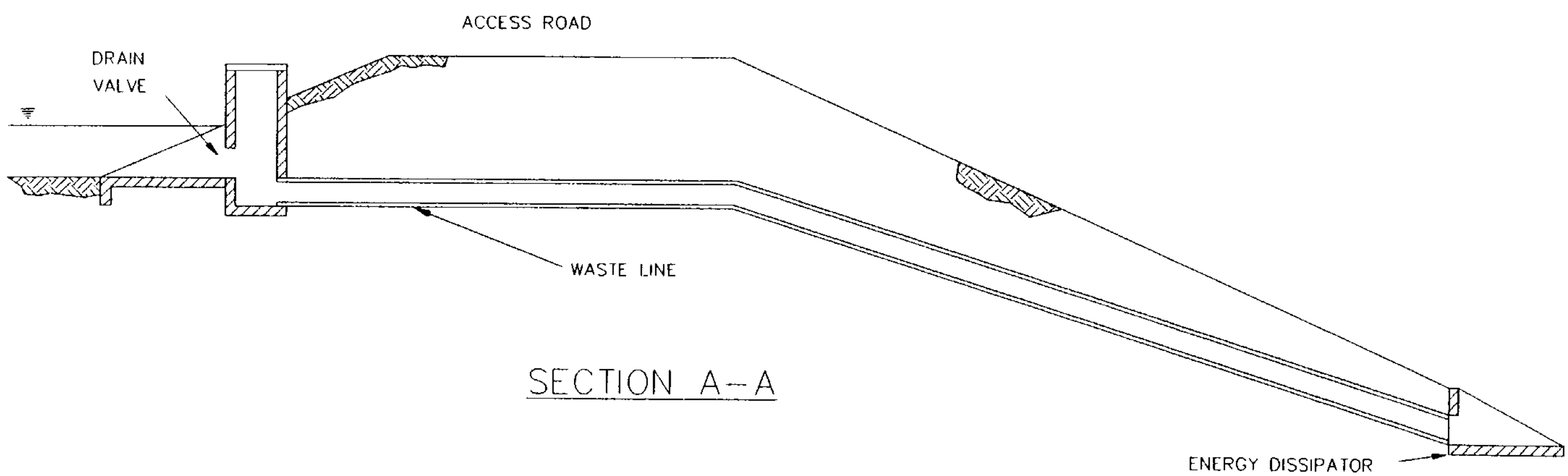
B.M.A. W.C.I.D. #1

CHECK STRUCTURE WITH OVERFLOW SPILLWAY

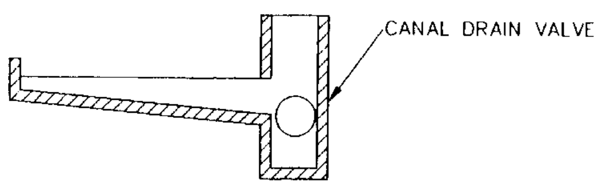


B.M.A. W.C.I.D. #1

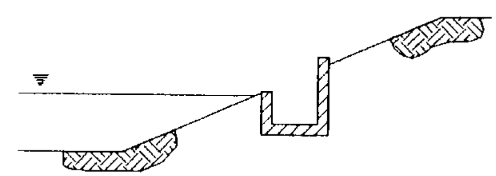
OVERFLOW STRUCTURE SECTIONS



SECTION A–A



SECTION B–B



SECTION C–C

BLACKWELL, LACKEY & ASSOCIATES INC.

708 E. Dessau Road ☆ Austin, Texas 78753 ☆ (512) 251-6169 ☆ (512) 251-8557 FAX

December 12, 1995

Mr. Alfredo Rodriguez
Project Manager
Texas Water Development Board
1700 N. Congress Avenue
Austin, Texas 78745

Subject: Final Interim Report - Medina Lake Recharge Study
TWDB Contract No. 95-483-071

Dear Alfredo:

Enclosed are twelve copies of the Final Interim Report for the Medina Lake Recharge Study for the period July 1994 through August 1995.

Sincerely,

BLACKWELL, LACKEY & ASSOCIATES INC.

Arthur J. Whallon, P.G.

cc: John Ward, BMA
Tom Moreno, BMWD - via MLK
Ed McCarthy, MLK
Lou Rosenberg, P.C. - via MLK
Rebecca Lambert, USGS
Michael Sullivan, MSA

FINAL INTERIM REPORT - FY 1995

HYDROLOGIC, RECHARGE AND WATER QUALITY ASSESSMENT OF MEDINA LAKE

CONTRACT NO. 95-483-071

DECEMBER, 1995

JOINT PROJECT BETWEEN
BEXAR METROPOLITAN WATER DISTRICT,
BEXAR-MEDINA-ATASCOSA COUNTIES WATER CONTROL AND IMPROVEMENT DISTRICT NO. 1,
TEXAS WATER DEVELOPMENT BOARD,
AND
U.S. GEOLOGICAL SURVEY

TABLE OF CONTENTS

1.0 INTRODUCTION

This draft interim report was prepared in accordance with Texas Water Development Board Contract No. 95-483-071 as a report of findings for the period July 1994 through August 1995, which is the first year of a three year project. The project is entitled the Hydrologic, Recharge and Water Quality Assessment of Medina Lake.

Medina and Diversion Lakes are located on the Medina River in northeastern Medina County and southeastern Bandera County (Figure 1). Medina Lake was constructed in 1912 to supplement existing irrigation supplies. The Medina River is impounded behind the upper dam at Medina Lake. Water from the upper dam is discharged down a four mile canyon to a smaller impoundment, Diversion Lake, where it is then diverted into a system of irrigation canals. Most of the reservoir area of Medina Lake and Diversion Lake overlies the Glen Rose Limestone.

Seepage of the impounded water in both lakes into the underlying bedrock has been documented by various sources. Qualitative assessments have observed that the channel connecting both lakes experience large seepage losses. Quantitative estimates have shown that seepage losses from Medina and Diversion Lakes range from 72,000 acre-feet per year (USBR, 1930) to 41,000 acre-feet per year from Medina Lake itself (Lowry, 1953). In recent past, the U.S. Geological Survey, while utilizing Lowry's methodology, have reported annual estimates of the change in reservoir storage for Medina Lake to be similar to the seepage losses reported by Lowry in 1953. Lowry's methodology involved the development of empirical curves based on observations of rising and falling reservoir levels. It did not include streamflow or rainfall data either into or out of the Medina Lake system.

Current methodologies used to calculate long term, average annual seepage losses from Medina and Diversion lakes, and from the connecting channel between them, into the underlying bedrock contain inherent imprecisions. Water management agencies and the scientific community have voiced important concerns regarding the accuracy of such calculations in determining the availability of excess reservoir water for downstream water users. As well, current water supply management practices require a greater understanding of the water balance of the Medina and Diversion lakes. This project has been organized into three phases to investigate these related issues.

Phase I is the assessment of hydrogeologic features in and around the lake system which involves the mapping of geologic features and hydrogeologic units and an inventory of wells and springs. This work will result in a better definition of which aquifers are receiving lake seepage. **Phase 2** will provide a water balance analysis of the area by measuring surface water inflows/outflows at critical locations, lake capacity relationships and evaporation estimates. The source and magnitude of water loss from the lake system will be more reliably quantified. **Phase 3** is the determination of surface water and ground-water quality in Medina and Diversion lakes and of ground water from wells in the adjoining land areas. The chemical characteristics of both surface and ground water will provide greater understanding of the dynamics of lake seepage into the different bedrock units that are contiguous to both lakes.

A key factor to the project is the oversight provided to the primary team members by the Technical Advisory Committee (TAC). TAC members with particular expertise in certain areas are kept appraised of the project's progress and are provided monthly progress reports detailing activities, findings and particular problems.

2.0 TECHNICAL ADVISORY COMMITTEE

The Technical Advisory Committee (TAC) is comprised of technically qualified and respected members of the scientific and regulatory communities. The members of the TAC review all phases of this project at meetings convened on a quarterly basis, assist in the execution of specific tasks, critique and provide comment of preliminary and final project results, and serve as overall technical consultants to the Project Team during the course of these investigations. The TAC is comprised of representatives of the following organizations:

- Bexar Metropolitan Water District (Bexar Met),
- Bexar-Medina-Atascosa Counties WCID No.1 (BMA),
- U.S. Geological Survey (USGS),
- Texas Water Development Board (TWDB),
- Texas Natural Resource Conservation Commission (TNRCC),
- Texas Parks and Wildlife Department (TP&WD),
- San Antonio Water System (SAWS),
- Edwards Underground Water District (EUWD),
- San Antonio River Authority (SARA),
- Medina County Underground Water Conservation District (MCUWCD), and
- Springhill Water Management District (SWMD).

The TAC met on five occasions during the first year of the project at dates/locations indicated below:

- July 15, 1994/ Plaza San Antonio
- October 7, 1994/ San Antonio River Authority
- January 6, 1995/ Castroville and Project Field Sites
- April 21, 1995/ Edwards Underground Water District
- August 24, 1995/ U. S. Geological Survey

These meetings were conducted in a forum that combined formal presentations by the Project Team followed by a question and answer period where all members were given the opportunity to hear from other TAC members and contribute to the meeting. Presentations have included topics such as:

- Site selection of field monitoring sites
- Hydrogeologic mapping
- Rainfall and streamflow characteristics

The Project Team has benefited from direct assistance by members of the TAC in the following areas: 1) personnel and equipment during the installation of monitoring equipment, 2) equipment for the measurement of streamflow data, 3) personnel to assist in the selection of field monitoring sites and 4) personnel and equipment to conduct technical oversight in areas involving field data collection and data analysis.

3.0 PHASE 1 - HYDROGEOLOGIC ASSESSMENT

Phase 1, which is an inventory and hydrogeologic assessment of the area, is being performed by the USGS. The hydrogeologic assessment includes field mapping of rock units that compose the Edwards and Trinity aquifers and a well inventory in the study area. A geologic and hydrogeologic map of the study area will be constructed which will include the identification of lithostratigraphic units of the Trinity and Edwards aquifers exposed in outcrop. An inventory of wells and springs in the study area, along with existing historical well data, will be used in Phases 2 and 3 to develop a three-dimensional conceptual model of the hydrogeology around Medina Lake and Diversion Reservoir. Available water-level measurements will be used to establish the depth to groundwater in inventoried wells and, if possible, determine the regional direction of ground-water flow in the Edwards and Trinity aquifers in the study area. The USGS will document this effort in a Phase 1 report.

3.1 Scope of Work Revisions

The scope of work proposed for the hydrogeologic assessment (Phase 1) is approximately 85-90 percent complete. Phase 1 tasks included 1) the compilation of available historical data, 2) field mapping of geologic features and hydrogeologic units of the Edwards and Trinity aquifers, 3) inventory of wells and springs, and 4) construction of cross sections and GIS coverages of the hydrogeologic units in the study area. The task of constructing geologic cross sections and water-level elevation maps will be completed in FY96. A preliminary draft report detailing the results of the field mapping was provided for review and comment to the TWDB and the Local Sponsors in October, 1995. The report is currently being peer reviewed at the USGS and will be finalized in March, 1996.

3.2 Findings

Significant findings, accomplishments and percent complete estimates for Phase 1 are described below in the following six tasks:

Task 1	Compile Data	100% Complete
Task 2	Map Hydrogeologic Units	100% Complete
Task 3	Inventory Wells and Springs	95% Complete
Task 4	Analyze Field Data	95% Complete
Task 5	Prepare Report	0% Complete
Task 6	Review Report	0% Complete

Seepage losses from Medina and Diversion Lakes have been documented by the USGS and other sources since completion of the irrigation structures in 1912. Historically, all of the water lost from the lakes has been assumed to enter the Edwards aquifer, either directly or indirectly through the Trinity aquifer. The overall objective of Phase 1 has been to determine if this assumption could be validated by more precisely mapping the geologic features and hydrogeologic units exposed in outcrop. Previous hydrogeologic investigations in the area mapped individual rock units only to the group or formation level, separating the Edwards Group (Edwards aquifer) from the Glen Rose Limestone (Trinity aquifer). One of the most recent maps, the geologic map of Texas published by the Bureau of Economic Geology (BEG) in 1992, shows geologic unit mapping at the Group and Formation level. The BEG map shows that Medina Lake is underlain by the Glen Rose Limestone, and that the intervening canyon between the two dams and Diversion Lake is underlain by the Edwards Group.

Compilation of historical data and field mapping (tasks 1 and 2) of the hydrogeologic assessment have been completed and the information is being used to develop a GIS coverage of the hydrogeologic units and structural features in the study area. This coverage is included in the draft report submitted by the USGS in October, 1995. Information was compiled from historical geologic and hydrogeologic maps, geologic cross-sections, geophysical and driller's logs, aerial photos, and other available pertinent information on Medina and Bandera Counties for use in field mapping. Next, the hydrogeologic units in the Medina and Diversion Lakes watershed were mapped. The mapping units were based on the hydrogeologic units defined in Maclay and Small (1976) for the Edwards aquifer and the geologic units modified from those defined in Stricklin, Smith, and Lozo (1971) for the Trinity deposits comprising the Trinity aquifer. Distinct marker beds, such as the regional dense member of the Person Formation (Edwards aquifer), and the Corbula bed and the evaporite zones in the Glen Rose Limestone (Trinity aquifer), were used as stratigraphic identifiers of the Glen Rose Limestone when possible. The porosity and permeability characteristics of each mappable unit were described. Structural and karst features, including faults and fractures, caverns, and sinkholes were also recorded.

Results from the field mapping confirmed the conclusion reached by previous investigations - that Medina Lake lies on rocks of the Upper Glen Rose Limestone. The upper end of Diversion Lake and the intervening canyon between the two dams also lie on the Upper Glen Rose Limestone, not on rocks of the Edwards Group as previously assumed. The lower end of Diversion Lake (near the dam) lies on a thin section of the lowermost unit in the Edwards Group - the Basal Nodular member. Rocks of the Edwards Group are present in the study area, primarily on the southern side of Medina Lake. In this region, rocks of the Edwards Group form the caps and bluffs on the hills surrounding the lake.

By separating the Edwards Group into smaller hydrogeologic units as described in Maclay and Small (1976), a more precise determination of the relative stratigraphic position in the section is being made and will be documented in the Phase 1 report by the USGS. The lithologic and hydrologic properties of the hydrogeologic units of the Edwards aquifer are similar to those that were mapped by Stein and Ozuna (1995) in Bexar County (Table 1). Most of the Edwards rocks that may be hydrologically connected with the lake system at higher lake stages are primarily from the Kainer Formation, stratigraphically the lowest formation in the Edwards Group. These rocks are exposed in outcrop as caps on the hills and bluffs to the south and west of Medina and Diversion Lakes.

As part of the hydrogeologic assessment (task 3), approximately 160 wells and 13 springs have been inventoried and field checked. Most of the inventoried wells are completed in rocks of the Trinity Group - primarily the Glen Rose Limestone and the Travis Peak Formation. These wells are located to the northwest, north and east of Medina Lake. Some Edwards wells have been inventoried, but these wells are located primarily to the south and west of Medina and Diversion Lakes. Information on existing wells and springs was obtained from files of the USGS, TWDB, EUWD, MCUWCD, SWMD, and other local agencies, drillers, and interested parties in the area. All of the inventoried well and spring information will be entered into the USGS's ground-water database and forwarded to the TWDB for assignment of a state well number in FY96. Water-level measurements were made, when possible, at each inventoried well. The water-level measurements will be used to determine the altitude of water in the Trinity and Edwards aquifers and if possible, determine the ground-water flow gradient in the vicinity of the lakes.

Table 1. Summary of the lithologic and hydrologic properties of the hydrogeologic subdivisions of the Edwards aquifer outcrop, Bexar County, Texas

[Hydrogeologic subdivisions modified from Maclay and Small (1976); groups, formations, and members modified from Rose (1972); lithology modified from Dunham (1962); and porosity type modified from Choquette and Pray (1970). CU, confining unit; AQ, aquifer]

Hydrogeologic subdivision			Group, formation, or member			Hydrologic function	Thickness (feet)	Lithology	Field identification	Cavern development	Porosity/ permeability type
Upper Cretaceous	Upper confining units		Eagle Ford Group			CU	30 - 50	Brown, flaggy shale and argillaceous limestone	Thin flagstones; petroliferous	None	Primary porosity lost/ low permeability
Upper Cretaceous	Upper confining units		Buda Limestone			CU	40 - 50	Buff, light gray, dense mudstone	Porcelaneous limestone with calcite-filled veins	Minor surface karst	Low porosity/low permeability
Upper Cretaceous	Upper confining units		Del Rio Clay			CU	40 - 50	Blue-green to yellow-brown clay	Fossiliferous; *Ilymatogyra arietina*	None	None/primary upper confining unit
Lower Cretaceous	I	Edwards aquifer	Georgetown Formation			Karst AQ; not karst CU	2 - 20	Reddish-brown, gray to light tan marly limestone	Marker fossil; *Waconella wacoensis*	None	Low porosity/low permeability
Lower Cretaceous	II	Edwards aquifer	Edwards Group	Person Formation	Cyclic and marine members, undivided	AQ	80 - 90	Mudstone to packstone; *miliolid* grainstone; chert	Thin graded cycles; massive beds to relatively thin beds; crossbeds	Many subsurface; may be associated with earlier karst development	Laterally extensive; both fabric and not fabric/ water-yielding
Lower Cretaceous	III	Edwards aquifer	Edwards Group	Person Formation	Leached and collapsed members, undivided	AQ	70 - 90	Crystalline limestone; mudstone to grainstone; chert; collapsed breccia	Bioturbated iron-stained beds separated by massive limestone beds; stromatolitic limestone	Extensive lateral development; large rooms	Majority not fabric/one of the most permeable
Lower Cretaceous	IV	Edwards aquifer	Edwards Group	Person Formation	Regional dense member	CU	20 - 24	Dense, argillaceous mudstone	Wispy iron-oxide stains	Very few; only vertical fracture enlargement	Not fabric/low permeability; vertical barrier
Lower Cretaceous	V	Edwards aquifer	Edwards Group	Kainer Formation	Grainstone member	AQ	50 - 60	*Miliolid* grainstone; mudstone to wackestone; chert	White crossbedded grainstone	Few	Not fabric/ recrystallization reduces permeability
Lower Cretaceous	VI	Edwards aquifer	Edwards Group	Kainer Formation	Kirschberg evaporite member	AQ	50 - 60	Highly altered crystalline limestone; chalky mudstone; chert	Boxwork voids, with neospar and travertine frame	Probably extensive cave development	Majority fabric/one of the most permeable
Lower Cretaceous	VII	Edwards aquifer	Edwards Group	Kainer Formation	Dolomitic member	AQ	110 - 130	Mudstone to grainstone; crystalline limestone; chert	Massively bedded light gray, *Toucasia* abundant	Caves related to structure or bedding planes	Mostly not fabric; some bedding plane-fabric/ water-yielding
Lower Cretaceous	VIII	Edwards aquifer	Edwards Group	Kainer Formation	Basal nodular member	Karst AQ; not karst CU	50 - 60	Shaly, nodular limestone; mudstone and *miliolid* grainstone	Massive, nodular and mottled, *Exogyra texana*	Large lateral caves at surface; a few caves near Cibolo Creek	Fabric; stratigraphically controlled/large conduit flow at surface; no permeability in subsurface
Lower Cretaceous	Lower confining unit		Upper member of the Glen Rose Limestone			CU; evaporite beds AQ	350 - 500	Yellowish tan, thinly bedded limestone and marl	Stair-step topography; alternating limestone and marl	Some surface cave development	Some water production at evaporite beds/ relatively impermeable

4.0 PHASE 2 - WATER BUDGET

Phase 2 consists of the development of a water budget for the Lake Medina and Diversion Reservoir System, and is being performed jointly by the engineers representing the Local Sponsors, the U.S. Geological Survey, and the Texas Water Development Board. Representatives of the USGS perform Quality Assurance oversight and provide the Local Sponsors with written guidance and field training to conduct Phase II activities in accordance with U.S. Geological Survey protocol. Representatives of the TWDB completed the bathymetric survey on Medina Lake and Diversion Lakes in July 1995.

4.1 Scope of Work Revisions

The initial scope of work for Phase 2 provided that the Local Sponsors and the Texas Water Development Board would collect, analyze and present the findings of the data gathered from all of the hydrologic monitoring stations and that the U. S. Geological Survey would provide oversight on a regular basis as a member of the TAC. Other members of the TAC expressed an interest that the protocols of the USGS would be followed during the actual data collection and analysis so that a standard familiar to the TAC members was incorporated into the water budget analyses. In discussions with the Local Sponsors and the TAC, it was decided that the USGS would assume the role of lead technical agency during Phase 2.

Representatives of the USGS are performing Quality Assurance oversight and have provided the Local Sponsors with written guidance and field training to conduct Phase 2 activities in accordance with USGS protocol. The USGS will review all surface water data collected by the Local Sponsors, program and load all data into the USGS surface water data base (ADAPS) and provide training on the use of ADAPS, conduct quality assurance field trips and storm-event field trips, maintain and operate the Medina Lake weather station, estimate evaporation and prepare a preliminary water budget.

4.2 Findings

Significant findings, accomplishments and percent complete estimates for Phase 2 are described below in the following four tasks:

Task 1	Establish Monitor Sites	100% Complete
Task 2	Hydrologic Data Collection	25% Complete
Task 3	Bathymetric Survey	50% Complete
Task 4	Hydrologic Data Analysis	10% Complete

As indicated by the percent complete figures, the first year efforts were directed toward establishing site locations and installing monitoring equipment at all of the sites. Approximately one-half of the monitoring sites were installed and began reporting hydrologic data during May-June, 1995. Installation of the remaining sites was completed during July-August, 1995.

4.2.1. Establish Monitor Sites

Reconnaissance for acceptable sites were conducted by the Local Sponsor's Project Engineers, Remote Operating Systems (ROS), and the USGS. ROS was selected to supply all real-time monitoring equipment for the streamflow gaging stations, rainfall stations and the weather station at the Main Dam. The primary consideration in the selection of ROS is their current contract with the EUWD to install and maintain an extensive network of streamflow and rainfall stations within the Medina River basin. The USGS provided all equipment for the weather station on the lake.

Factors affecting the final selection of each site involved the accessibility of the site for measurement during regular and peak flow events, condition of the channel cross-section, the ability to make a discharge measurement, slope stability, and range of possible flow conditions per U.S. Geological Survey oversight and protocol. Site selection also included obtaining permission to install and operate the station from the proper authorities and/or landowners.

The site types were categorized as either a recording streamflow station, a recording weather station, a recording precipitation station, a recording lake level station or a non-recording peak-stage station. A recording station contains a specific ROS sensor(s) that continuously transmits, in six minute intervals, real time data to the project's Master Terminal Unit (MTU). A non-recording station must be physically visited to record the peak stage of a runoff event. The project's MTU is located in the offices of BMA's District Engineer in San Antonio. Attachment A is a description of each site and the monitoring equipment that has been installed.

Eight (8) streamflow stations, two (2) weather stations, seven (7) precipitation stations (includes one at each weather station), two (2) lake level sensors and four (4) peak stage stations have been instrumented and are reporting data. In addition, four recording precipitation stations operated by the EUWD in the general area of the lake system are available to the project team and are used primarily as advance warning of rainfall events. One of the weather stations is located on land at the west side (spillway side) of the Main Dam and the other station is on the lake surface, moored on a platform off of Walton Island, about two miles north of the dam. A description of the monitoring equipment and a map showing the location of each site is provided in Attachment A.

A broad-crested weir was installed in the main canal immediately downstream of the Diversion dam to improve the gaging of canal flows into irrigation system. This flow control structure will also provide a more accurate measure of discharge from Diversion Lake.

4.2.2. Hydrologic Data Collection

At all recording stations, unit values of river stage, lake stage, rainfall and climatic data are collected on a continuous basis at six minute increments to document the intensity and duration of a particular parameter. These data are transmitted via radio signals from each individual field unit to the Bandera microwave tower. The Local Sponsor's MTU has a direct telephone line to the tower that queries the tower every six minutes for data from each site. These data are transmitted to the MTU so that real time information can be observed at any time for any field station.

Alarm levels are programmed into the MTU that will call selected telephone numbers and inform the individual that a certain station has reached an alarm limit. This information is used to determine if a field trip is immediately required to measure streamflow in rising streams.

Five field trips to measure both baseflow and stormflow events have been undertaken since May, 1995. Measurements have recorded streamflows at all eight recording stations and at three of the four peak-stage stations. The data collected during these measurement events are summarized in Attachment B. Hydrologic data collection during the summer of 1995 has shown the short duration of runoff in the watersheds around Medina Lake.

Surveys have been conducted at all streamflow sites for use in generating stage-discharge rating curves at each of the sites.

4.2.3. Hydrologic Data Analysis

The analysis of the hydrologic data collected during the first year has been limited to measurements of streamflow and the preparation of field survey data for use in developing rating curve information. Extensive analyses will be undertaken during the second year of the project to include the development of rating curves and stage discharge relationships for each site.

Stream discharges are computed immediately following a field trip. These analyses are reviewed and confirmed by USGS personnel for accuracy and consistency with USGS protocols. The stream discharge measurements are summarized in Attachment B. Raw stage data recorded in all stream-level sensors and daily rainfall amounts measured at all continuous precipitation stations are illustrated in Attachment C.

A preliminary rating curve for the broad-crested flume that was installed in the main canal immediately downstream of the Diversion dam was completed following its installation in June, 1995. Field verification of the rating curve for the flume is being conducted. This flow control structure has allowed a more efficient means of gaging outflows entering the downstream irrigation system.

To accurately determine the amount of loss from Medina and Diversion Lakes to the ground-water system, a water balance for each lake will be constructed to account for all components that affect storage in the lakes. The water balance will be solved for ground-water outflow thus:

$$Gw_{out} = Ppt + Sw_{in} + Gw_{in} - Sw_{out} - E \ (+/-) \ S_{change}$$

Precipitation (Ppt) is being measured on a continuous basis at seven recording precipitation stations (Attachment A). Components of surface-water inflow and outflow (Sw_{in} and Sw_{out}) are being determined by continuous monitoring of stage at eight gaging stations (Attachment A). Evaporation (E) will be estimated in a mass balance approach using continuously recorded data from two weather stations, one on the land at the Main Dam and one on the lake. These stations are recording wind speed, air temperature, relative humidity and lake surface temperature. An evaporation pan at the land weather station is also being monitored in an attempt to correlate the mass balance estimates with the pan data in order to derive a reasonable lake pan coefficient. Ground-water inflow (GW_{in}) is assumed to be insignificant over the time frame of several months to years because the regional water table is well below the altitude of the lake. Lake storage changes (S_{change}) will be monitored by a continuous stage recorder at each lake and a stage-to-volume relationship that is being developed through the bathymetric survey.

4.2.4. Bathymetric Survey

The Texas Water Development Board conducted a bathymetric survey of both Medina and Diversion lakes during the summer of 1995. The data collected is being analyzed by TWDB staff and a final report of this work will be completed and distributed in February or March, 1996. A draft version of bathymetric survey map is included in Attachment D. It does not include surveyed information above the water surface of the lake at the time of the field survey but will be amended to show this area.

5.0 PHASE 3 - WATER-QUALITY ASSESSMENT

The water-quality assessment (Phase 3), will be performed by the U.S. Geological Survey (USGS). The primary objective of Phase 3 is to characterize the quality of water in the Medina and Diversion Lakes watershed, and determine, if possible, regions where lake water may enter the Edwards or Trinity aquifers. Water-quality samples from selected ground- and surface-water sites will be collected and analyzed for selected inorganic constituents, trace elements, nutrients, and stable isotopes (Table 2). These analyses will provide additional information on the hydrologic communication between the lakes and the aquifers. The isotopic analyses will be used to determine the "source" of water in samples and, if possible, to trace the isotopic signature of surface water from Medina and Diversion Lakes into the Edwards or Trinity aquifers.

5.1 Scope of Work Revisions

The scope of work proposed for the water-quality assessment (Phase 3) is approximately 5-10 percent complete. Phase 3 tasks include 1) selection of water-quality sampling sites, 2) collection of water samples at 35 ground-water sites, 3) collection of water samples at 3 surface-water sites, and 4) analysis of water-quality and hydrogeologic data. The selection of ground- and surface-water sampling sites has been completed. A map is being prepared which will show the locations of all surface water and ground-water sampling sites.

Initial collection of surface-water samples was conducted in May 1995 to allow for additional site selection and installation of gaging equipment by the Local Sponsors. Surface water samples were collected at site locations: # 6 (Koenig Creek), # 7 (Medina River below Main Dam) and # 9 (Medina River below Diversion Dam) during May, 1995. Lake water samples were collected during May and August, 1995. Surface water samples will be collected during November, 1995 at site locations: # 1 (Medina River at English Crossing), # 7 (Medina River below Main Dam) and # 9 (Medina River below Diversion Dam).

A greater percentage of wells completed in the Trinity aquifer were selected for ground-water sampling because of problems in obtaining enough wells completed in the Edwards aquifer that were suitable for sampling. Ground-water sampling was rescheduled to July 1995 so that additional inventory of wells on the south and west sides of Medina Lake could be conducted to locate more wells completed in the Edwards aquifer. Sampling of the ground-water sites began the last week of July and three wells were sampled. At that time, Phil Nordstrom (TWDB) indicated that TWDB probably would not be billed for any samples sent to the Texas Department of Health Lab (TDHL) until the next fiscal year when TWDB would no longer have a contract with the TDHL. Based on this information, the USGS and TWDB agreed to postpone collection and processing of additional samples until TWDB finalizes a contract with the new lab. Postponing the collection and analysis of samples will maintain the integrity of the dataset because both rounds of sampling will be analyzed by a single lab, thus decreasing the potential for errors introduced by multiple labs. The first ground-water sampling event will occur in November, 1995.

5.2 Findings

Significant findings, accomplishments and percent complete estimates for Phase 3 are described below in the following six tasks:

Task 1	Select Water Quality Sampling Sites	100% Complete
Task 2	Sample Ground Water	40% Complete
Task 3	Sample Surface Water	25% Complete
Task 4	Analyze Water Quality Data	10% Complete
Task 5	Prepare Report	0% Complete
Task 6	Review Report	0% Complete

Surface-water sampling began in May 1995. Water-quality samples were collected at three sites (Nos. 6,7 and 9 - see Attachment A Figure A-1) and analyzed for standard inorganics, trace elements, and nutrients (Table 2). Two water-quality surveys to determine the stratification characteristics of Medina Lake were conducted in May and August 1995 at five transect locations. The five sites are located at the upper end of the lake (riverine environment), the mid-section of the lake near Mormon Bluff (transition zone), approximately 500 ft upstream of the main dam, Elm Cove, and Habys Cove. At each transect, a depth profile along the transect was made. At the center portion of each transect, measurements of temperature, specific conductance, pH, and dissolved oxygen were collected at 10 ft intervals. The results of this water-quality survey indicate that Medina Lake was well-mixed in May and August, and did not show any stratification. Additional surveys will be conducted in the fall and winter to determine if stratification does occur.

Additional water-quality results are expected within the next few months from samples submitted to the Texas State Health Lab. Results from the isotopic analysis are not yet available from the National Water Quality Lab, but are expected within six months.

REFERENCES CITED

Barnes, V.E. and others, 1992, Geologic map of Texas: Bureau of Economic Geology, The University of Texas, Austin, Texas.

Burleigh, H. L., 1949, Extract from report of geologic reconnaissance, Medina Project: U.S. Bureau of Reclamation typed report, p. 9-15.

Choquette, P. W., and Pray, L. C., 1970, Geologic nomenclature and classification of porosity in sedimentary carbonates: American Association of Petroleum Geologists Bulletin, v. 54, no. 2, p. 207-250.

Dunham, R.J., 1962, Classification of carbonate rocks according to depositional texture, in Classification of Carbonate Rocks Symposium: American Association of Petroleum Geologists Memoir 1, p. 108-121.

Lowry, R.L., 1953, Hydrologic Report: Medina River Above the Applewhite Dam Site: unpublished report prepared for the San Antonio City Water Board, August, 1953, 43 p.

Maclay, R.W., and T.A. Small, 1976, Progress report on geology of the Edwards aquifer, San Antonio area, Texas, and preliminary interpretation of borehole geophysical and laboratory data on carbonate rocks: U.S. Geological Survey Open-File Report 83-537, 72 p.

Rose, P. R., 1972, Edwards Group, surface and subsurface, central Texas: University of Texas at Austin, Bureau of Economic Geology Report of Investigations 74, 198 p.

Stein, W.G., and G.B. Ozuna, 1995, Geologic framework and hydrogeologic characteristics of the Edwards aquifer recharge zone, Bexar County, Texas: U.S. Geological Survey Water-Resources Investigations Report 95-4030, 8 p.

Stricklin, F.L., C.L. Smith, and F.E. Lozo, 1971, Stratigraphy of Lower Cretaceous Trinity Deposits of Central Texas: University of Texas Bureau of Economic Geology Report of Investigations No. 71, 63 p.

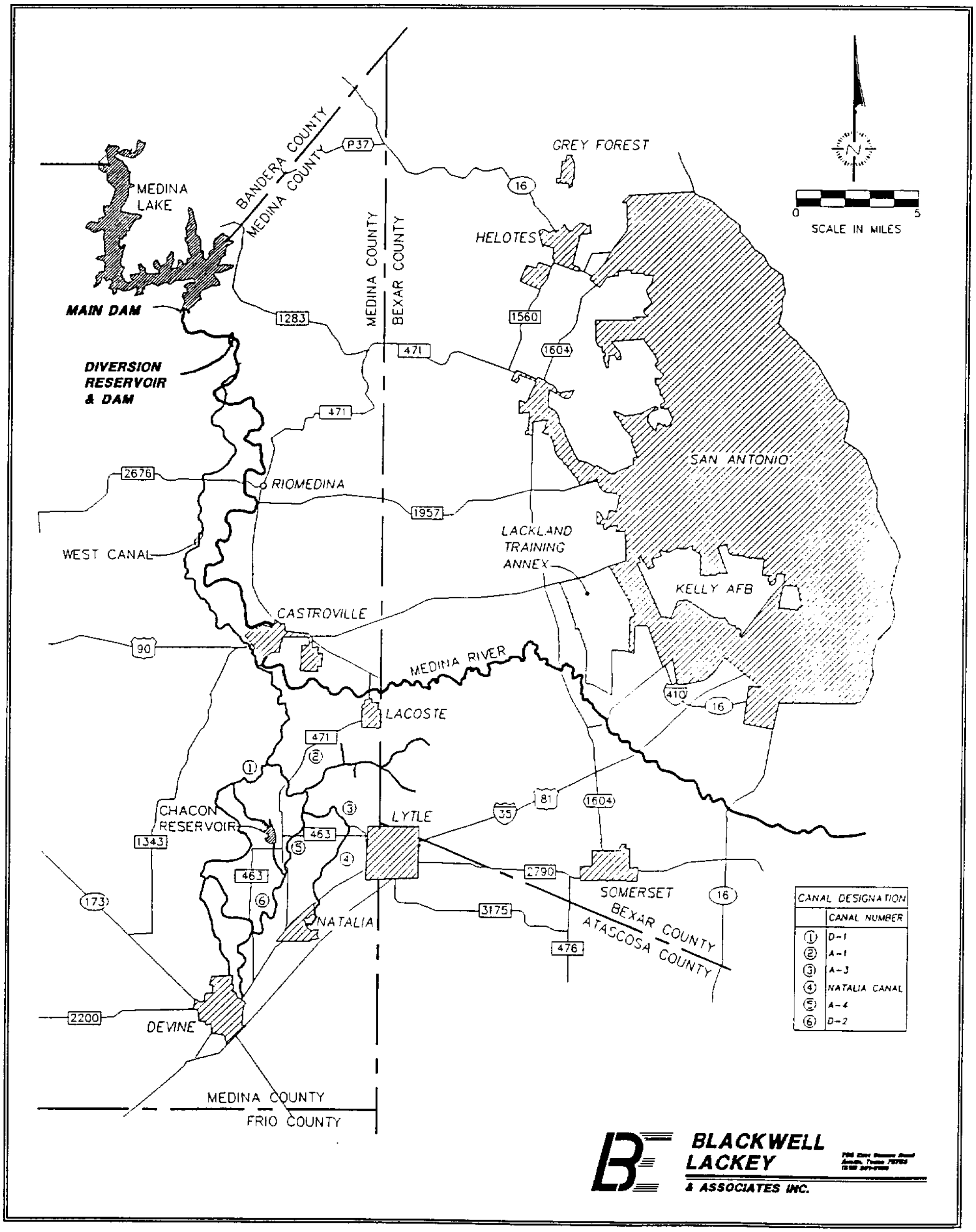
TABLE 2

Water Quality Parameters
Surface Water and Ground Water

Major Anions/Cations	Trace Elements	Nutrients
Sulfate	Arsenic	Nitrate-N
Chloride	Barium	Nitrite-N
Fluoride	Beryllium	Ammonia-N
Silica	Bromide	Kjeldahl - N
	Cadmium	Orthophosphate-P
	Chromium	
Isotopes	Cobalt	
	Copper	**Water Properties**
Oxygen	Iron	
	Lithium	Alkalinity
	Lead	Conductance
	Manganese	pH
	Mercury	Temperature
	Molybdenum	
	Nickel	
	Silver	
	Strontium	
	Vanadium	
	Zinc	

FIGURE 1

MEDINA LAKE LOCATION MAP



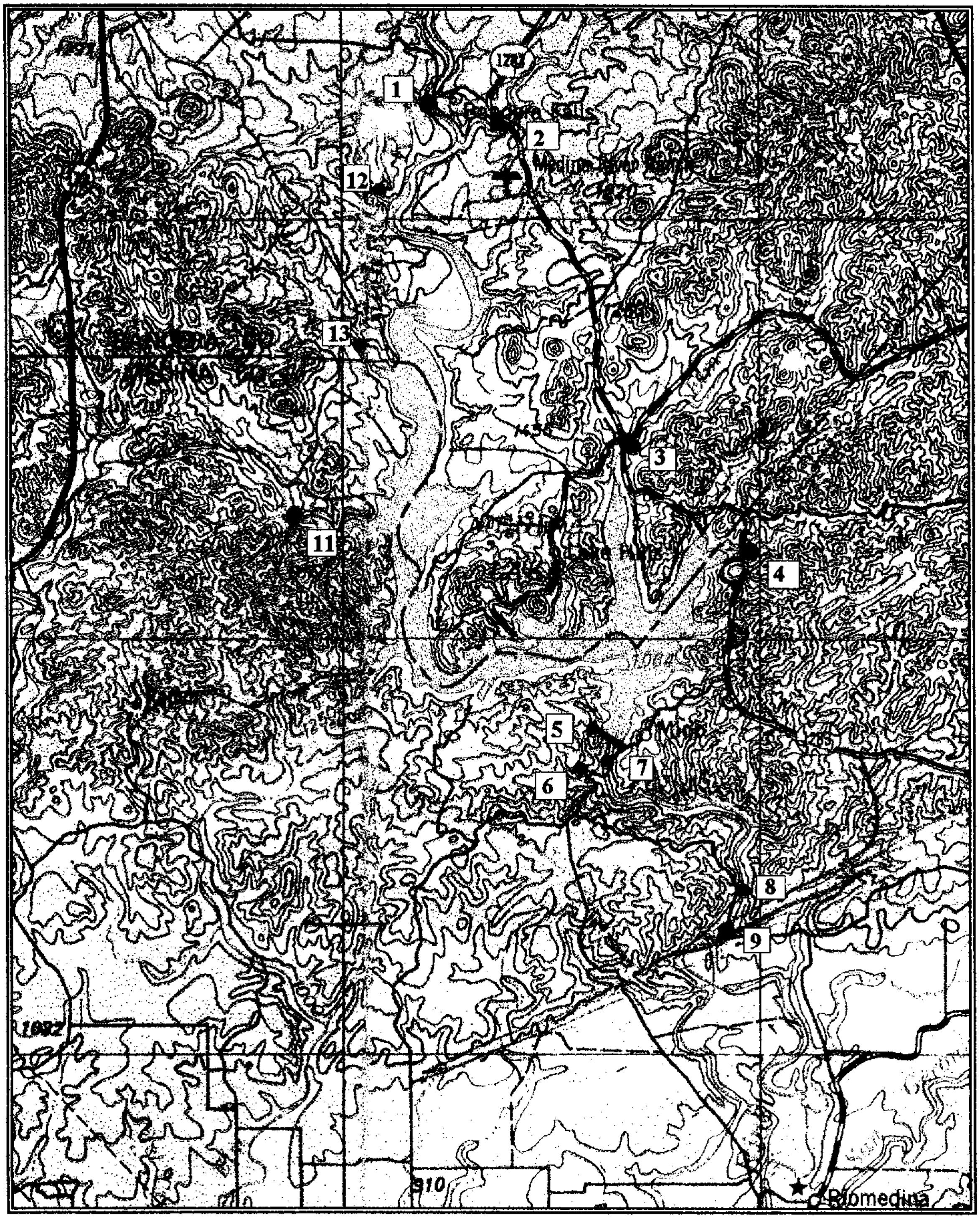
ATTACHMENT A

HYDROLOGIC DATA COLLECTION SITES

The following is a brief description of each site and the hydrologic monitoring equipment that has been installed to assess the volume of seepage of ground-water outflow from Medina and Diversion Lake into the Edwards and Trinity aquifers. The hydrologic data which will be collected includes: precipitation, streamflow, water stage during storm events, lake levels and lake evaporation.

The **Site #** designation is used for BMA water management issues. The alpha-numeric designation following the site's name is used for the combined BMA/EUWD real-time data collection system. If this designation is absent, then the data is collected during site visits or from a non-transmitting data logger (Site 5A).

HYDROLOGIC MONITORING SITES



Site #1 Medina River at English Crossing - BA 02

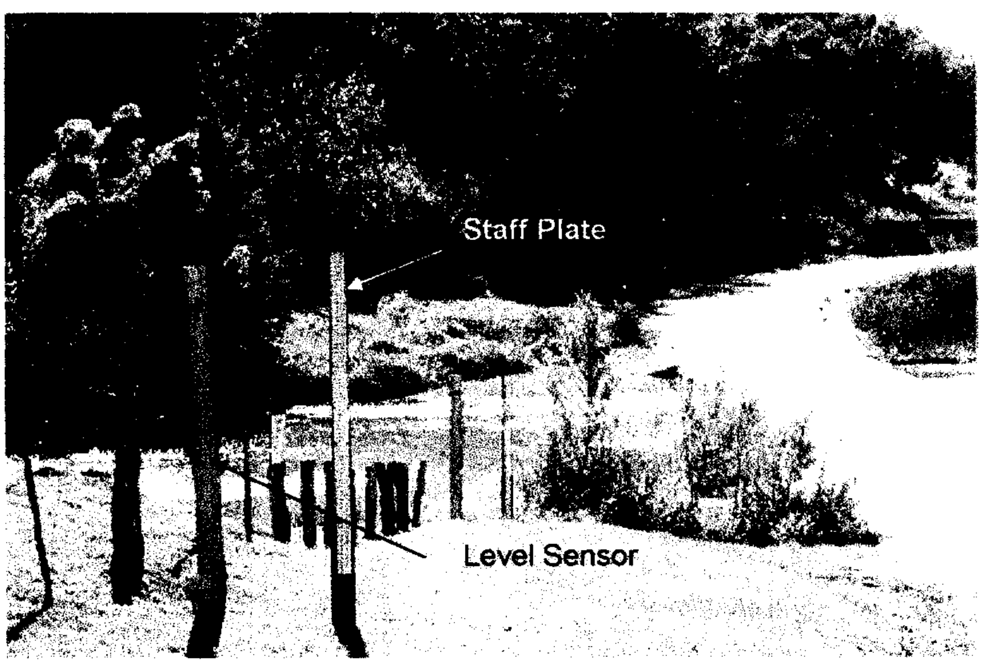
Site No. 1 is located on the Medina River upstream of the low water crossing at English Crossing, near its confluence with Medina Lake. This site collects perennial streamflow data as inflow into Medina Lake from a watershed area of approximately 310,000 acres, or about 76 percent of the Medina Lake watershed. The installation, maintenance and rating of this site is being performed under another contract by the Edwards Underground Water District (EUWD) and the United States Geological Survey (USGS). The USGS has designated this site as one of three surface water stations for water quality characterization.

The monitoring equipment installed at this site include:

Description	Quantity
ROS Remote Terminal Unit	1
Level Sensor - 7.5 X 1/10"	3
Crest Stage Gage	1

SITE #1
MEDINA RIVER AT ENGLISH CROSSING - BA 02

Looking upstream about two miles above Medina Lake; RTU pole in front of park sign.



Looking southeast; river flow left to right

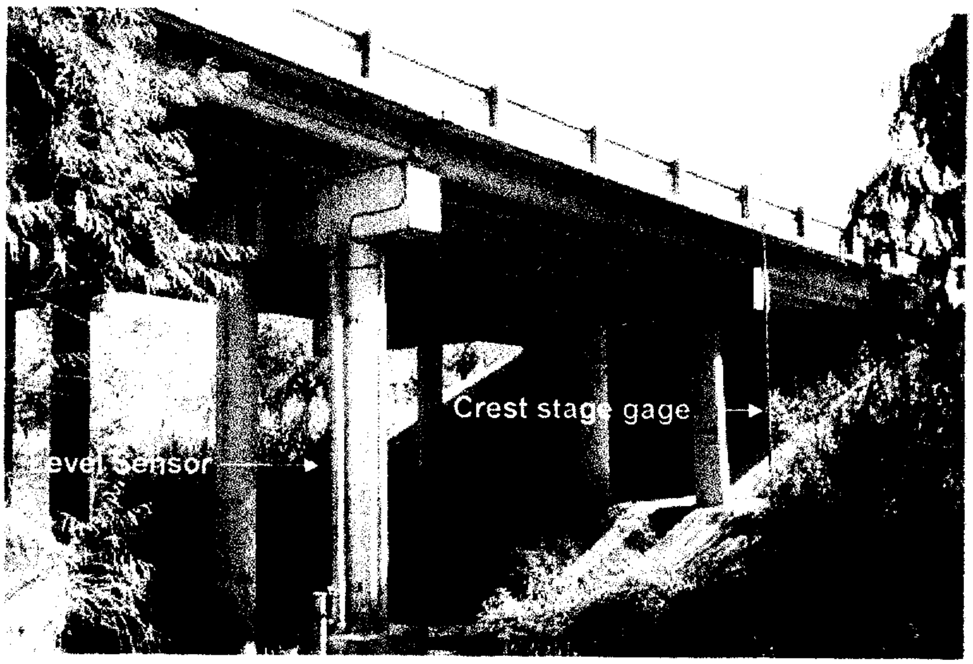
Site #2 Red Bluff Creek - BA 01

Site No. 2 is located on Red Bluff Creek at the FM 1283 bridge crossing. This site collects ephemeral streamflow data as inflow to Medina Lake from a watershed area of approximately 40,000 acres, or about 10 percent of the Medina Lake watershed. The installation, maintenance and rating of this gage site is performed under another contract by EUWD and USGS. BMA/BMWD has added an ROS Raingage to the EUWD equipment at this site to record continuous precipitation data.

The monitoring equipment installed at this site includes:

Description	Quantity
Remote Terminal Unit	1
Level Sensor - 10' X 1/10"	1
Raingage	1
Crest Stage Gage	1

SITE #2
RED BLUFF CREEK - BA01



Looking upstream; about one mile above Medina River.

Site #3 Elm Creek - BMA 03

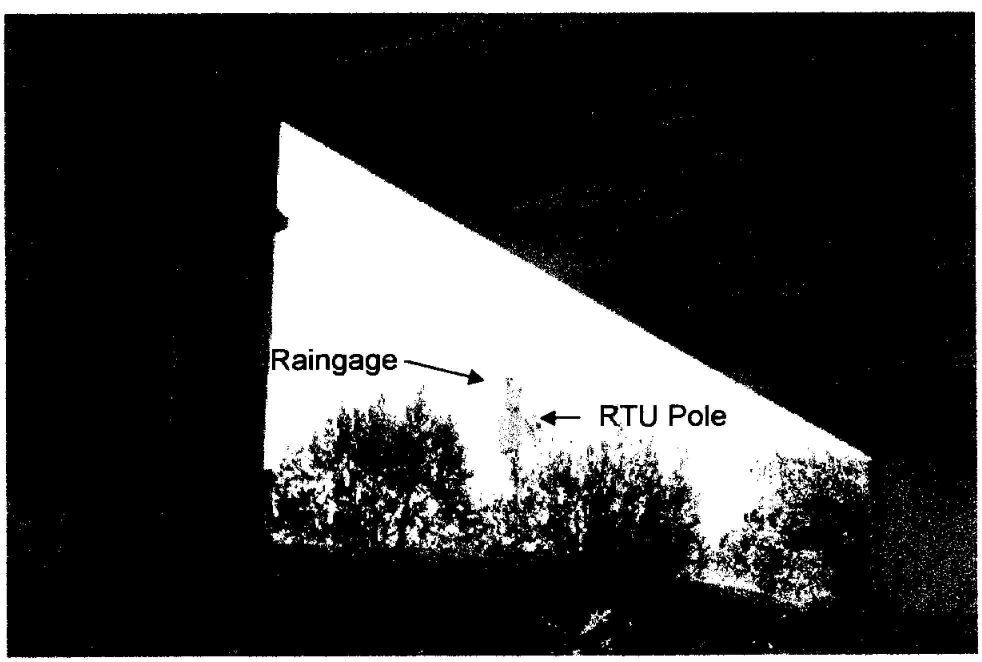
Site No. 3 is on Elm Creek at the FM 1283 bridge crossing. This site collects ephemeral streamflow data as inflow into Medina Lake from a watershed area of approximately 10,000 acres or about three percent of the Medina Lake watershed. The site also includes a raingage to collect continuous precipitation data.

The monitoring equipment installed at this site include:

Description	Quantity
Remote Terminal Unit	1
Level Sensor - 10' X 1/10"	1
Crest Stage Gage	1
Raingage	1

SITE #3
ELM CREEK - BMA 03

Looking upstream; about one-half mile above Medina Lake.



RTU pole with solar panel and cone shape raingage.

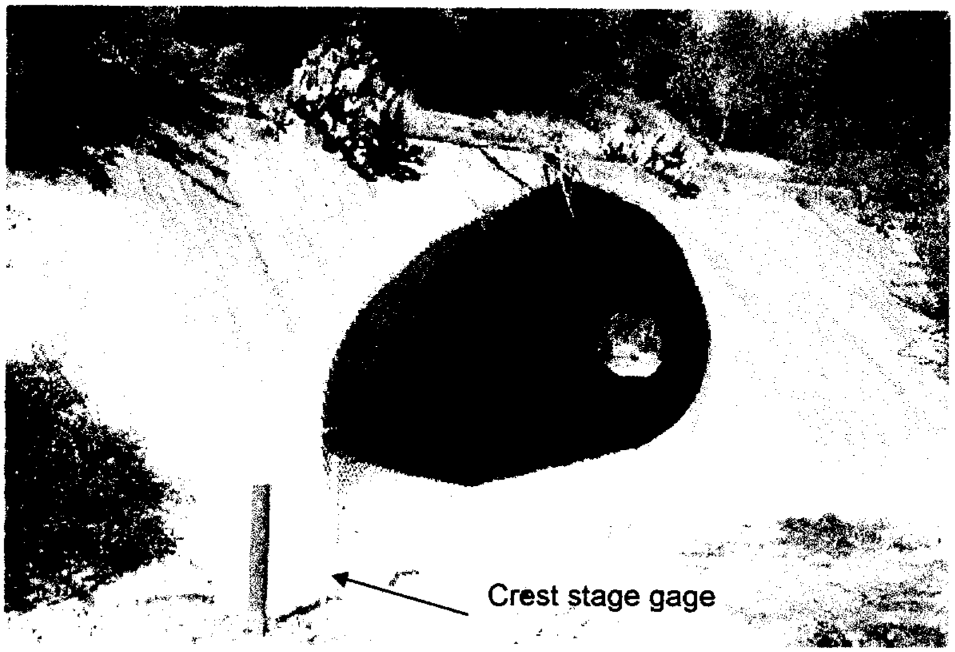
Site #4 Unnamed Creek

Site No. 4 is located on an ephemeral, unnamed creek, south of Mescal Creek, at the FM 1283 bridge crossing east of the lake. This site collects peak stage data, on the upstream and downstream side of the bridge, as inflow into Medina Lake from a watershed area of approximately 4,000 acres or about one percent of Medina Lake watershed.

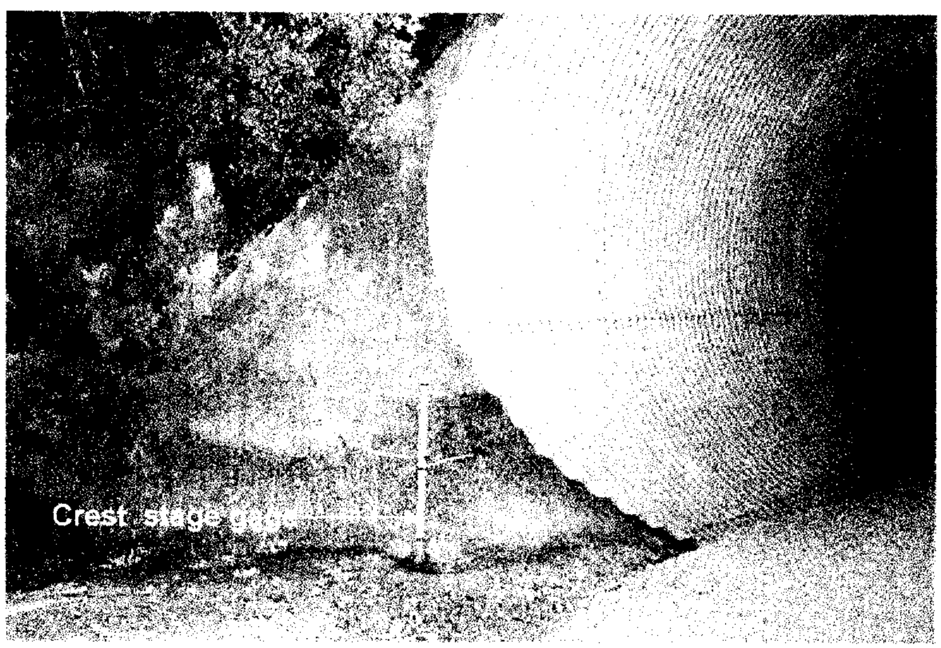
The monitoring equipment installed at this site include:

Description	Quantity
Crest Stage Gage	2

SITE #4
UNNAMED CREEK



Looking downstream; about one-half mile above Medina Lake. Red pipe deflects large debris from gage.



Downstream crest stage gage anchored to culvert abutment.

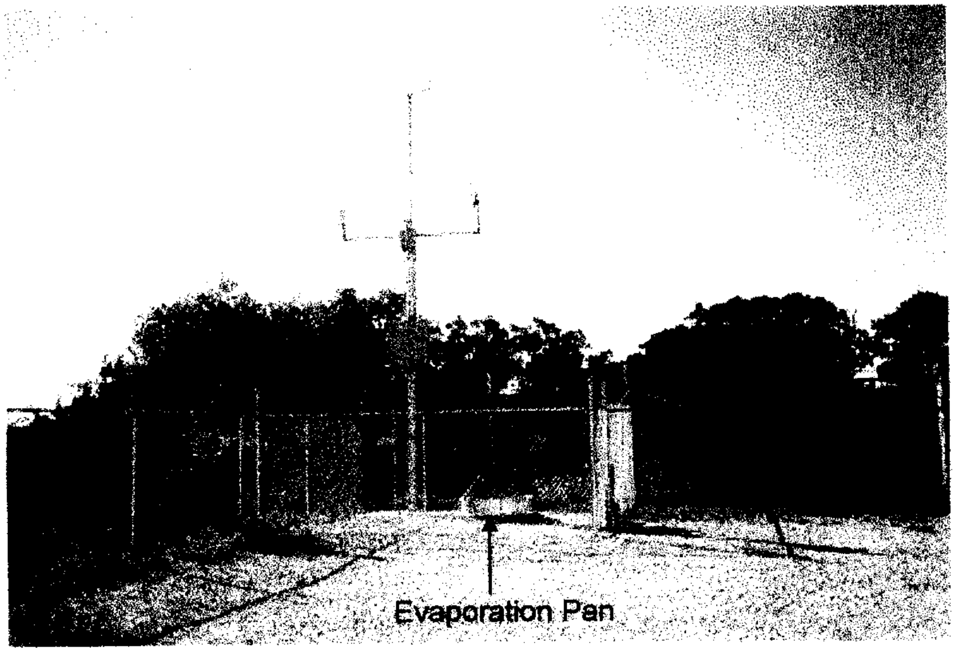
Site #5 Main Dam Weather Station - BMA 05

Site No. 5 is located at the west end of the Medina Lake dam. This site consists of a weather station, a lake temperature probe and a lake level sensor. The weather station is located on the land surface at the western side of the dam and the lake level sensor is located about 20 feet from the existing wire weight gage. The weather station continuous records various climatic parameters, including evaporation pan data in order to compute evaporation as outflow from Medina Lake. A lake evaporation pan coefficient will also be calculated.

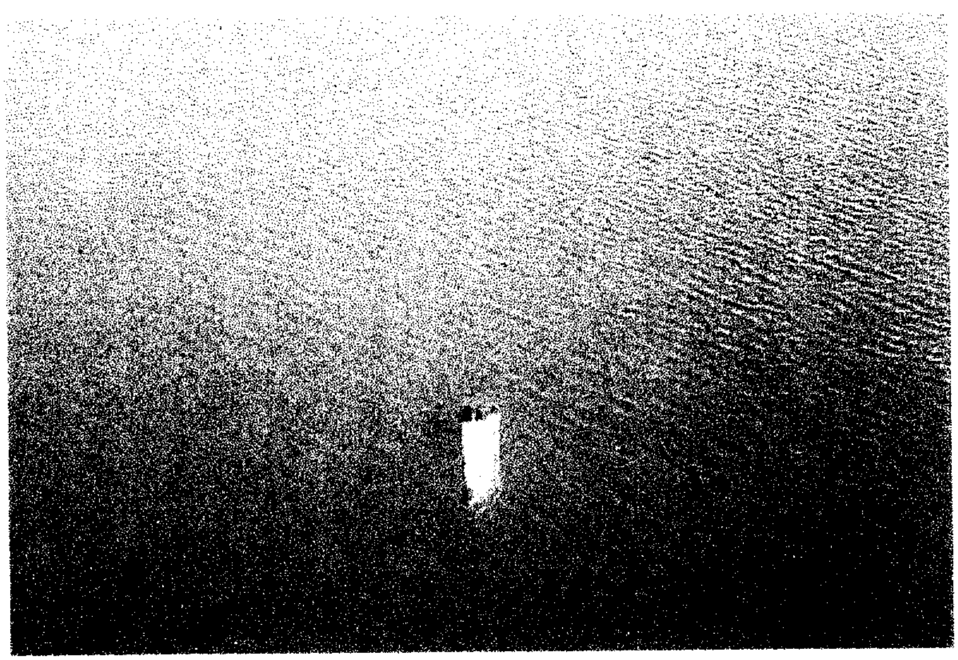
The monitoring equipment installed at this site include:

Description	Quantity
9400 Remote Terminal Unit	1
Lake Level Sensor 20'X1/10" with 150' cable	1
Anemometer WAA 15A	1
Wind Vane WAV 15A	1
Humidity/Temp Probe HMWD20yb	1
Solar Radiation Shield 2212 HM	1
Barometer PTB 100A	1
Mast/Cross Arms 20' WAT 12	1
Rain Gage	1
Evaporation Pan	1
Evap Pan Level Sensor 18"X1/10"	1
Lake Water Temp Probe ROS	1

SITE #5
MAIN DAM WEATHER STATION - BMA 05

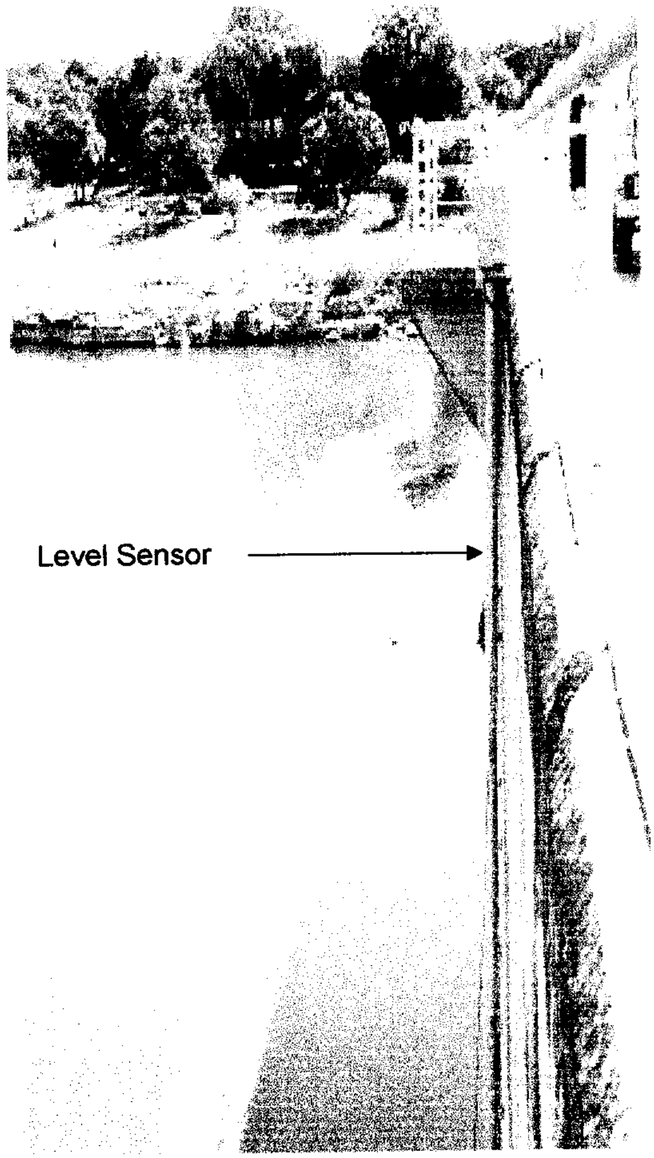


Weather station on west side of main dam; evaporation pan on ground with 1.5 foot level sensor.



Lake water temperature probe anchored to buoy approximately 100 feet from dam.

SITE # 5
MAIN DAM WEATHER STATION - BMA 05



Lake level sensor at Medina Lake, looking east.

Site #5A Medina Lake Weather Station

Site 5A is located on Medina Lake about two miles north of the dam on a floating platform moored off of Walton Island. The station will collect climatic data similar to the land weather station on the main dam, except as noted below. The USGS installed and will maintain this station for the length of the project. The data from this station will be recorded onto an on-site data logger and serviced every 2-4 weeks. The data from this site is not included in the BMA/EUWD real-time data collection system.

The monitoring equipment installed at this site include:

Description	Quantity
Wind Speed & Direction	1
Rain Gage	1
Air & Water Temperature	1
Relative Humidity	1
Wind Gusts	1
Pyranometer	1
Solar Reflector	1

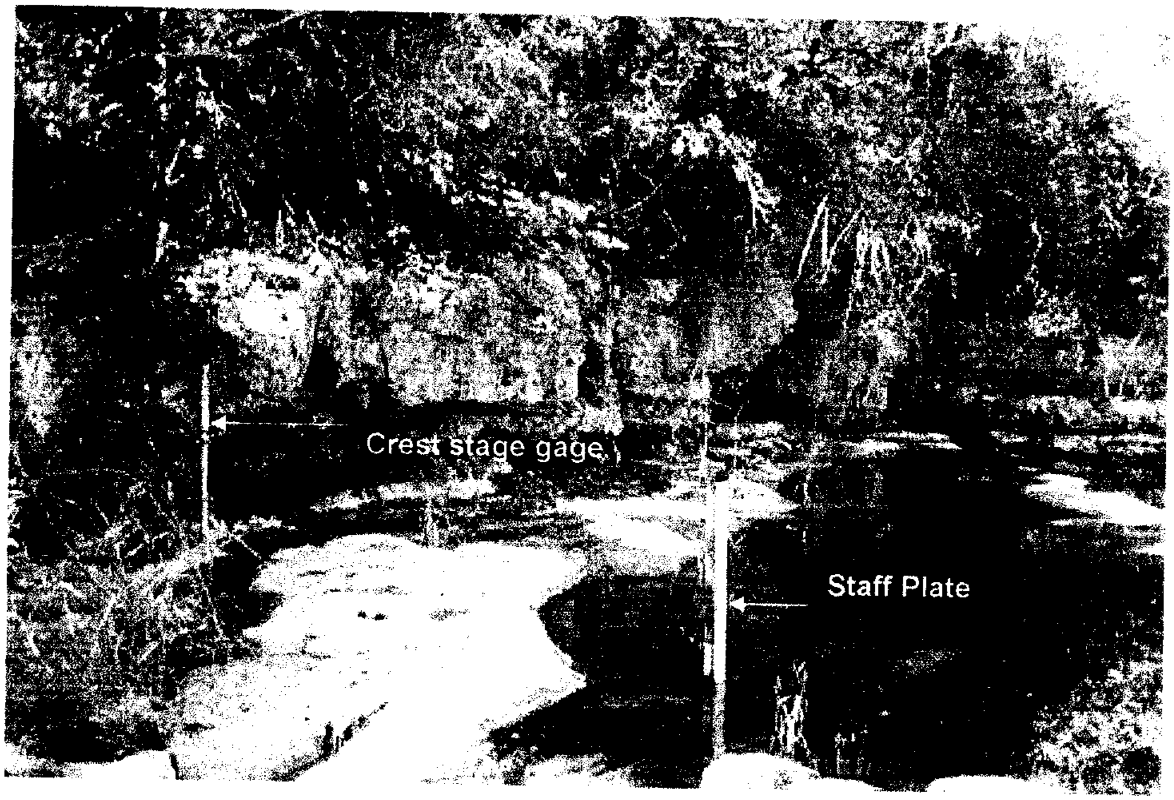
Site #6 Koenig Creek - BMA 06

Site No. 6 is located on Koenig Creek at a county road crossing about 200 feet upstream from its confluence with the Diversion Lake. This site will collect peak stage data as inflow into Diversion Lake from a watershed area of approximately 3500 acres.

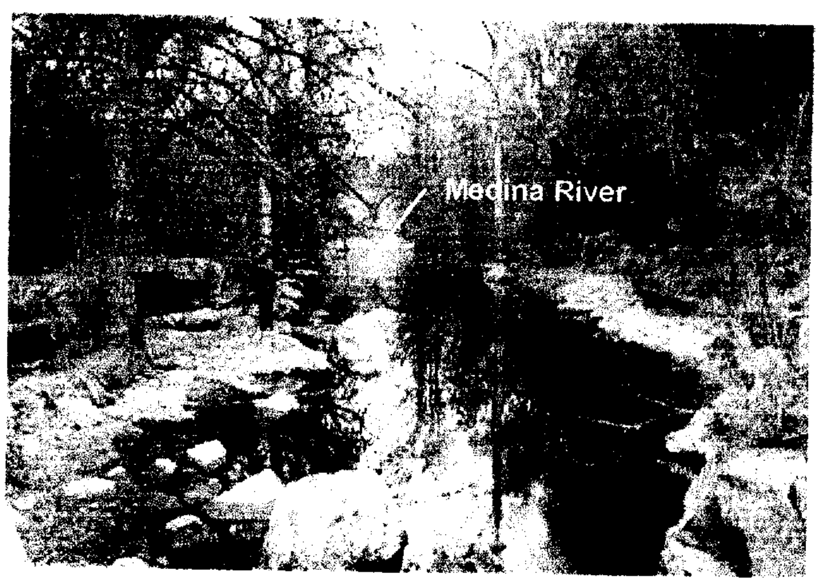
The monitoring equipment installed at this site include:

Description	Quantity
Crest Stage Gage	1

SITE #6
KOENIG CREEK - BMA 06



Looking upstream about 300 feet from the Medina Riverbelow the main dam.



Looking downstream at backwater near confluence with Medina River below the main dam.

Site #7 Medina River Below Main Dam - BMA 07

Site No. 7 is located approximately 1500 feet downstream of the Medina Lake dam. This site collects streamflow data as outflow from Medina Lake and as inflow into Diversion Lake. The USGS has designated this site as one of three surface water stations for water quality characterization.

The monitoring equipment installed at this site include:

Description	Quantity
7100 Remote Terminal Unit	1
Level Sensor 7.5'X1/10"	1
Crest Stage Gage	3

SITE #7
MEDINA RIVER BELOW MAIN DAM - BMA 07

Looking upstream at left bank with backwater in background.

Looking upstream from right bank.

Looking upstream at staff plate and crest stage gages on right bank of channel

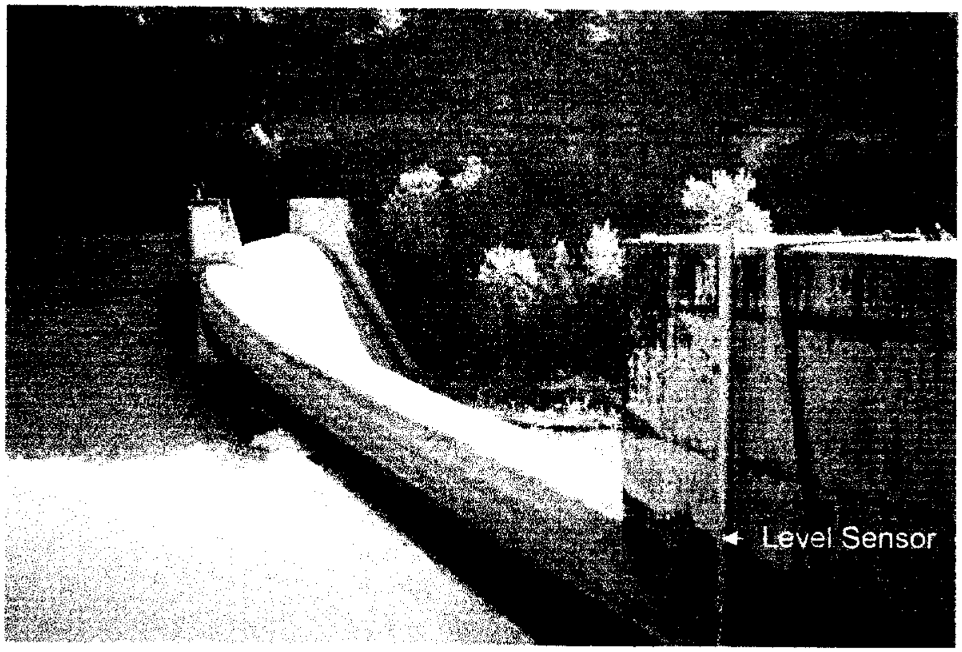
Site #8 a,b,c Diversion Dam - ME 05

Site No. 8 is located at the Diversion Lake dam. This site collects lake level data (8a), flow data at the head of the irrigation canal system as outflow from Diversion Lake (8b) and streamflow data on the Medina River as outflow from the Diversion Lake (8c). The EUWD has installed the RTU and the lake level sensor.

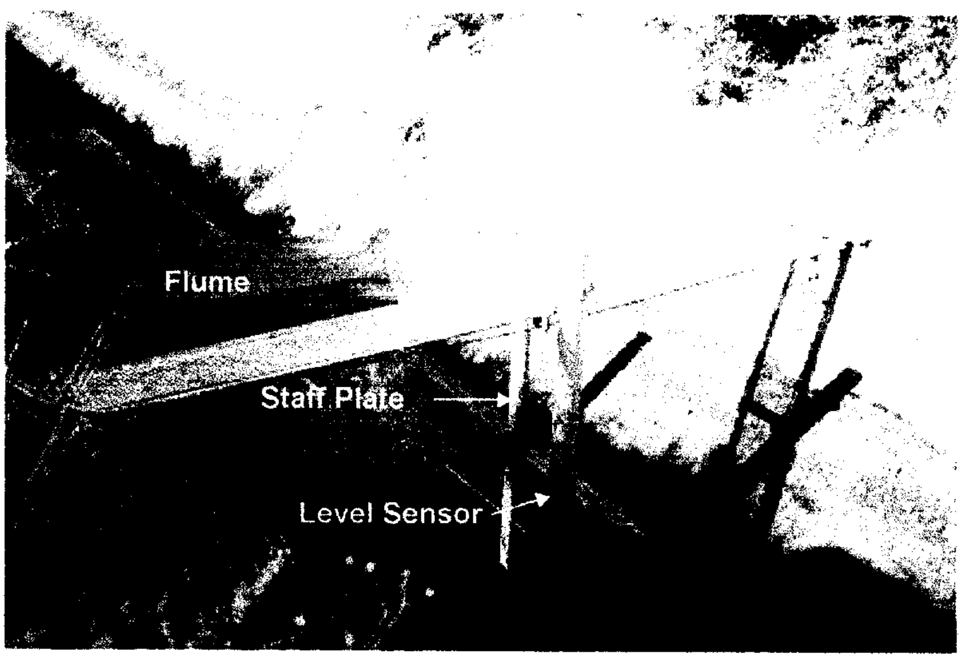
The monitoring equipment to be installed at this site include:

Description	Quantity
7100 Remote Terminal Unit	1
Raingage	1
Gate Control Reader	1
Lake Level Sensor 20'X1/10"	1
Canal Level Sensor 6'X1/4"	1
Level Sensor for Weir 18"X1/10"	1
Crest Stage Gage	1

SITE #8
DIVERSION DAM - ME 05

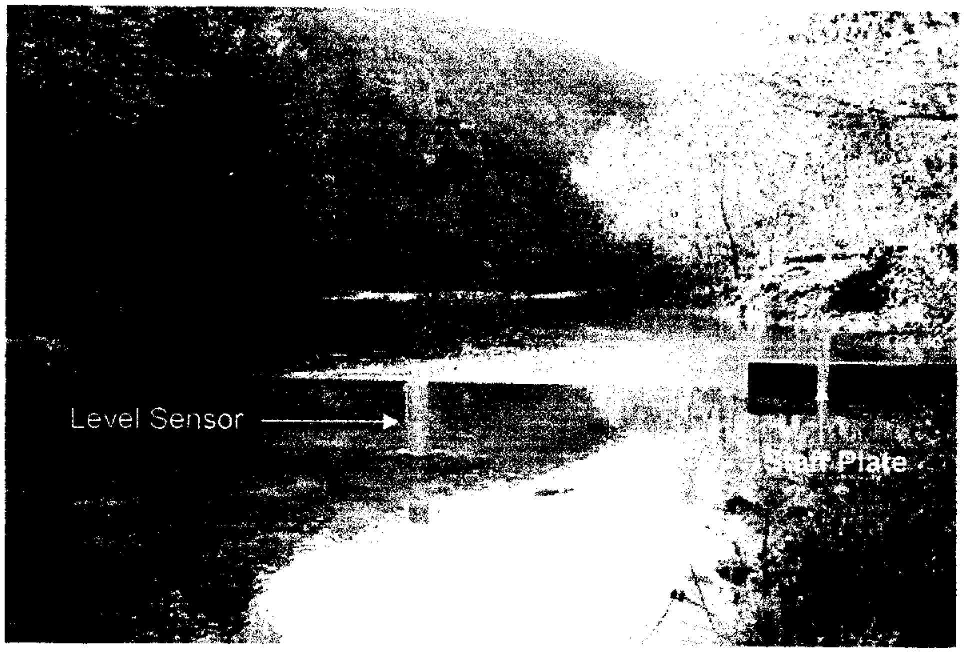


Looking east at Diversion Dam.



Looking downstream at main canal, broad crested flume in background.

SITE # 8
DIVERSION DAM - ME 05

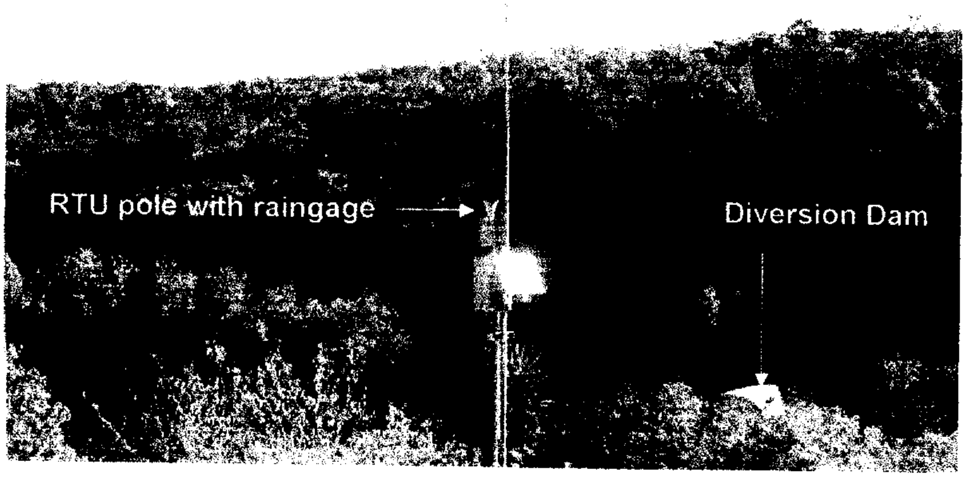


Looking downstream on Medina River below Diversion Dam and above Haby's Crossing Fault.

Looking upstream on Medina River below Diversion Dam and above Haby's Crossing Fault.

SITE # 8
DIVERSION DAM - ME 05

Press-to-read box on top of canal turn-out; canal gate controls on right.



Looking east from ridge above Diversion Dam.

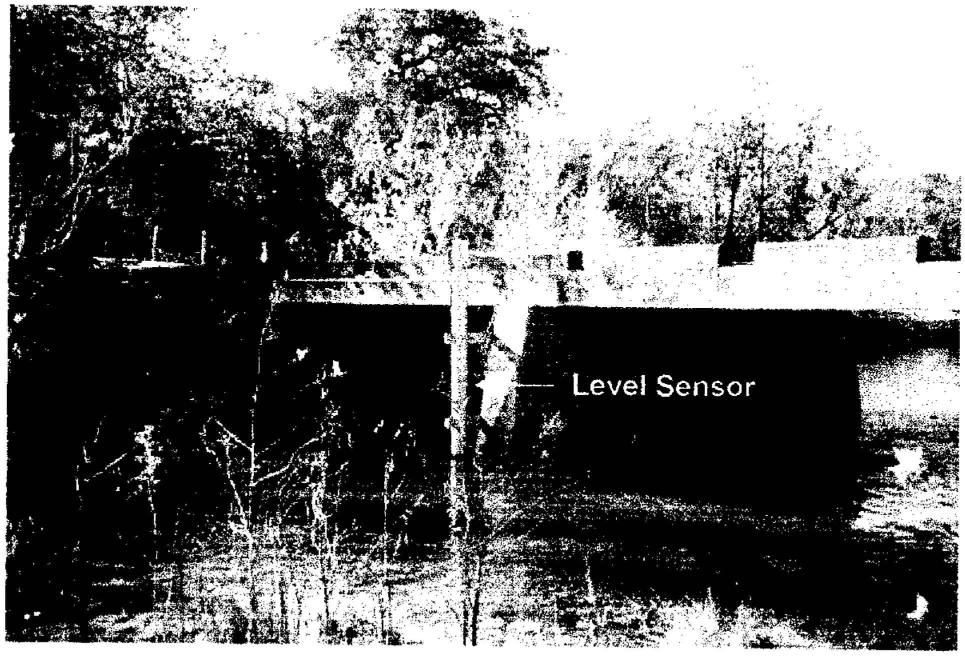
Site #9 Medina River below Diversion Dam - ME 04

Site No. 9 is located on Medina River about 4500 feet downstream of the Diversion Dam. This site collects perennial streamflow data between the Diversion Dam and Habys Crossing fault, which is located about 150 feet upstream of the gage site. The USGS has designated the outflow gage to the Medina River as one of three surface water stations for water quality characterization. The installation, maintenance and rating of this site is being performed under another contract by EUWD and USGS.

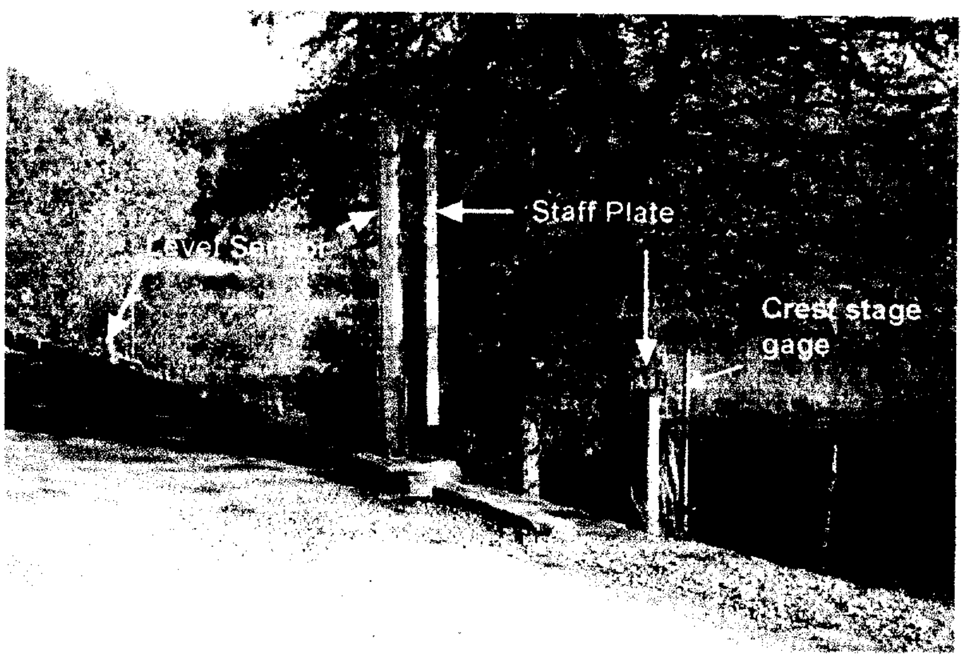
The monitoring equipment installed at this site include:

Description	Quantity
7100 Remote Terminal Unit	1
Level Sensor 10'X1/10"	2
Crest Stage Gage	2

SITE # 9
MEDINA RIVER BELOW DIVERSION DAM - ME 04



Looking downstream at low-mid stage level sensor.



Looking upstream at high stage level sensor and staff plate.

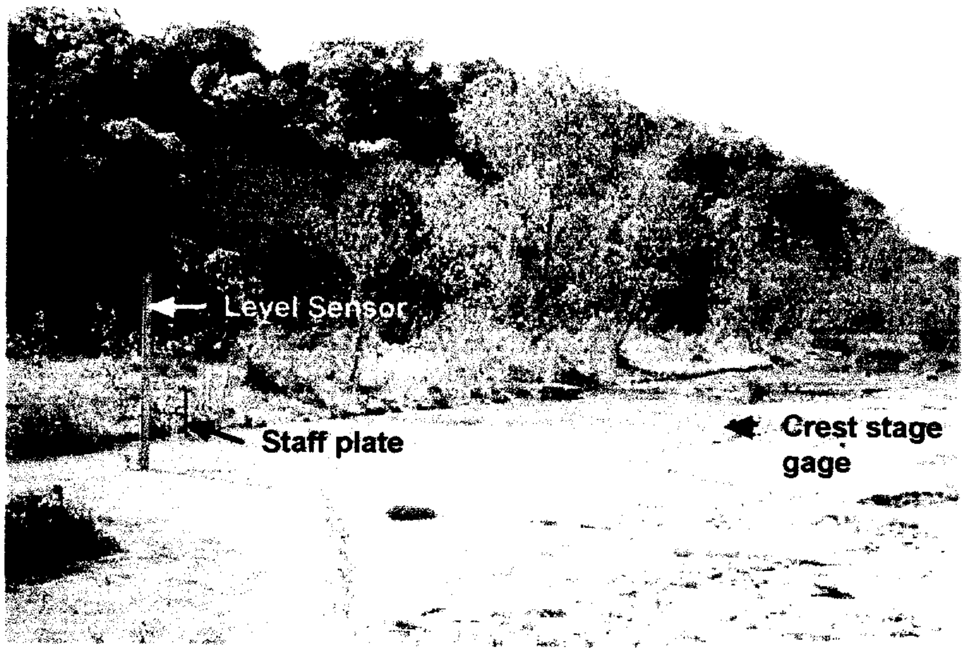
Site #11 Cypress Creek - BMA 11

Site No. 11 is located near the confluence of Cypress Creek and Medina Lake on the west side of the lake. This site collects perennial streamflow data from a watershed area of approximately 10,000 acres or about three percent of the Medina Lake watershed. A raingage is also at the site to collect continuous precipitation data.

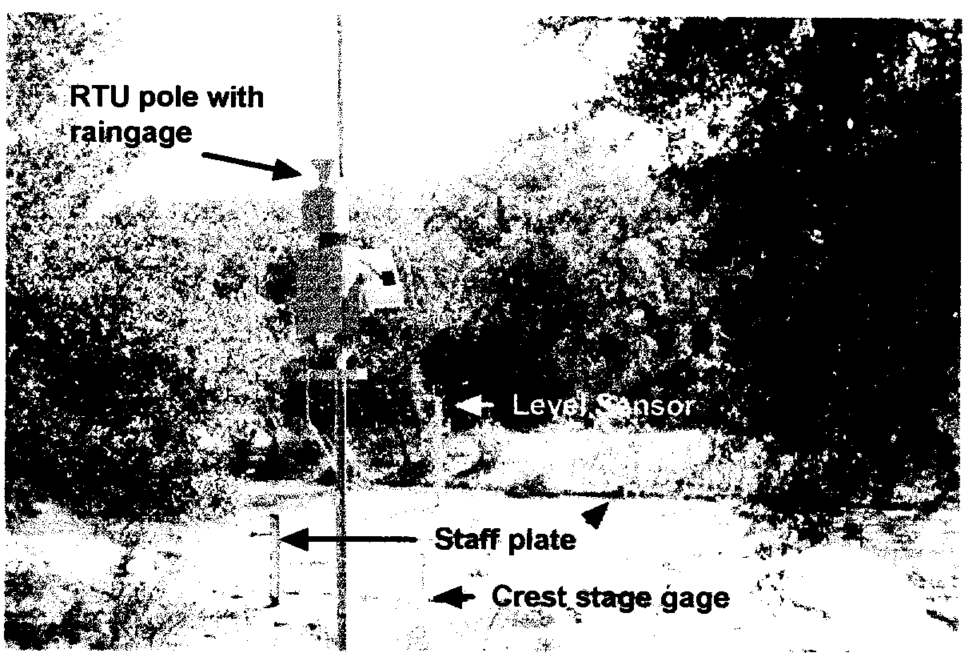
The monitoring equipment installed at this site include:

Description	Quantity
7100 Remote Terminal Unit	1
Level Sensor 10X1/10"	1
Raingage	1
Crest Stage Gage	2

SITE # 11
CYPRESS CREEK - BMA 11



Looking upstream about one-half mile from Medina Lake.



Looking downstream about one-half mile above Medina Lake.

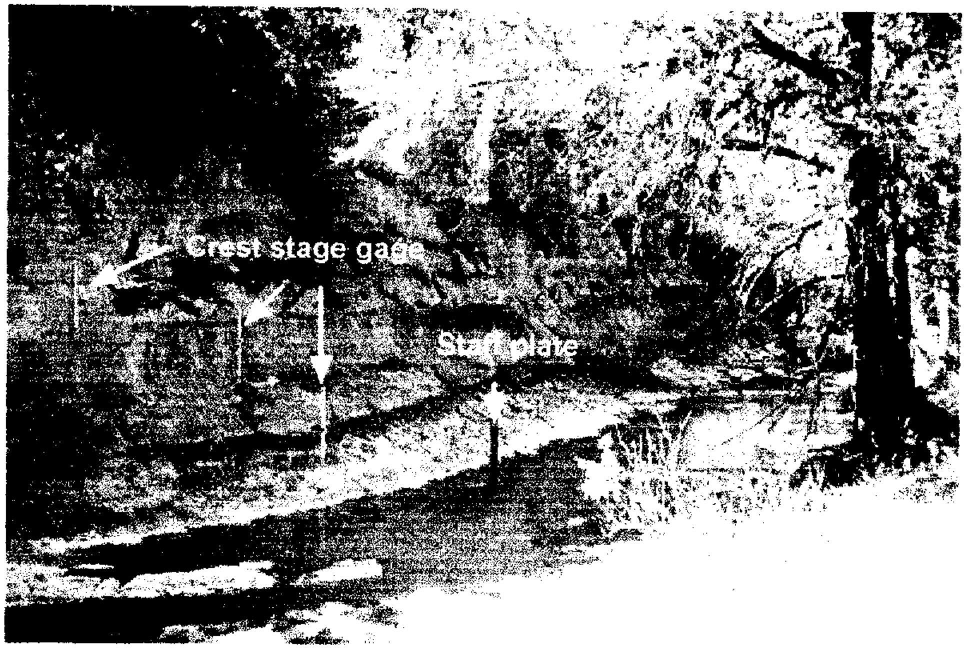
Site #12 Bruins Creek - BMA 12

Site no. 12 is located near the confluence of Bruins Creek and Medina Lake on the west side of the lake. This site collects peak stage data from a watershed area of approximately 6000 acres or about one and one half percent of the Medina Lake watershed. A raingage is also located higher in the watershed of Bruins Creek to collect continuous precipitation data.

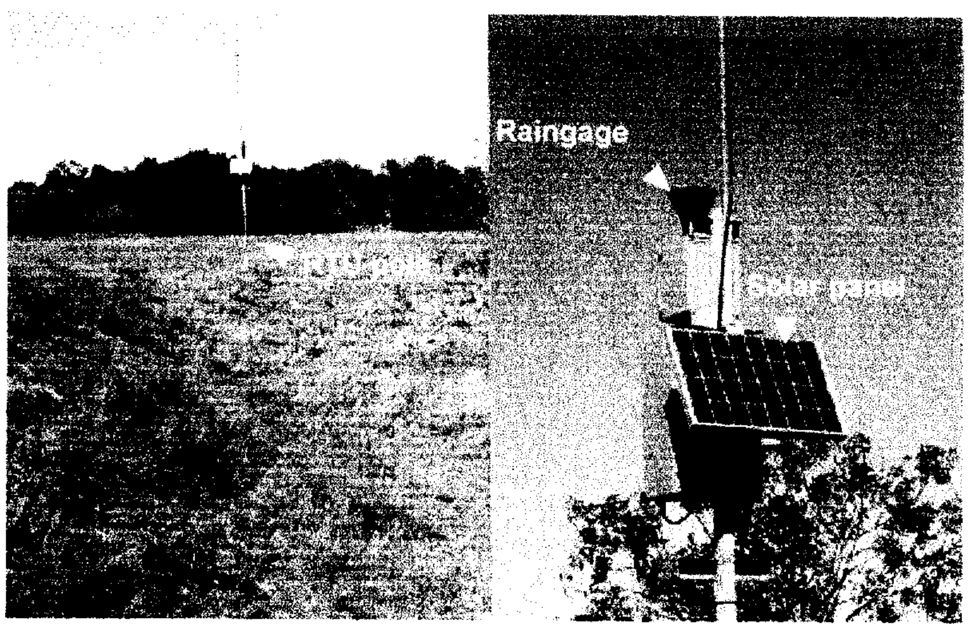
The monitoring equipment installed at this site include:

Description	Quantity
Raingage	1
Crest Stage Gage	5

SITE # 12
BRUINS CREEK - BMA 12



Looking upstream about 300 feet from Medina Lake.



Near Walker Ranch pond about 1.5 miles above Medina Lake.

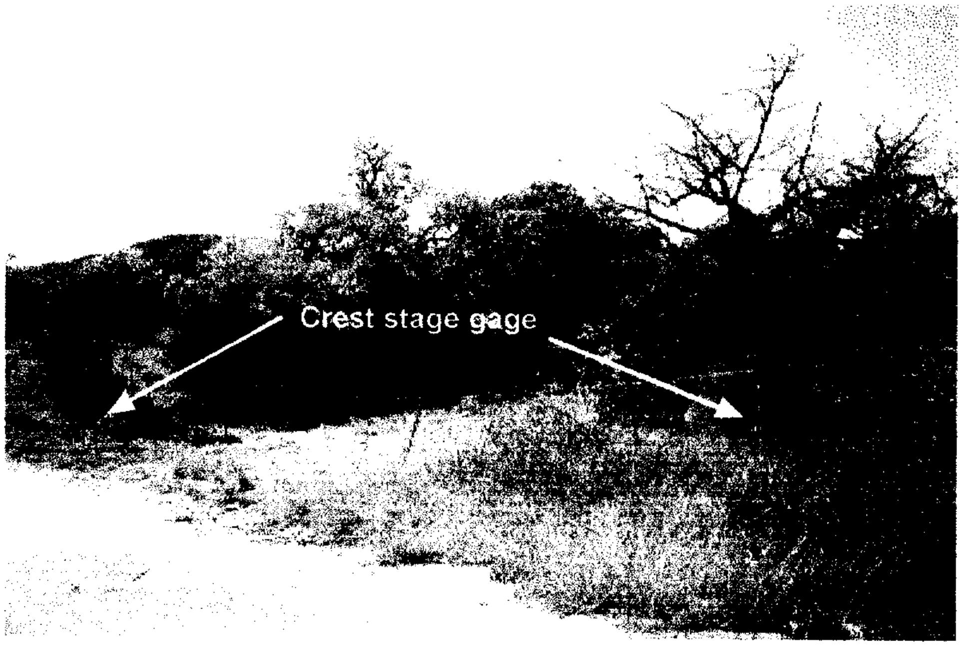
Site #13 Rocky Creek

Site No. 13 is located near the confluence of Rocky Creek and Medina Lake on the west side of the lake. This site collects peak stage data from a watershed area of approximately 4000 acres or about one percent of the Medina Lake watershed.

The monitoring equipment installed at this site include:

Description	Quantity
Crest Stage Gage	4

SITE # 13
ROCKY CREEK



Looking upstream from Old Castroville Road.

Looking upstream about 400 feet from Old Castroville Road.

ATTACHMENT B

STREAMFLOW AND RAINFALL DATA

Site No.	Site Name	Date	CSG Ft.	GH Ft.	Avg. Ve Ft/Sec	Dischg. CFS	Rainfall Patterns Month/Day=Inches
Site No.	Site Name	Date	CSG Ft.	GH Ft.	Avg. Ve Ft/Sec	Dischg. CFS	Rainfall Patterns Month/Day=Inches
1/ BA02	MR @ English Crossing	Apr 26,95	na	TD=2.2	2.19	76.9	
s		May 30, 95	na	no SP	- - -	- - -	
		Jun 20,95	na	TD=2.0	1.02	144	
		Jun 30,95	na	TD=-0.87	1.36	319	
		Aug 17,95	na	3.07	0.5	53.1	
2 / BA01	Red Bluff Creek	Apr 26,95	na	TD=2.46	0	0	4/17=0.56
s,r		May 30, 95	na	1.07	- - -	- - -	5/5=0.53; 5/6=0.37; 5/8=1.48; 5/24=0.86; 5/27=0.66
		Jun 19,95	na	TD=0.1	0.3	0.71	5/30=3.59; '6/11=0.65; 6/18=0.21; 6/26=0.95; 6/29=1.69;
		Jun 29,95	2.57	TD=-19.71	1.43	120	7/3=0.69; 7/6=0.12; 8/21=1.15; 8/28=1.15; 8/31=0.16
		Aug 18,95	0	0	0	0	
3 / BMA03	Elm Creek	May 5, 95	0	- - -	- - -	- - -	8/12=0.03; 8/13=0.19; 8/18=0.03; 8/19=0.03
s,r		May 30, 95	0	TD=16.65	0.79	1.61	8/21=0.23; 8/31=1.79
		Jun 12, 95	1.5	TD=15.1	0.82	1.91	
		Jun 19,95	na	TD=16.82	0.89	0.39	
		Jun 29, 95	0	TD=16.37	1.15	4.66	
		Aug 18,95	0	TD=15.65	0.19	0.035	
		Sept 20,95	1.75	TD=14.60	1.01	11.1	
		Oct 6,95	0	TD=17.01	0.14	0.184	
4 / - -	Unnamed Creek	May 5, 95	U&D = 0	- - -	no flow	- - -	
csg		May 31, 95	U&D= 0	- - -	- - -	- - -	
		Jun 19,95	na	na	na	na	
		Aug 18,95	0	na	na	na	
5 / - -	Main Dam Weather Sta						Operational August 1995
r,ll.cl,e							
5/ - -	Lake Weather Station						Operational in August 1995
r,cl							
6	Koenig Creek	May 5, 95	0	0.80	- - -	- - -	
csg		May 31, 95	0	0.86	- - -	- - -	
		Aug 18,95	0	1.46	0.5	0.77	

s-stage recorder, r-raingage, ll-lake level, csg-crest stage gage, cl-weather station, e-evaporation pan

Site No.	Site Name	Date	CSG Ft.	GH Ft.	Avg. Ve Ft/Sec	Dischg. CFS	Rainfall Patterns Month/Day=Inches
7 / BMA07	MR bel Main Dam	Jun 1, 95	0.58	1.62	0.89	34.3	
s		Jun 27, 95	0.43	2.36	1.43	89.1	
		Aug 18,95	0.54	2.76	1.99	146	
		Oct 5,95	0.65	1.59	0.99	32.8	
8a / ME05	Lake Level @ Div Dam						
ll							
8b / ME05	Canal bel Div Dam	May 8, 95	2.83	1.82	- - -	- - -	5/28=On; 5/30=1.28; 6/11=2.27; 6/26=0.16; 6/29=4.61;
s,r		Jun 1, 95	3.26	dry	- - -	- - -	7/3=0.69; 8/13=0.53
		Jun 13, 95	- - -	2.64	1.81	35.3	
		Jun 13, 95	- - -	2.85	2.27	52.0	
		Jun 13, 95	- - -	3.67	3.23	120.6	
		Jun 13, 95	- - -	3.67	3.37	126	
		Jun 20, 95	- - -	3.52	3.20	109.8	
		Oct 5,95	- - -	1.61	2.51	70.4	
8c / ME05	MR bel Div Dam	Mar 8, 95	none	- - -	0.58	3.23	
		Mar 8,95	na		0.54	2.7	
s		May 8, 95	0	1.29	- - -	- - -	
		Jun 1, 95	0	1.32	0.80	8.04	
		Oct 6,95	0	0.24	0.8	6.75	
9 / ME04	MR bel Paradise Canyon	Mar 8, 95	- - -	- - -	0.50	15.6	
s		Mar 8,95			0.51	15.1	
		Jun 19,95	na	TD=6.31	0.9	30.9	
10	MR @ RioMedina	Mar 9, 95	- - -	- - -	0.49	20.7	
		Mar 9,95			0.58	23.5	
11 / BMA11	Cypress Cr @ Haby	May 8, 95	0	0.57	- - -	- - -	7/30=0.18; 8/12=0.11; 8/18=0..07; 8/21=0.38; 8/31=0.30
s,r		May 30, 95	- - -	0.95	1.15	27.6	
		Jun 12, 95	0	0.64	0.5	6.69	
		Jun 29,95	4.3	1.08	1.35	33.5	
		Aug 16,95	0	0.19	0.34	1.57	
		Sept 20,95	0.3	0.46	0.96	19.1	
		Oct 5.95	0	0.24	0.31	3.99	

s-stage recorder, r-raingage, ll-lake level, csg-crest stage gage, cl-weather station, e-evaporation pan

MEDINA LAKE STREAMFLOW AND RAINFALL DATA

Site No.	Site Name	Date	CSG Ft.	GH Ft.	Avg. Ve Ft/Sec	Dischg. CFS	Rainfall Patterns Month/Day=Inches
12 / BMA12	Bruins Creek @ Walker	May 8, 95	0	0.20	- - -	- - -	6/11=2.11; 6/19=0.35; 6/26=1.00'6/29=2.05; 7/3=0.55
r		May 31, 95	0	0.36	- - -	- - -	7/30=0.11; 8/12=0.19; 8/21=1.04; 8/28=1.79
		Jun 12, 95	0	0.28	0.22	0.42	
		Jun 29,95	0.12	0.47	0.72	5.48	
		Aug 21,95	0	0	0	0	
		Sept 20,95	0.63	0.44	0.41	6.36	
13	Rocky Creek	May 5, 95	0	- - -	- - -	- - -	
csg		May 30, 95	0.94	- - -	1.30	38.0	
- -/ME07	EUWD South Lake						5/5=0.12; 5/6=0.20; 5/8=1.15; 5/18=0.08; 5/27=1.38;
r							5/30=2.25;6/11=1.88;6/19=0.20;6/26=0.12;6/29=3.58
							7/3=0.40; 7/30=0.12; 8/18=0.20; 8/21=0.08
xxx	Medina R. @ Bandera	Jun 20,95	na	4.94	1.64	75.6	

s-stage recorder, r-raingage, ll-lake level, csg-crest stage gage, cl-weather station, e-evaporation pan

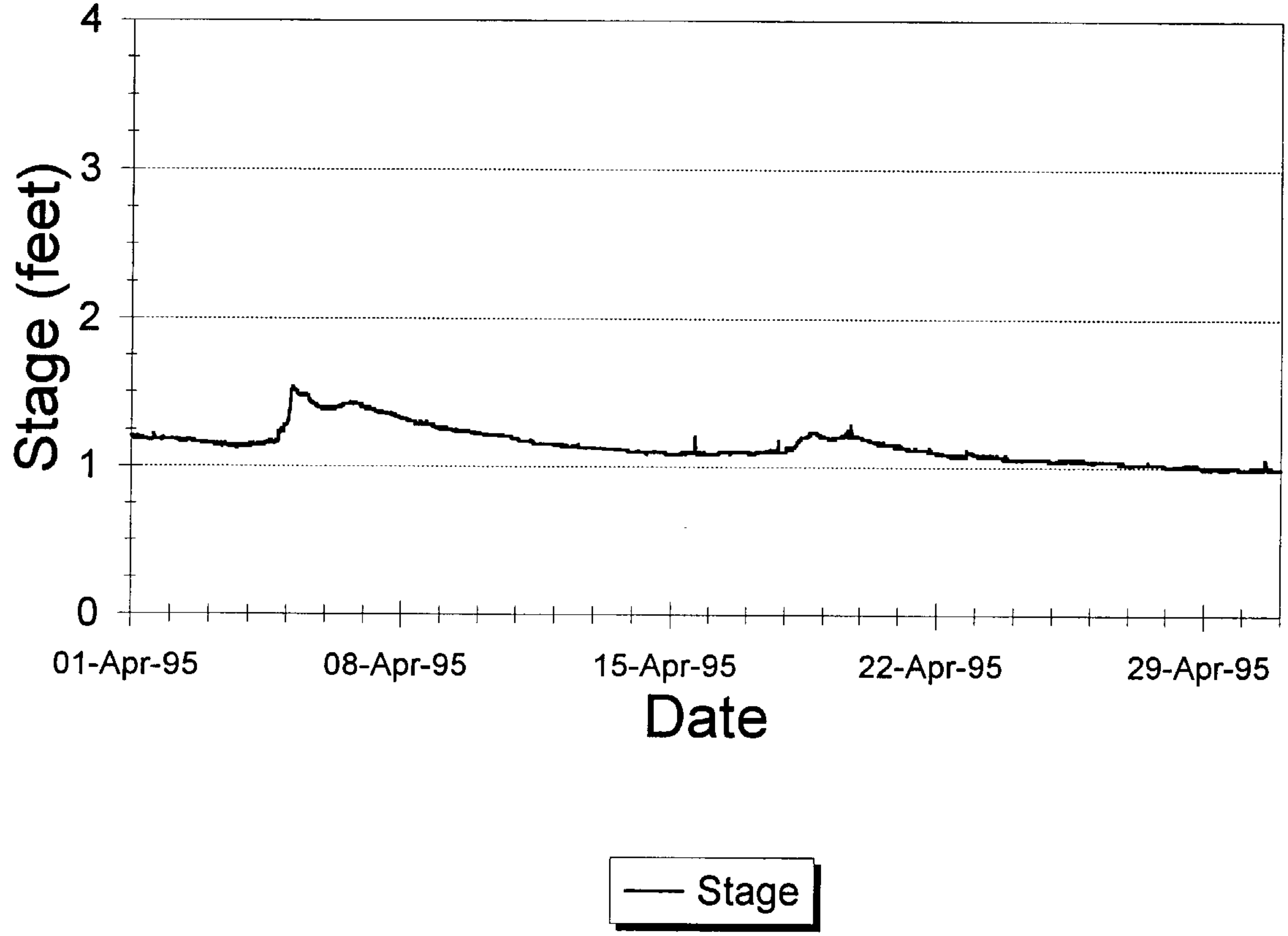
ATTACHMENT C

STAGE AND RAINFALL CHARTS

MEDINA LAKE RECHARGE STUDY

Site: BA-02 / BMA 1 English Crossing

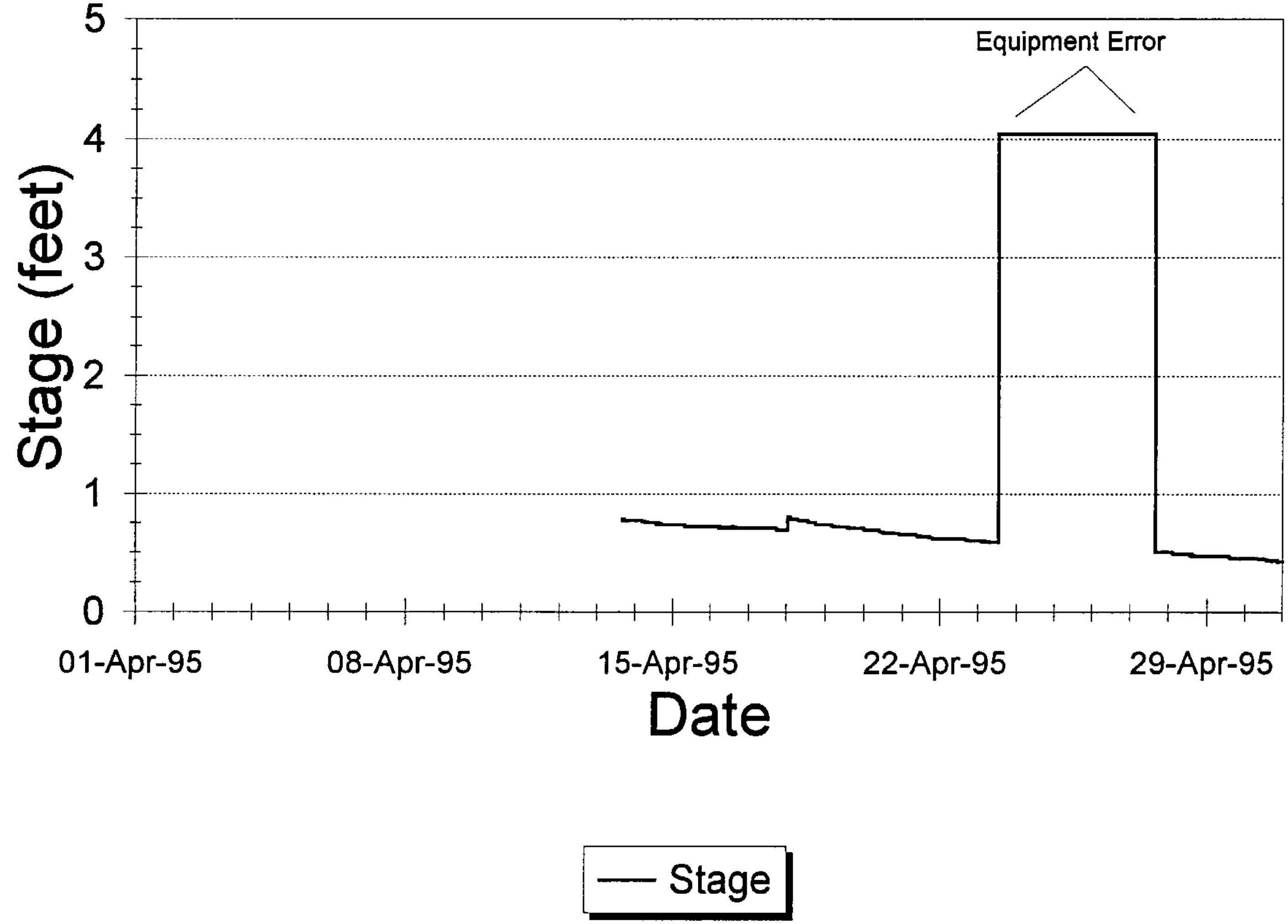
Data from April 1, 1995 to May 1, 1995



MEDINA LAKE RECHARGE STUDY

Site: BA-01 / BMA 2 Red Bluff Creek

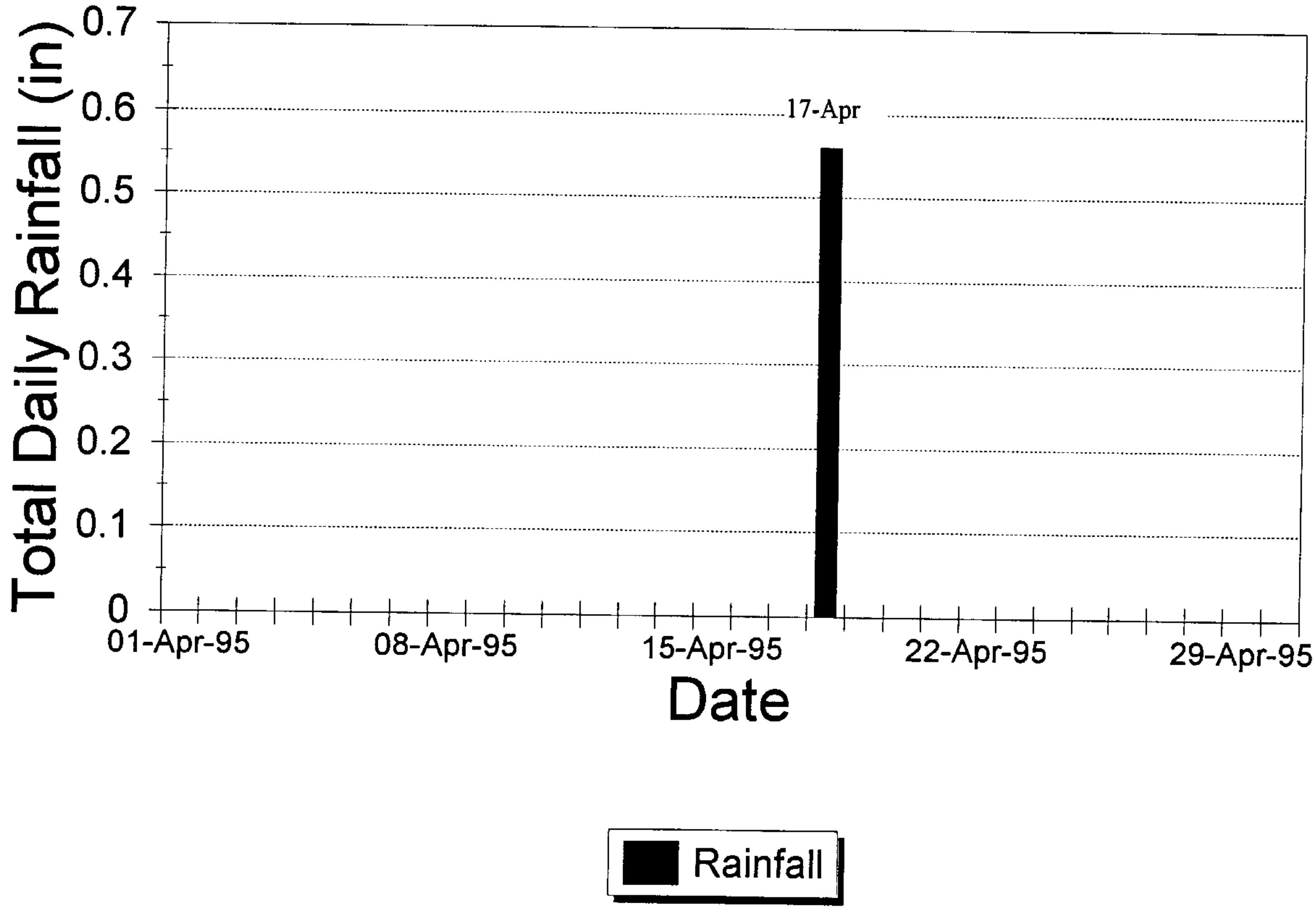
Data from April 13, 1995 to May 1, 1995



MEDINA LAKE RECHARGE STUDY

Site: BA-01 / BMA 2 Red Bluff Creek

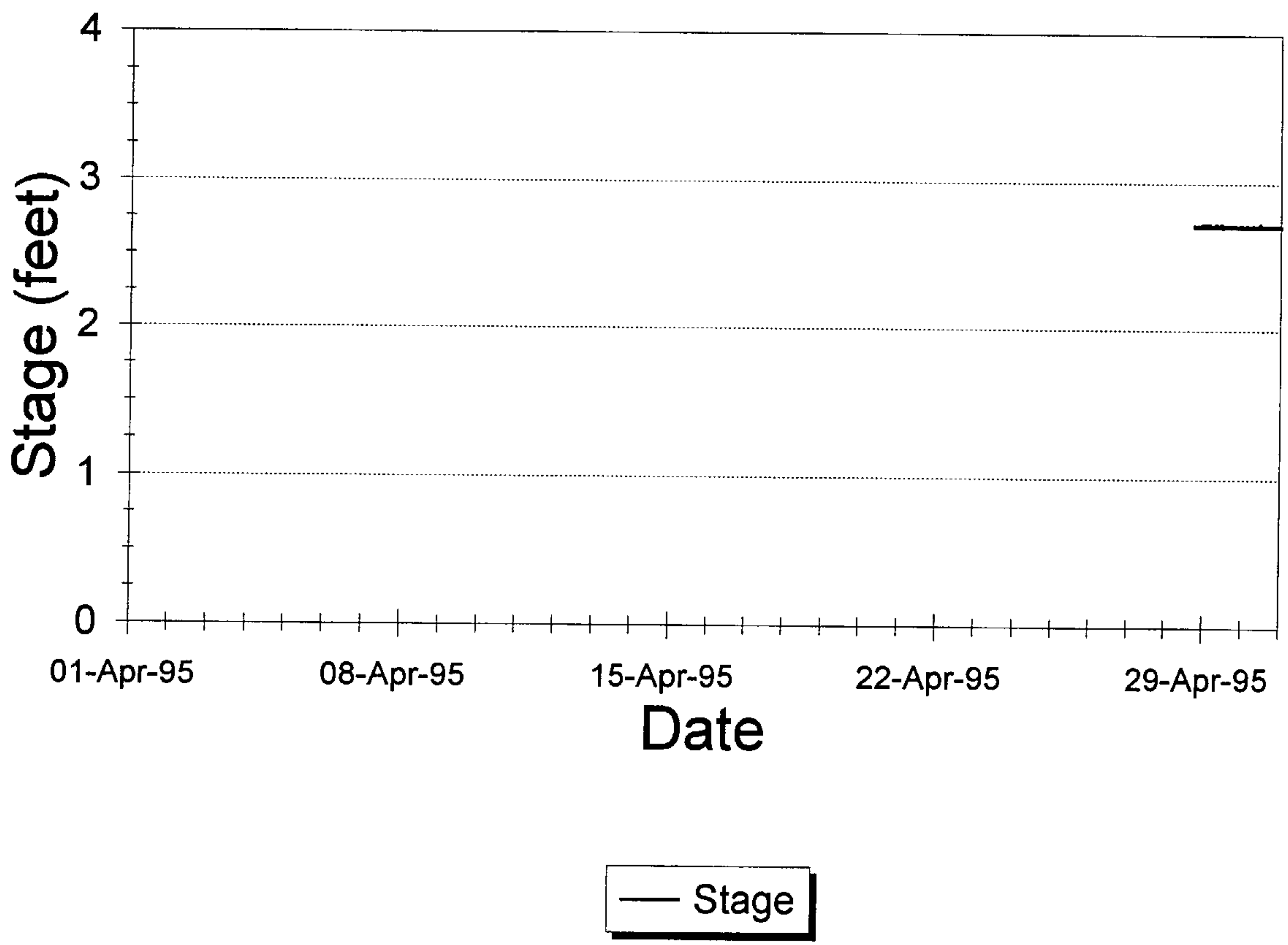
Data from April 1, 1995 to May 1, 1995

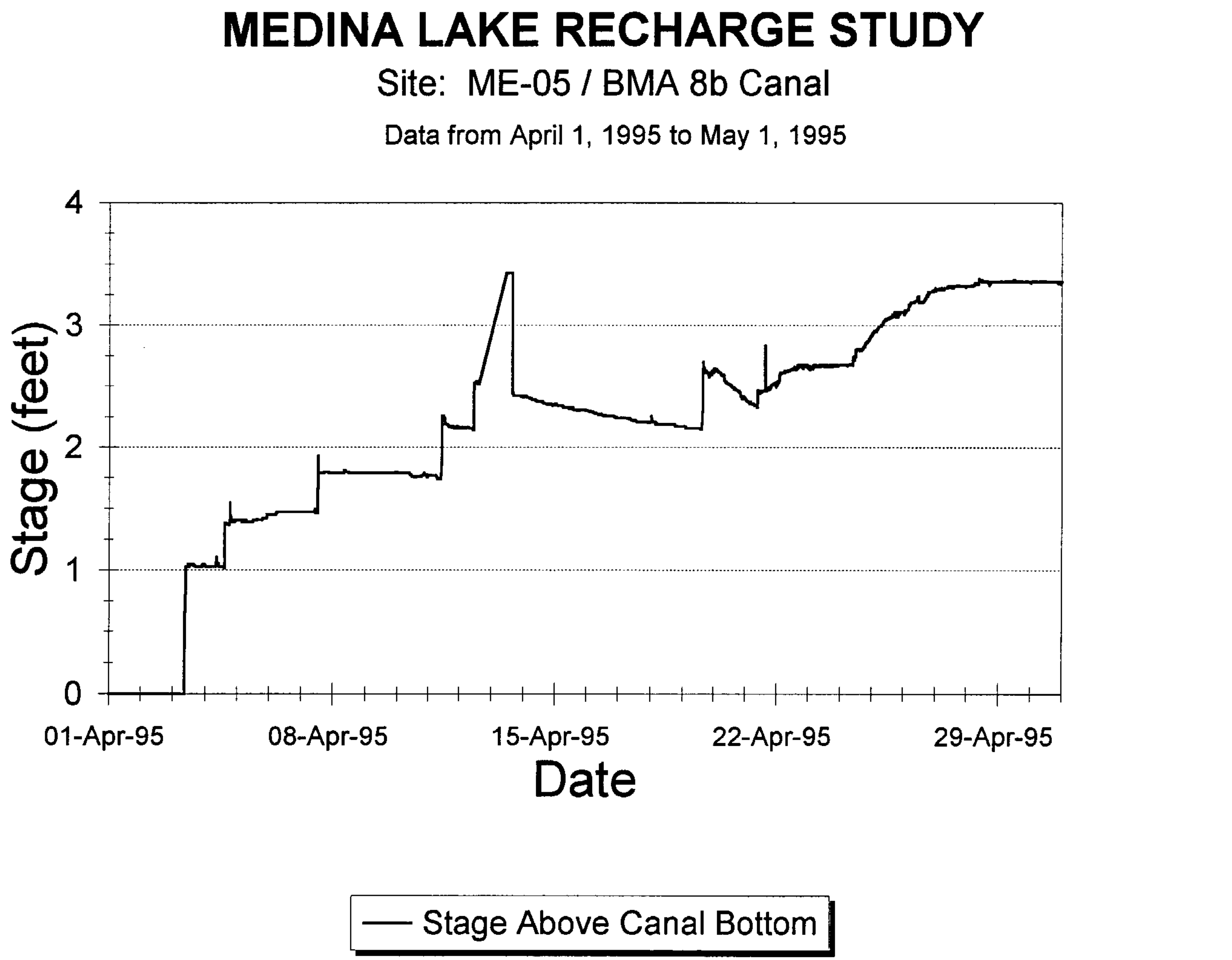


MEDINA LAKE RECHARGE STUDY

Site: BMA-07 / BMA 7 M.R. Below Main

Data from April 28, 1995 to May 1, 1995

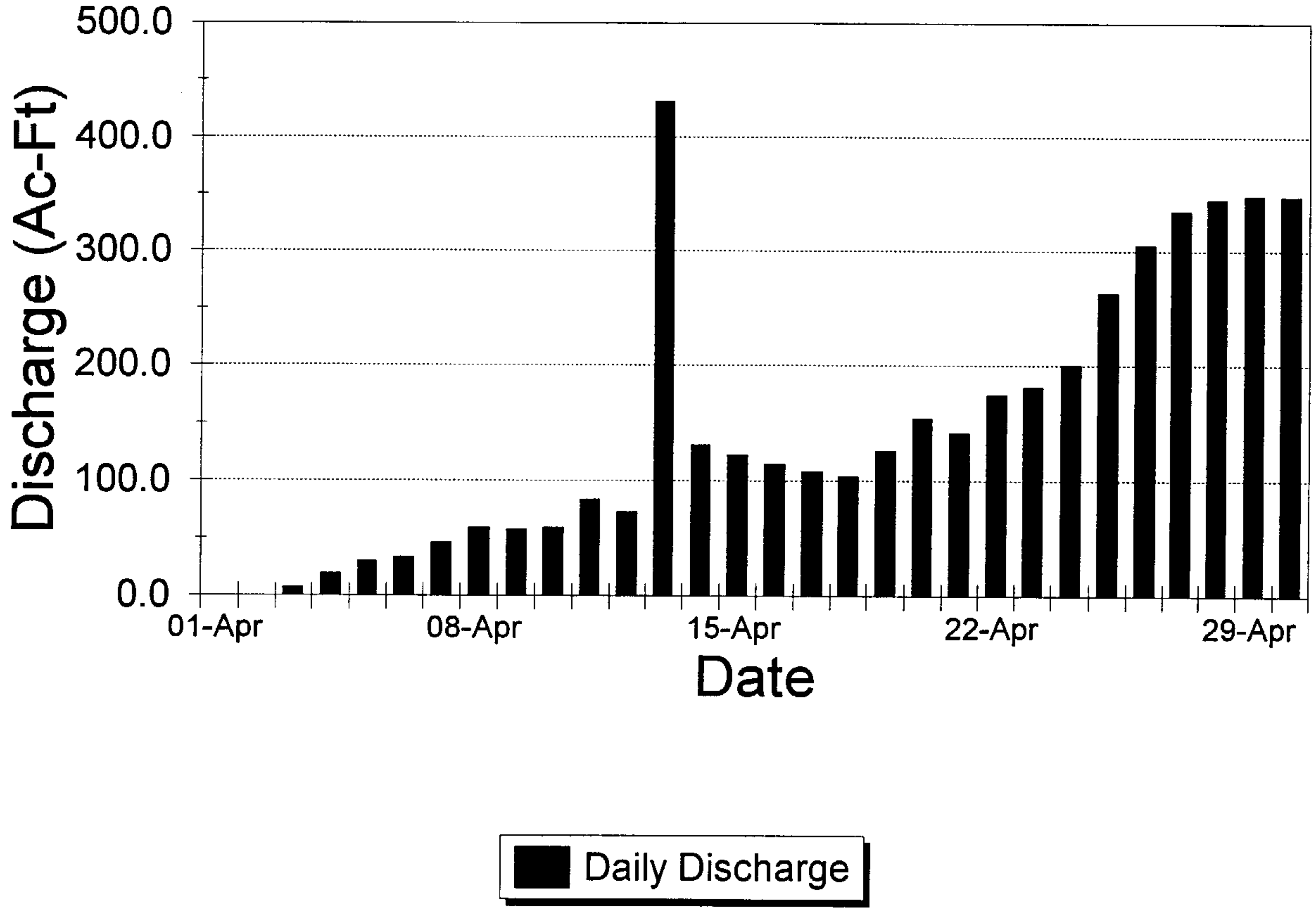



MEDINA LAKE RECHARGE STUDY
Site: ME-05 / BMA 8b Canal
Data from April 1, 1995 to May 1, 1995
Stage (feet)
0
1
2
3
4
01-Apr-95
08-Apr-95
15-Apr-95
22-Apr-95
29-Apr-95
Date
Stage Above Canal Bottom

MEDINA LAKE RECHARGE STUDY

Site: ME-05 / BMA 8b Canal

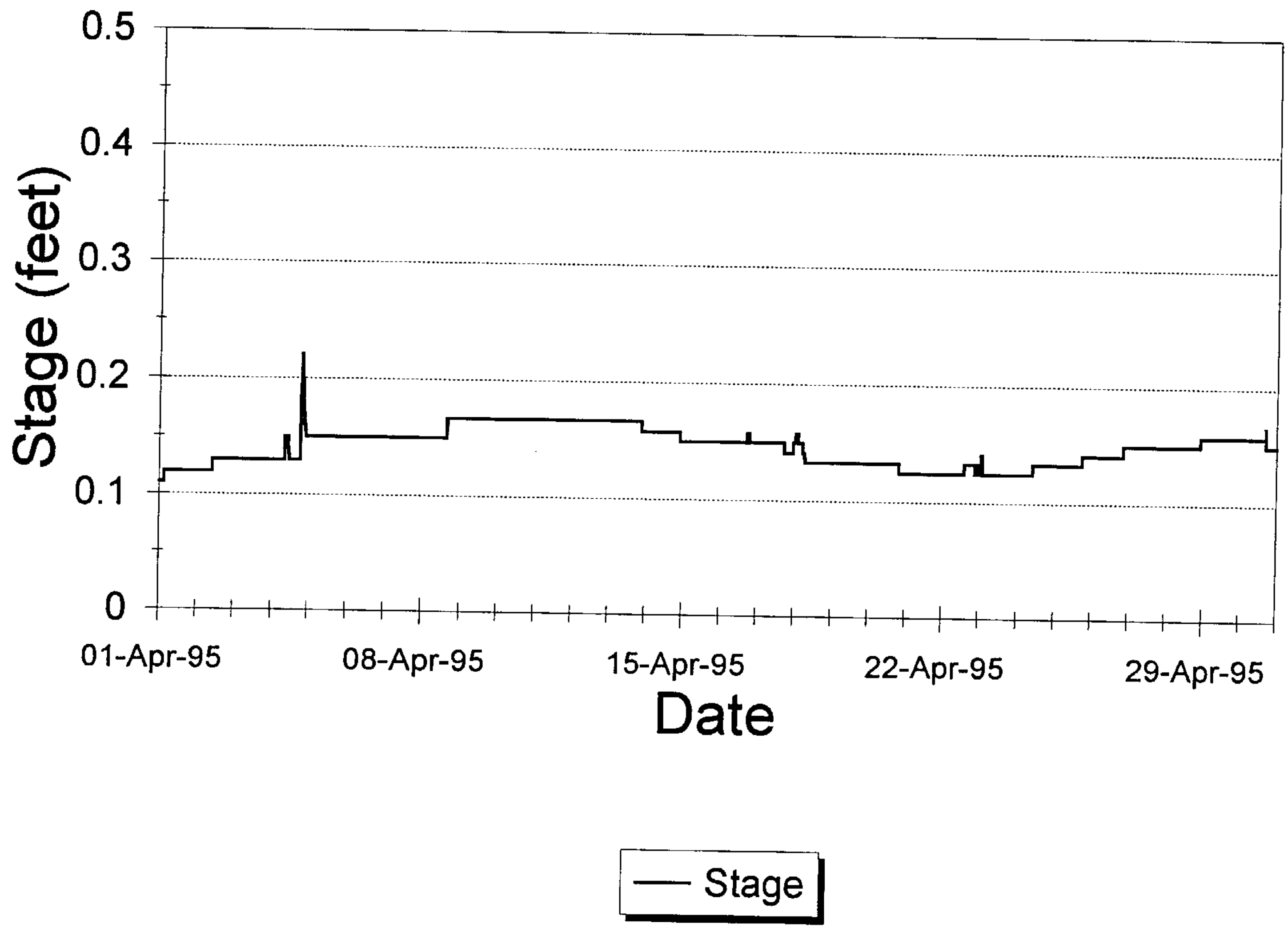
Daily Discharge Data from April 1, 1995 to April 30, 1995

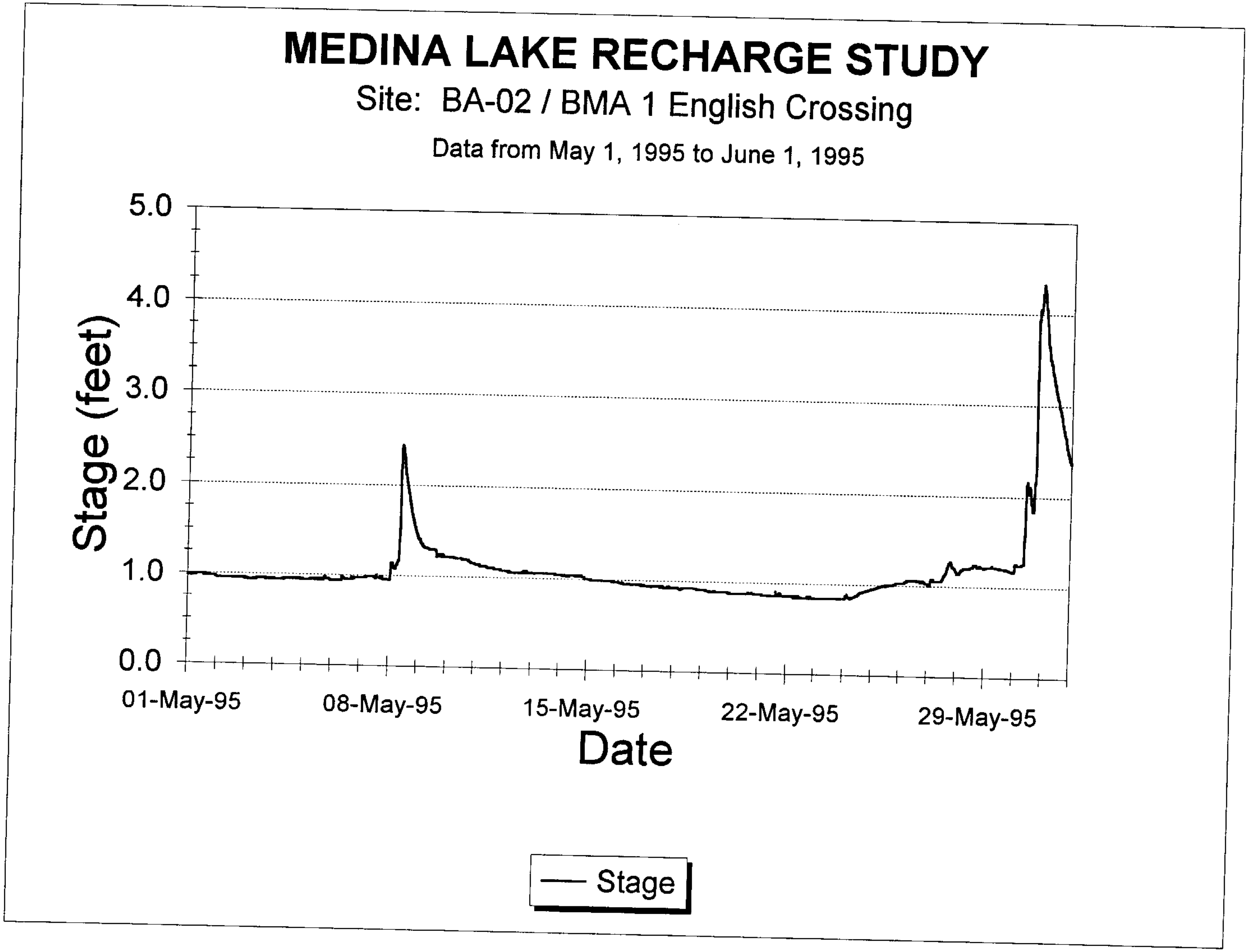


MEDINA LAKE RECHARGE STUDY

Site: ME-04 / BMA 9 M.R. @ Haby C.

Data from April 1, 1995 to May 1, 1995

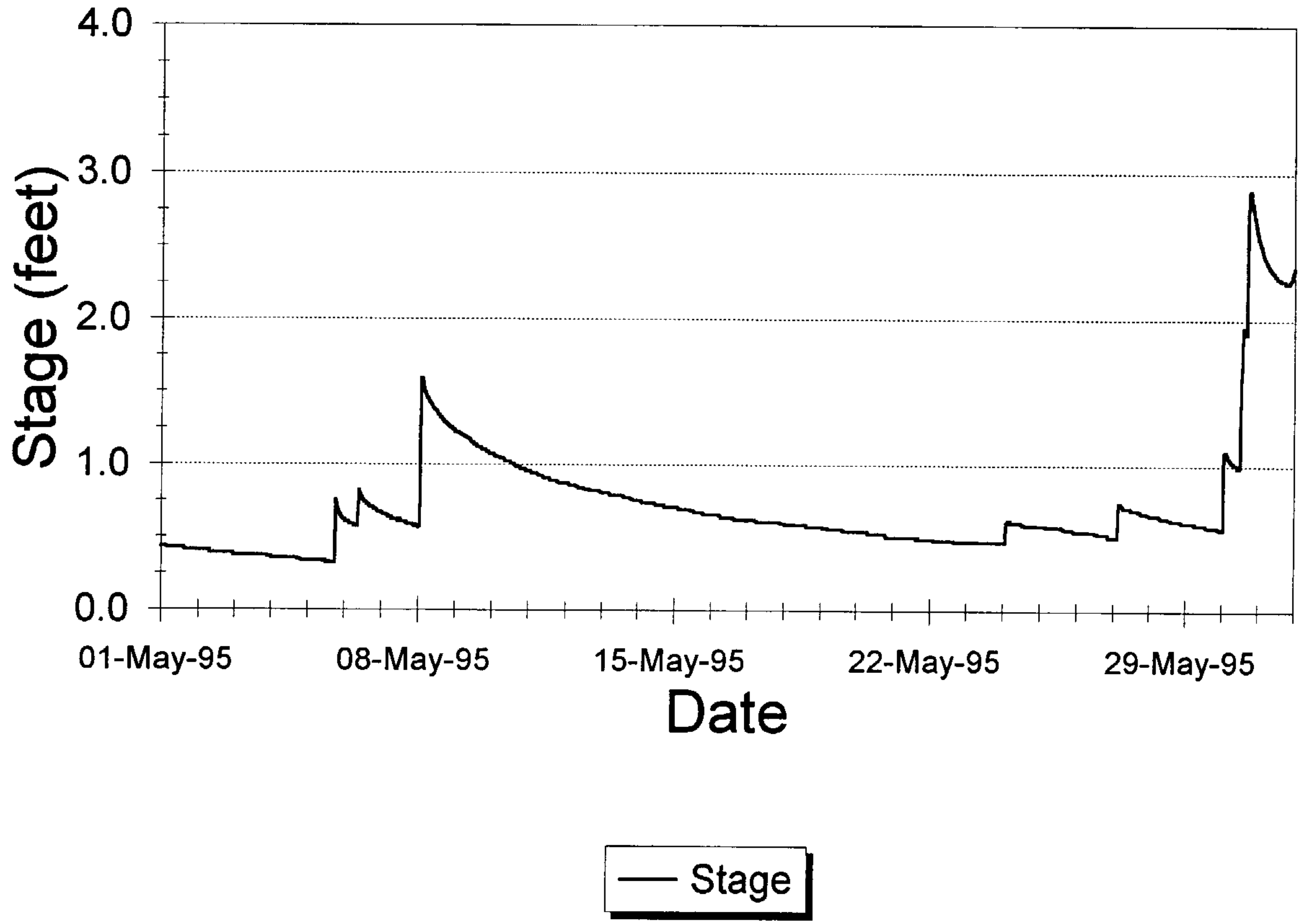



MEDINA LAKE RECHARGE STUDY
Site: BA-02 / BMA 1 English Crossing
Data from May 1, 1995 to June 1, 1995
Stage (feet)
5.0
4.0
3.0
2.0
1.0
0.0
01-May-95
08-May-95
15-May-95
22-May-95
29-May-95
Date
Stage

MEDINA LAKE RECHARGE STUDY

Site: BA-01 / BMA 2 Red Bluff Creek

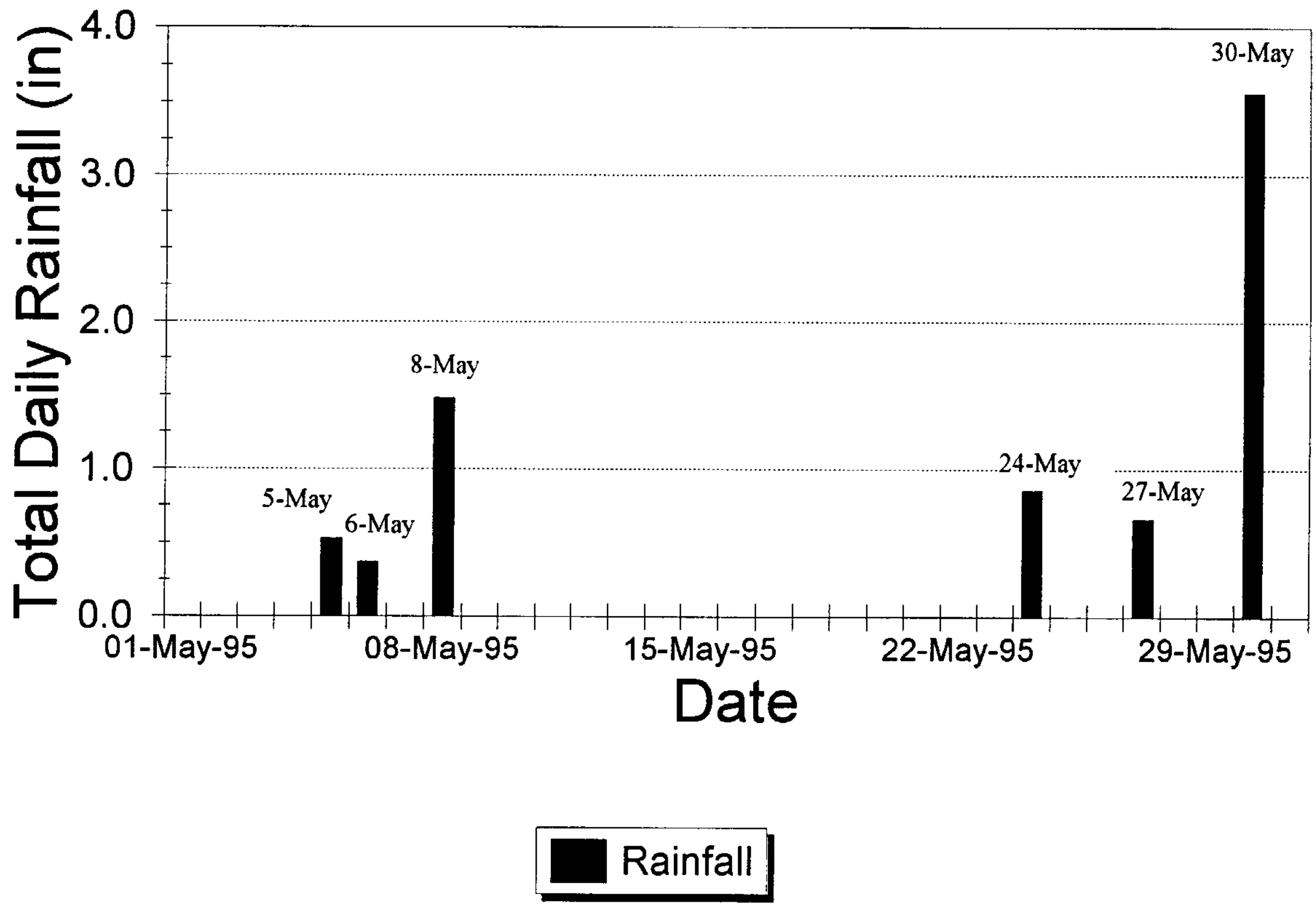
Data from May 1, 1995 to June 1, 1995



MEDINA LAKE RECHARGE STUDY

Site: BA-01 / BMA 2 Red Bluff Creek

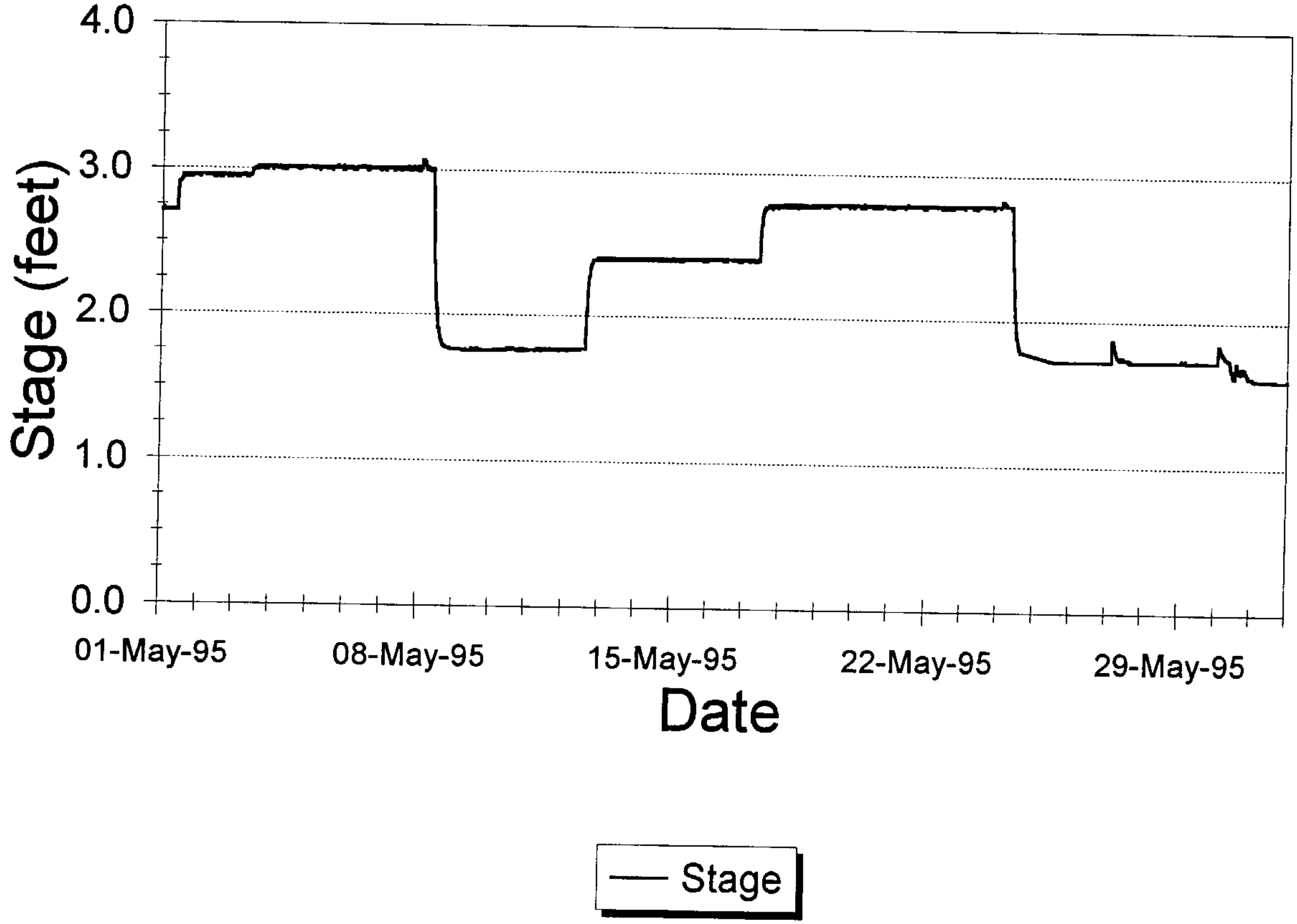
Data from May 1, 1995 to June 1, 1995

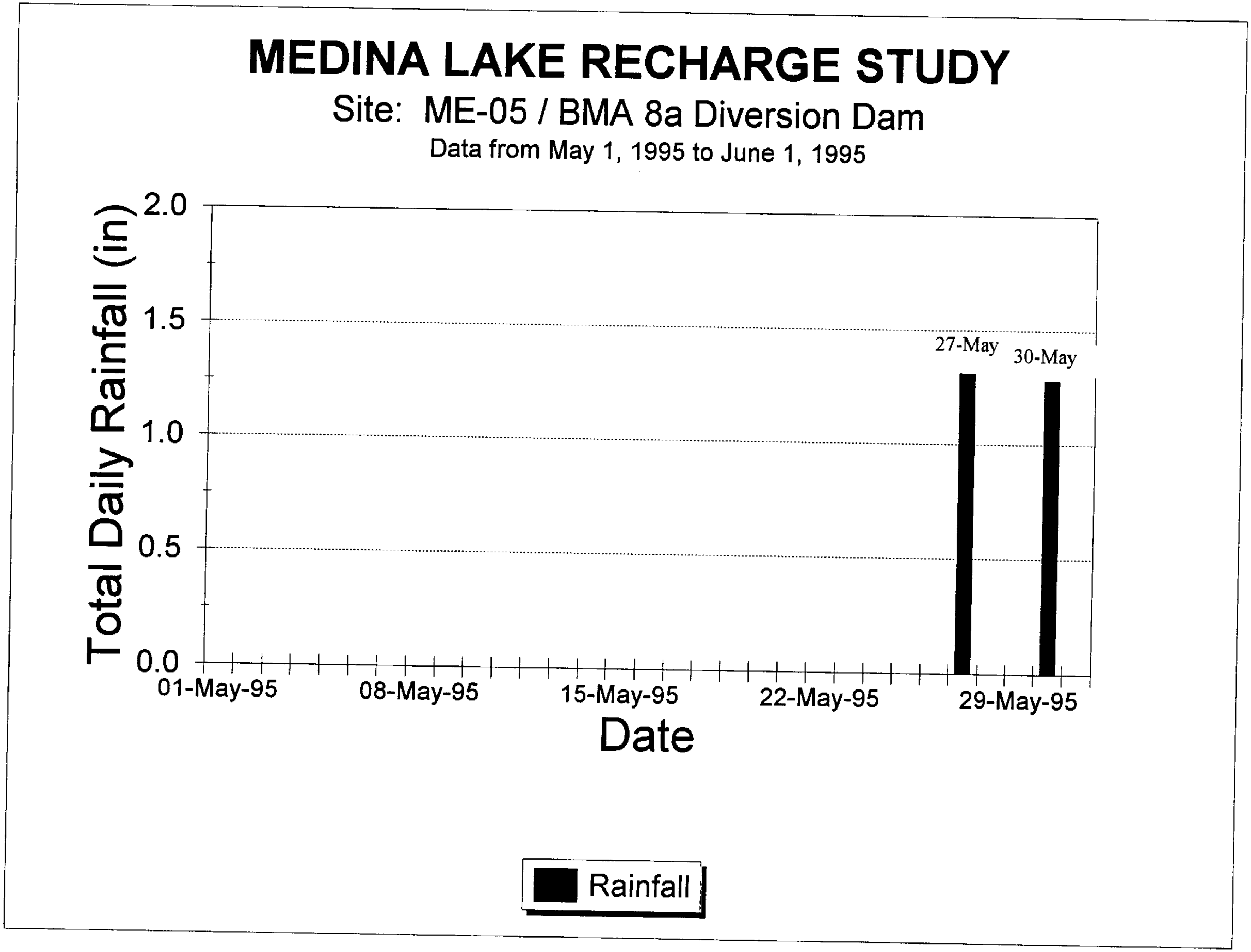


MEDINA LAKE RECHARGE STUDY

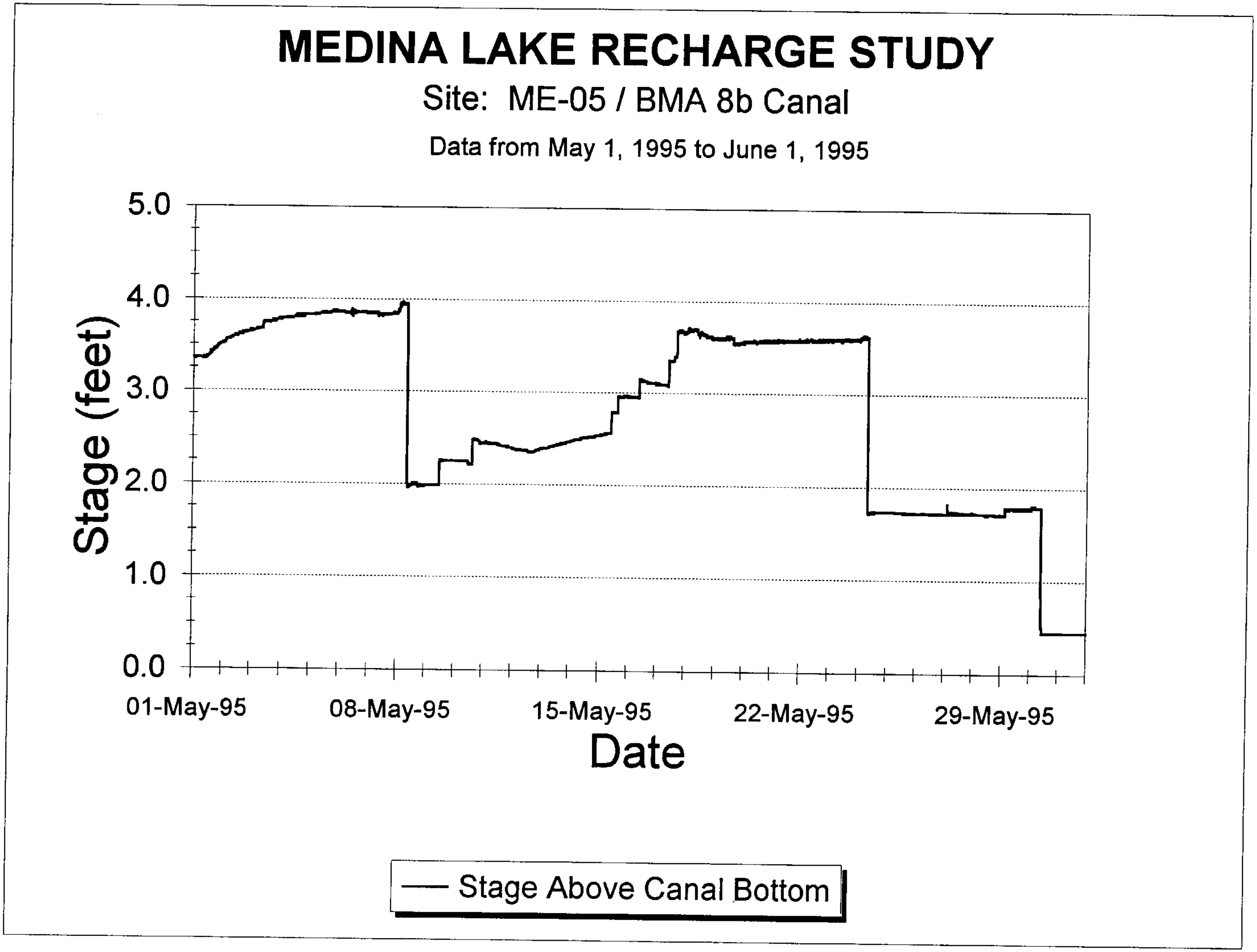
Site: BMA-07 / BMA 7 M.R. Below Main

Data from May 1, 1995 to June 1, 1995





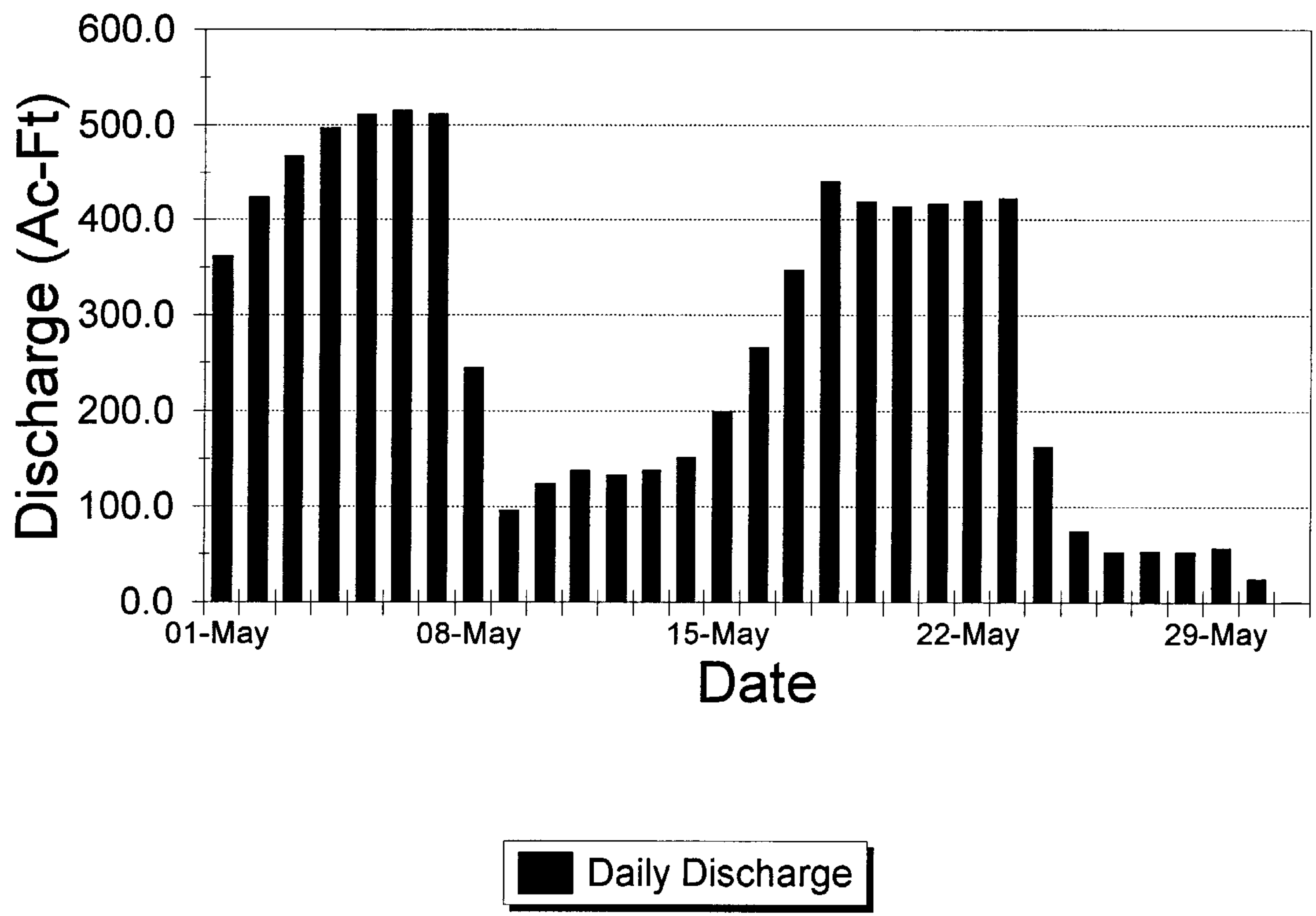
MEDINA LAKE RECHARGE STUDY
Site: ME-05 / BMA 8a Diversion Dam
Data from May 1, 1995 to June 1, 1995
Total Daily Rainfall (in)
2.0
1.5
1.0
0.5
0.0
27-May
30-May
01-May-95
08-May-95
15-May-95
22-May-95
29-May-95
Date
Rainfall

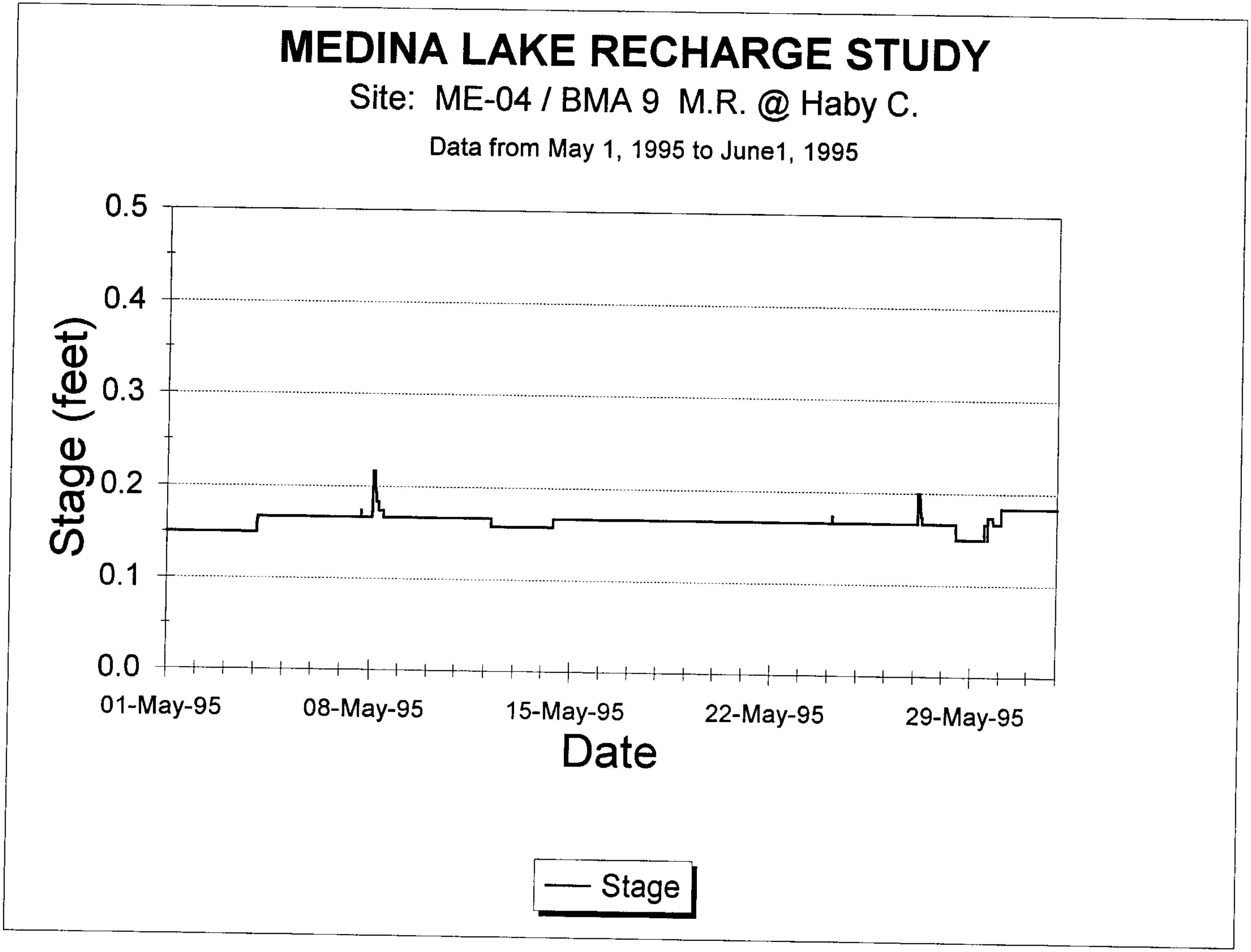

MEDINA LAKE RECHARGE STUDY
Site: ME-05 / BMA 8b Canal
Data from May 1, 1995 to June 1, 1995
5.0
4.0
3.0
2.0
1.0
0.0
Stage (feet)
01-May-95
08-May-95
15-May-95
22-May-95
29-May-95
Date
Stage Above Canal Bottom

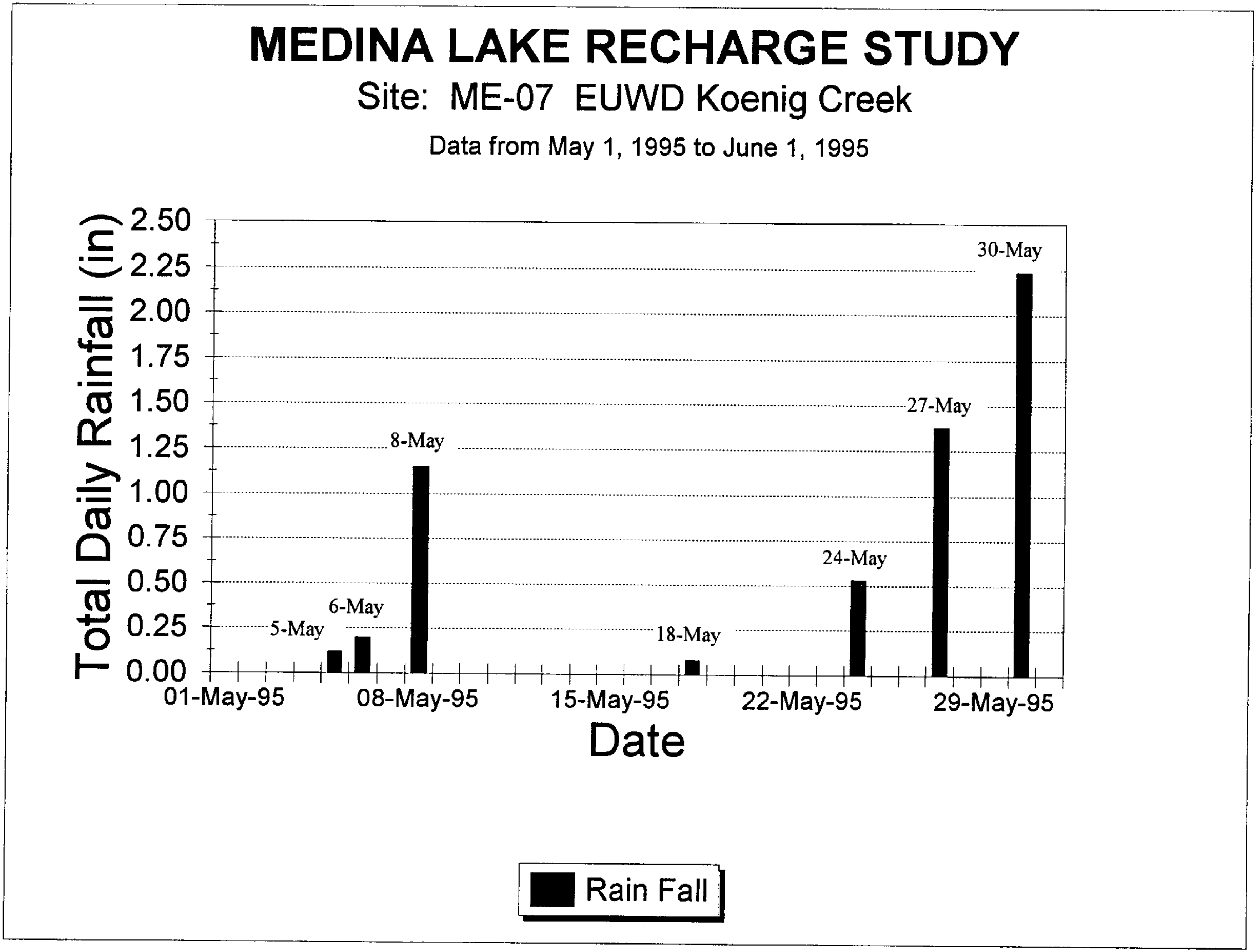
MEDINA LAKE RECHARGE STUDY

Site: ME-05 / BMA 8b Canal

Daily Discharge Data from May 1, 1995 to June 1, 1995



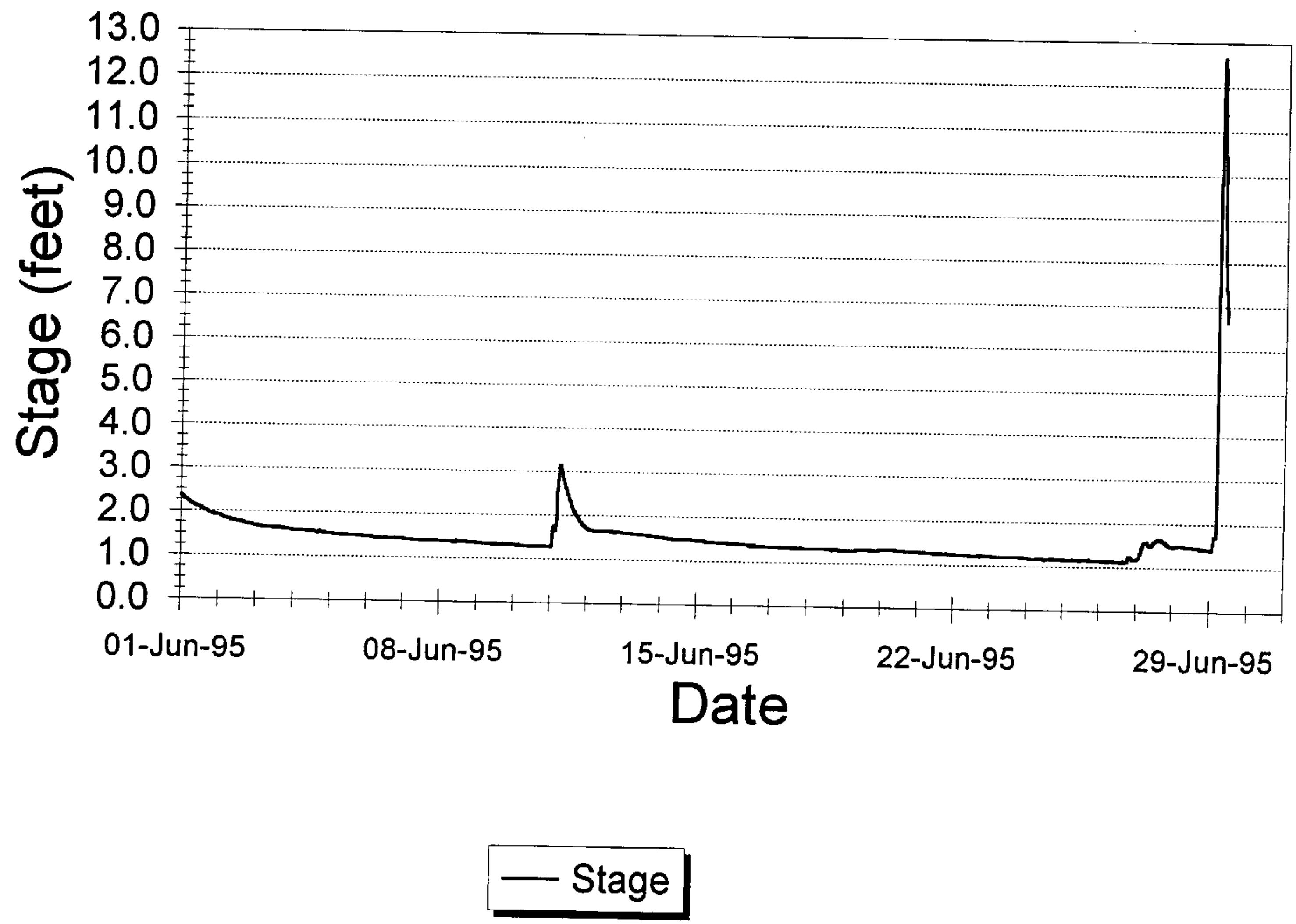

MEDINA LAKE RECHARGE STUDY
Site: ME-04 / BMA 9 M.R. @ Haby C.
Data from May 1, 1995 to June1, 1995
Stage (feet)
0.5
0.4
0.3
0.2
0.1
0.0
01-May-95
08-May-95
15-May-95
22-May-95
29-May-95
Date
Stage


MEDINA LAKE RECHARGE STUDY
Site: ME-07 EUWD Koenig Creek
Data from May 1, 1995 to June 1, 1995
Total Daily Rainfall (in)
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
5-May
6-May
8-May
18-May
24-May
27-May
30-May
01-May-95
08-May-95
15-May-95
22-May-95
29-May-95
Date
Rain Fall

MEDINA LAKE RECHARGE STUDY

Site: BA-02 / BMA 1 English Crossing

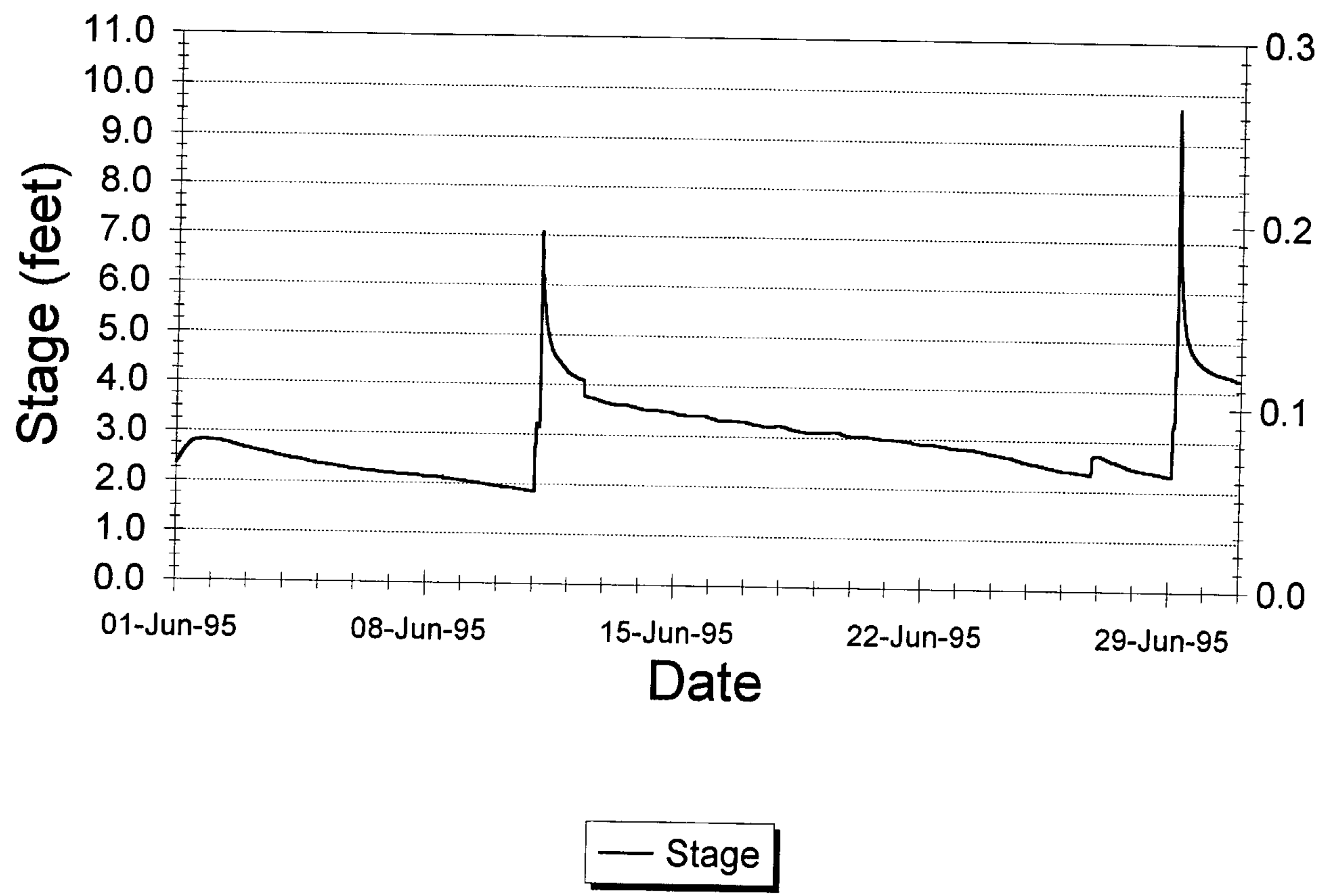
Data from June 1, 1995 to July 1, 1995



MEDINA LAKE RECHARGE STUDY

Site: BA-01 / BMA 2 Red Bluff Creek

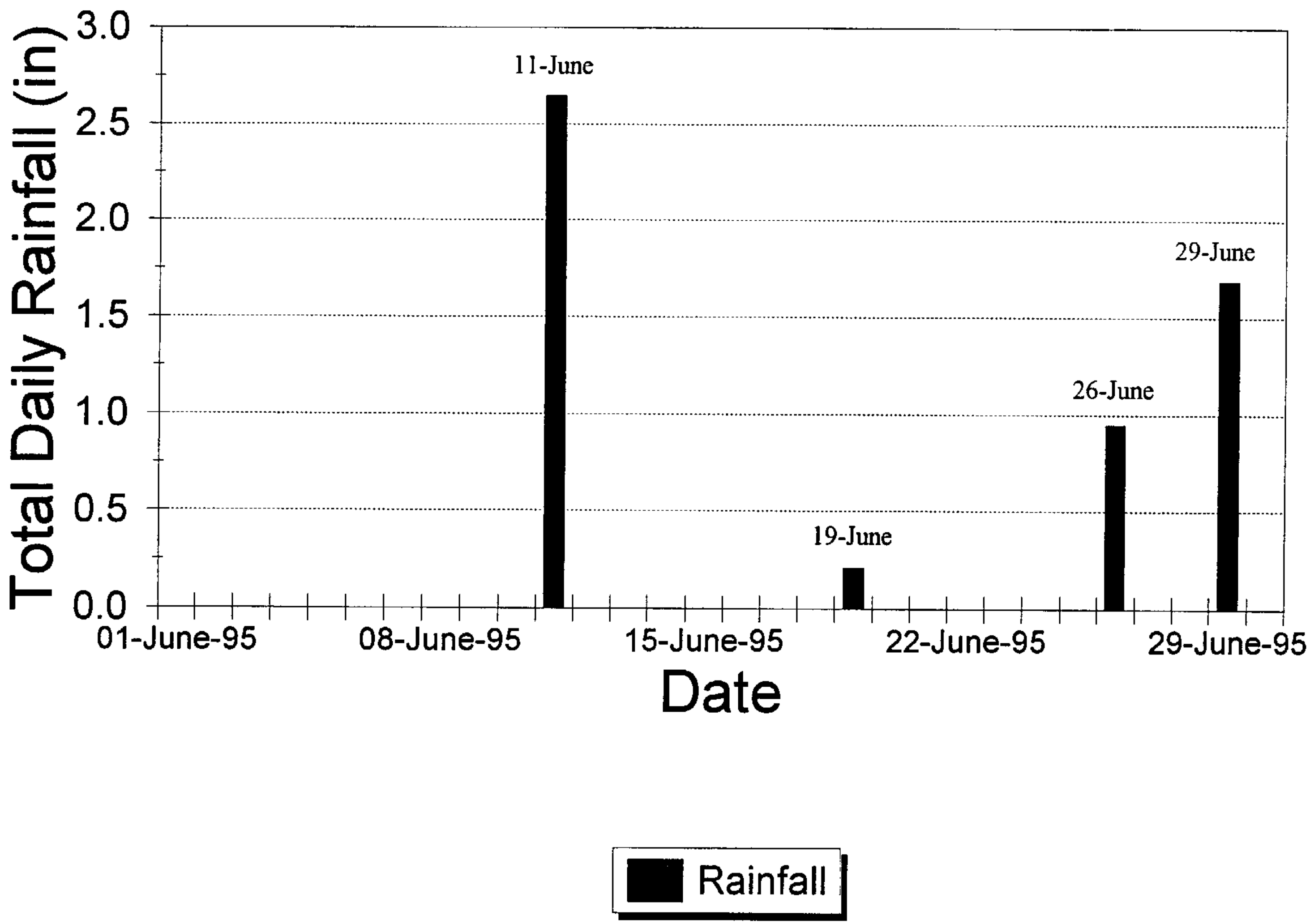
Data from June 1, 1995 to July 1, 1995

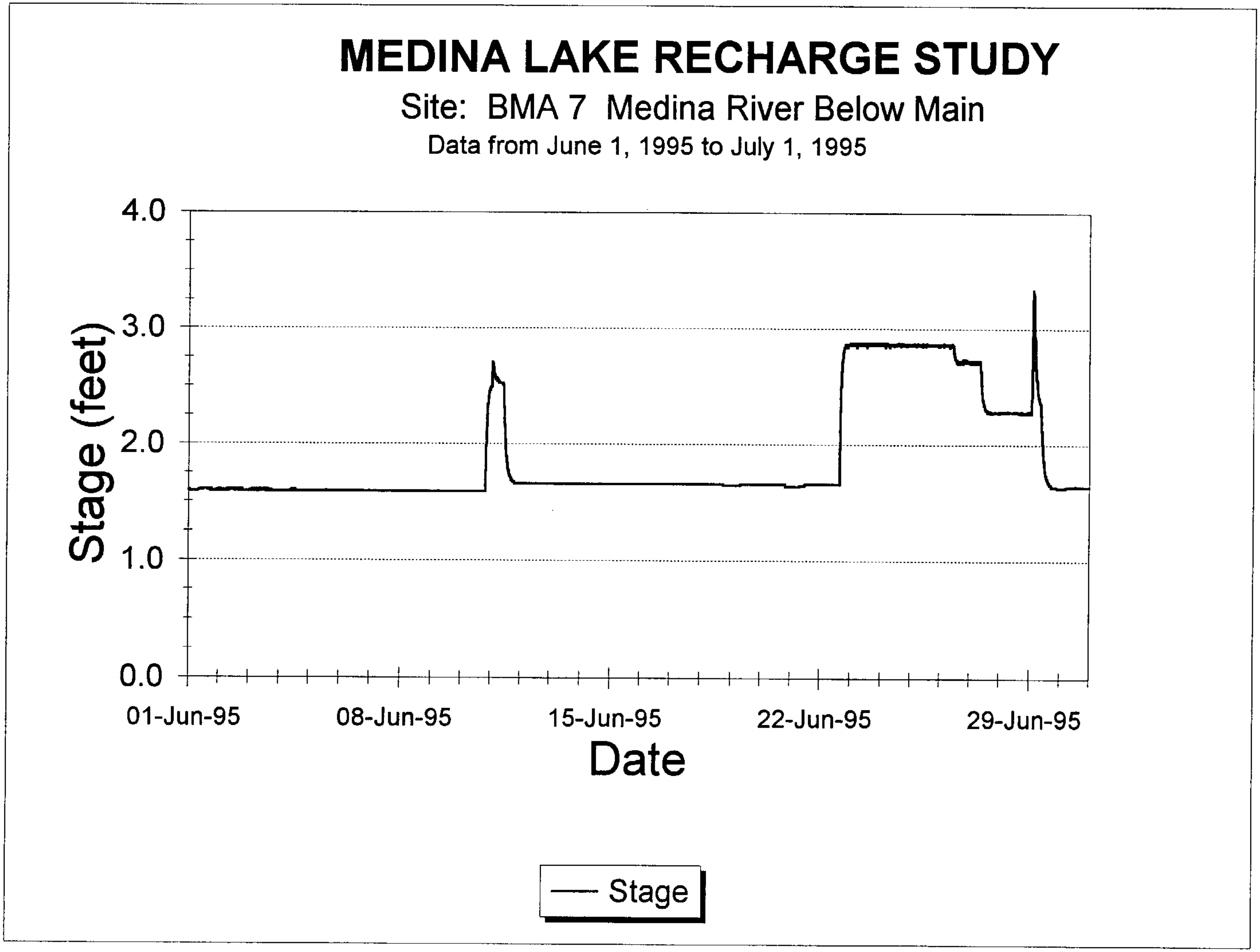


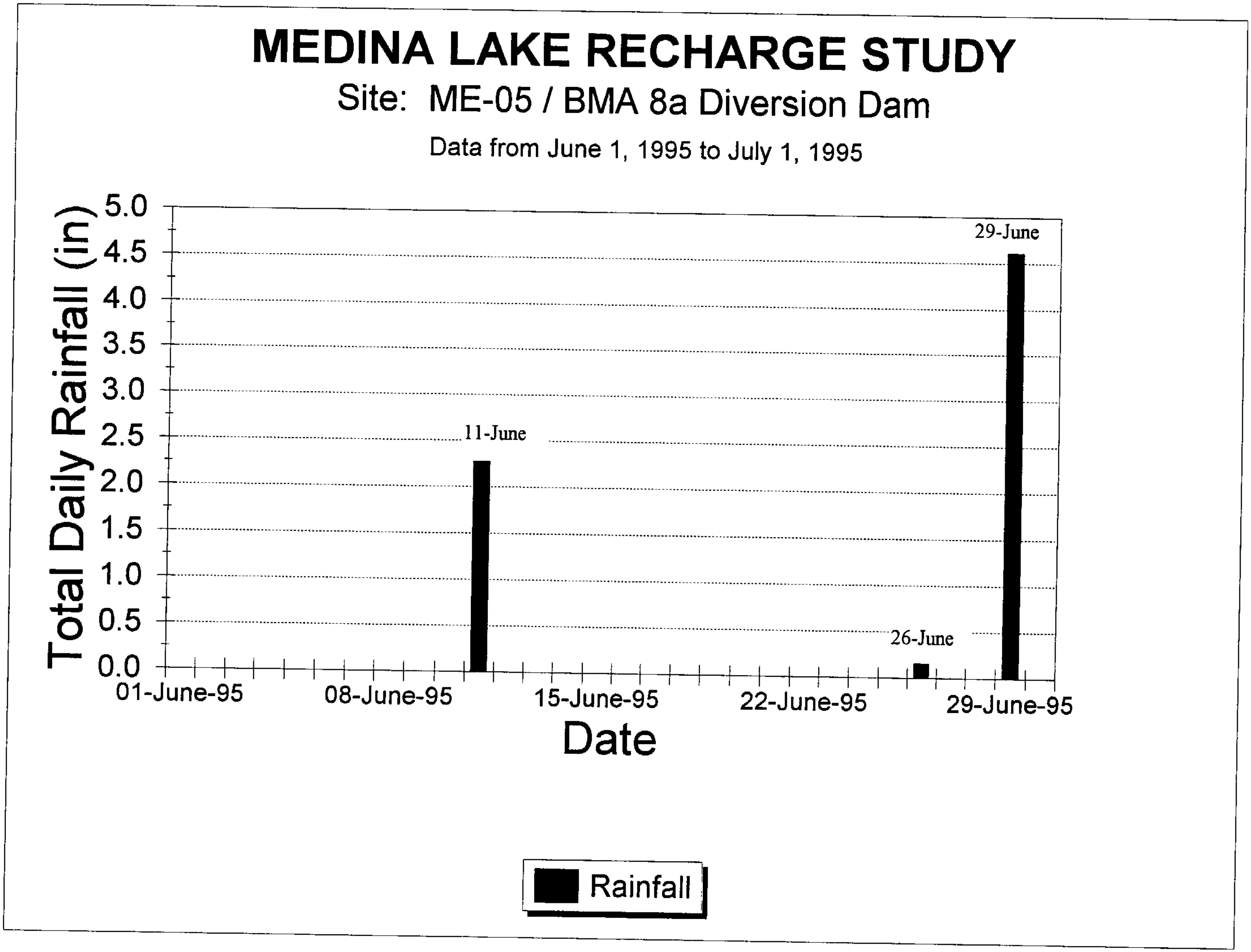
MEDINA LAKE RECHARGE STUDY

Site: BA-01 / BMA 2 Red Bluff Creek

Data from June 1, 1995 to July 1, 1995



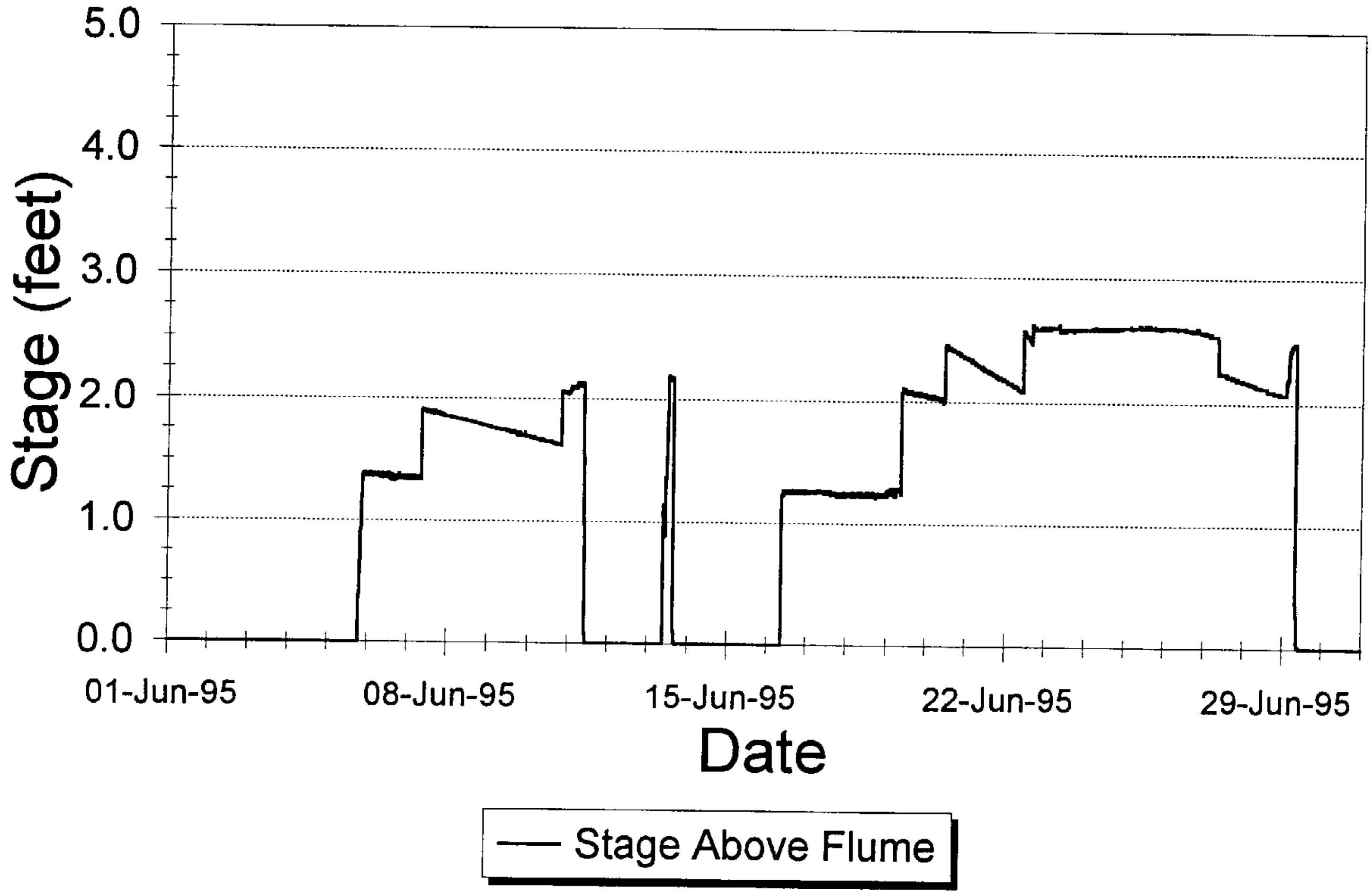

MEDINA LAKE RECHARGE STUDY
Site: BMA 7 Medina River Below Main
Data from June 1, 1995 to July 1, 1995
Stage (feet)
4.0
3.0
2.0
1.0
0.0
01-Jun-95
08-Jun-95
15-Jun-95
22-Jun-95
29-Jun-95
Date
Stage


MEDINA LAKE RECHARGE STUDY
Site: ME-05 / BMA 8a Diversion Dam
Data from June 1, 1995 to July 1, 1995
Total Daily Rainfall (in)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
11-June
26-June
29-June
01-June-95
08-June-95
15-June-95
22-June-95
29-June-95
Date
Rainfall

MEDINA LAKE RECHARGE STUDY

Site: ME-05 / BMA 8b Canal

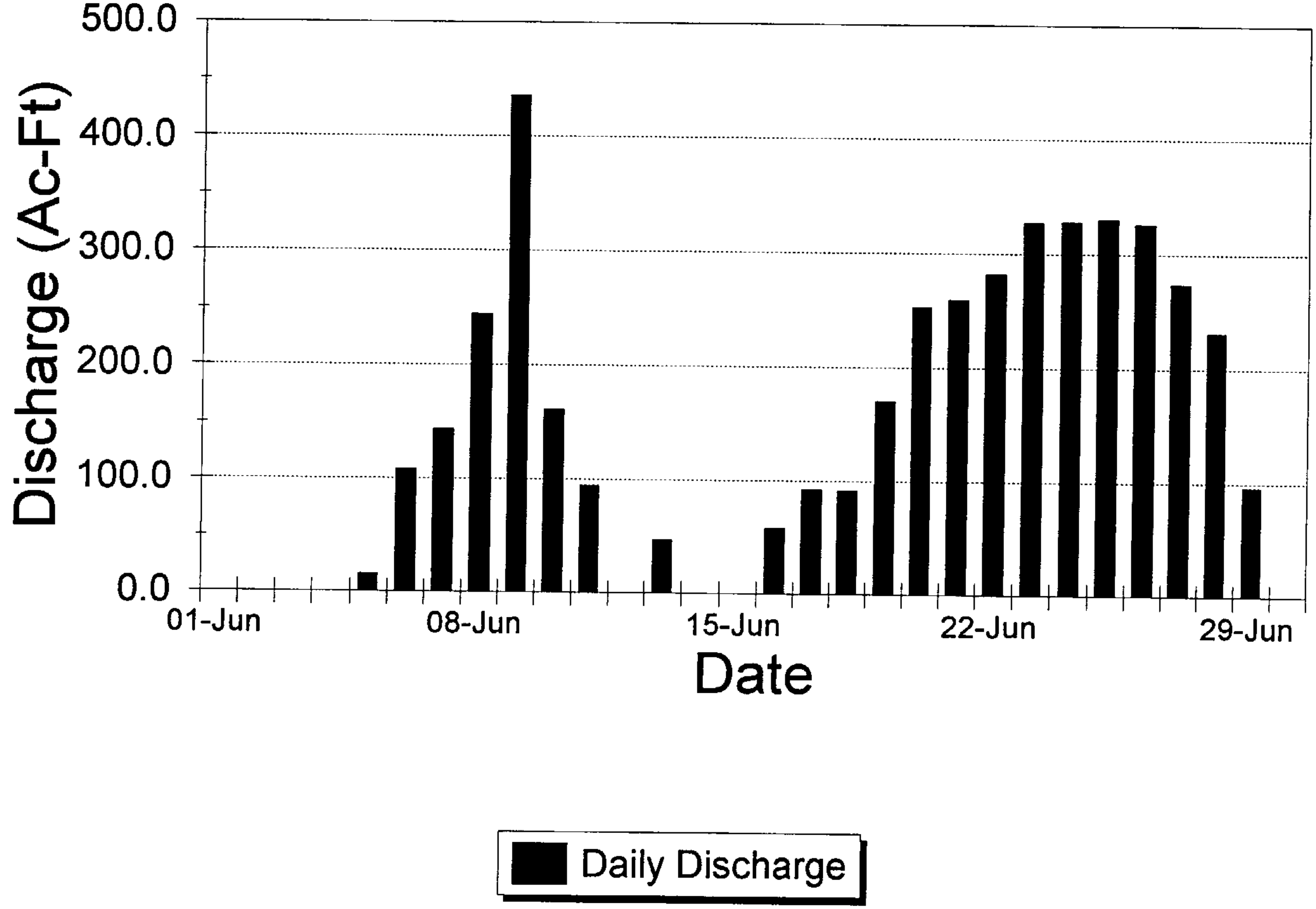
Data from June 6, 1995 to July 1, 1995



MEDINA LAKE RECHARGE STUDY

Site: ME-05 / BMA 8b Canal

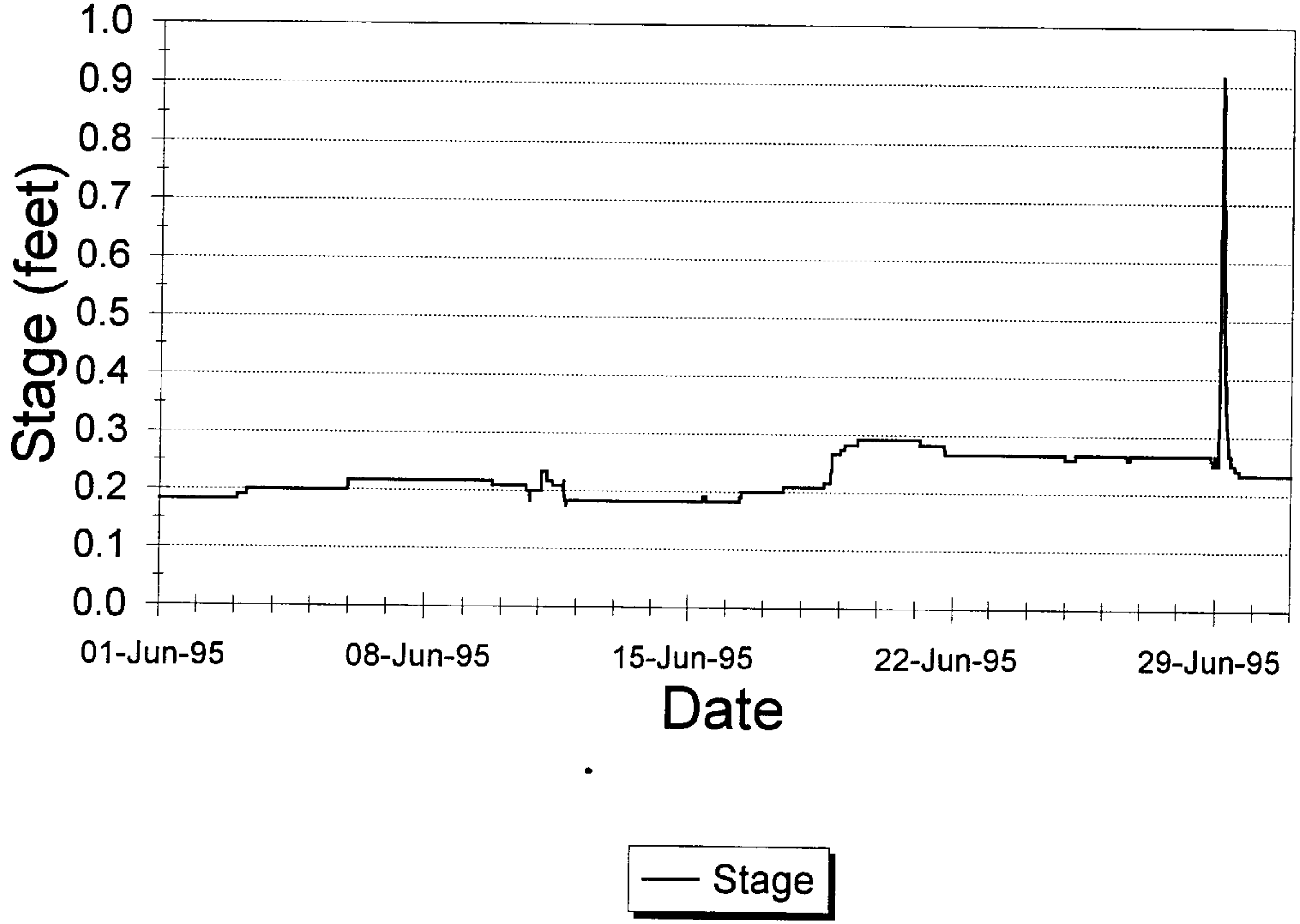
Daily Discharge Data from June 1, 1995 to June 30, 1995

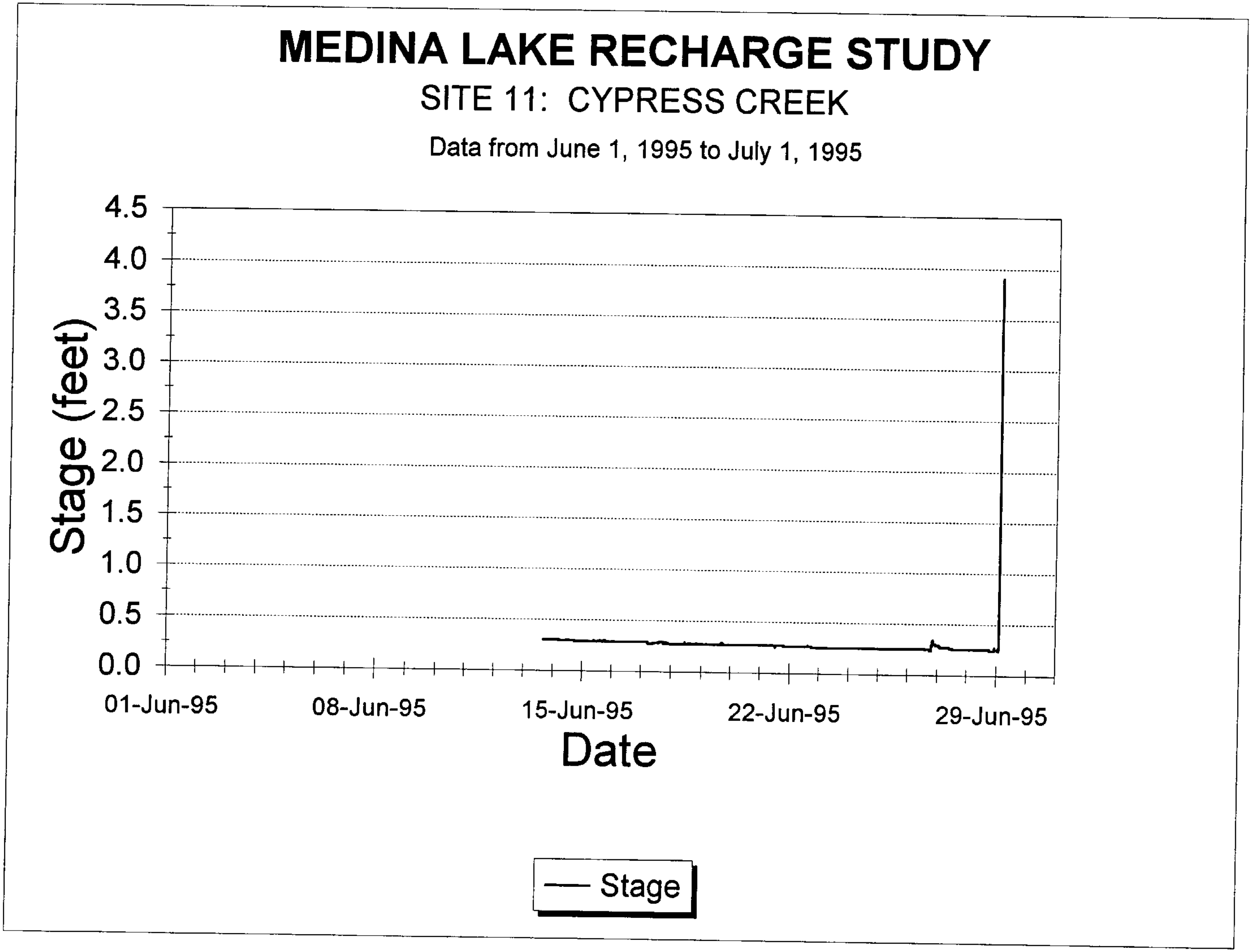


MEDINA LAKE RECHARGE STUDY

Site: ME-04 / BMA 9 M.R. @ Haby C.

Data from June 1, 1995 to July 1, 1995

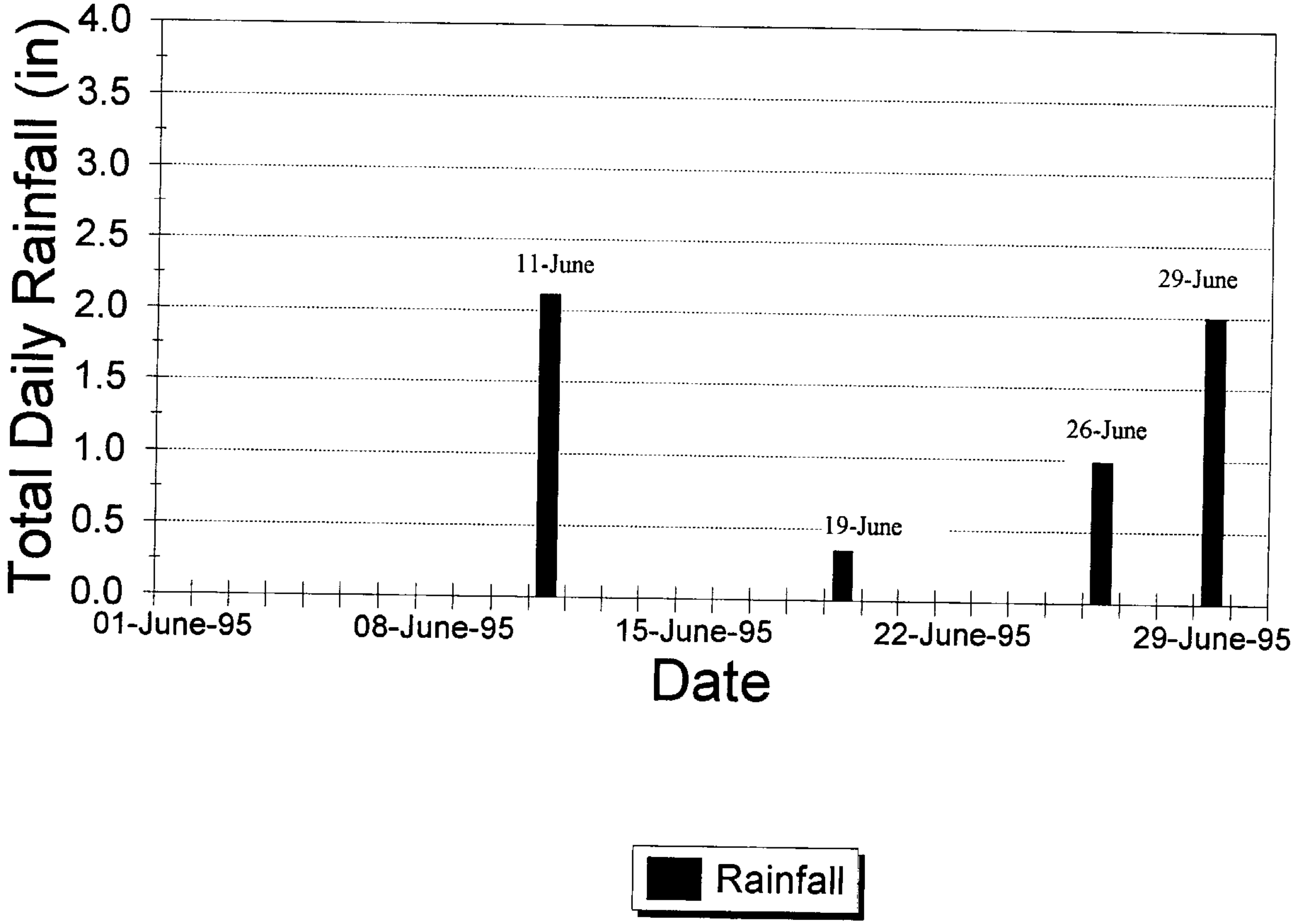


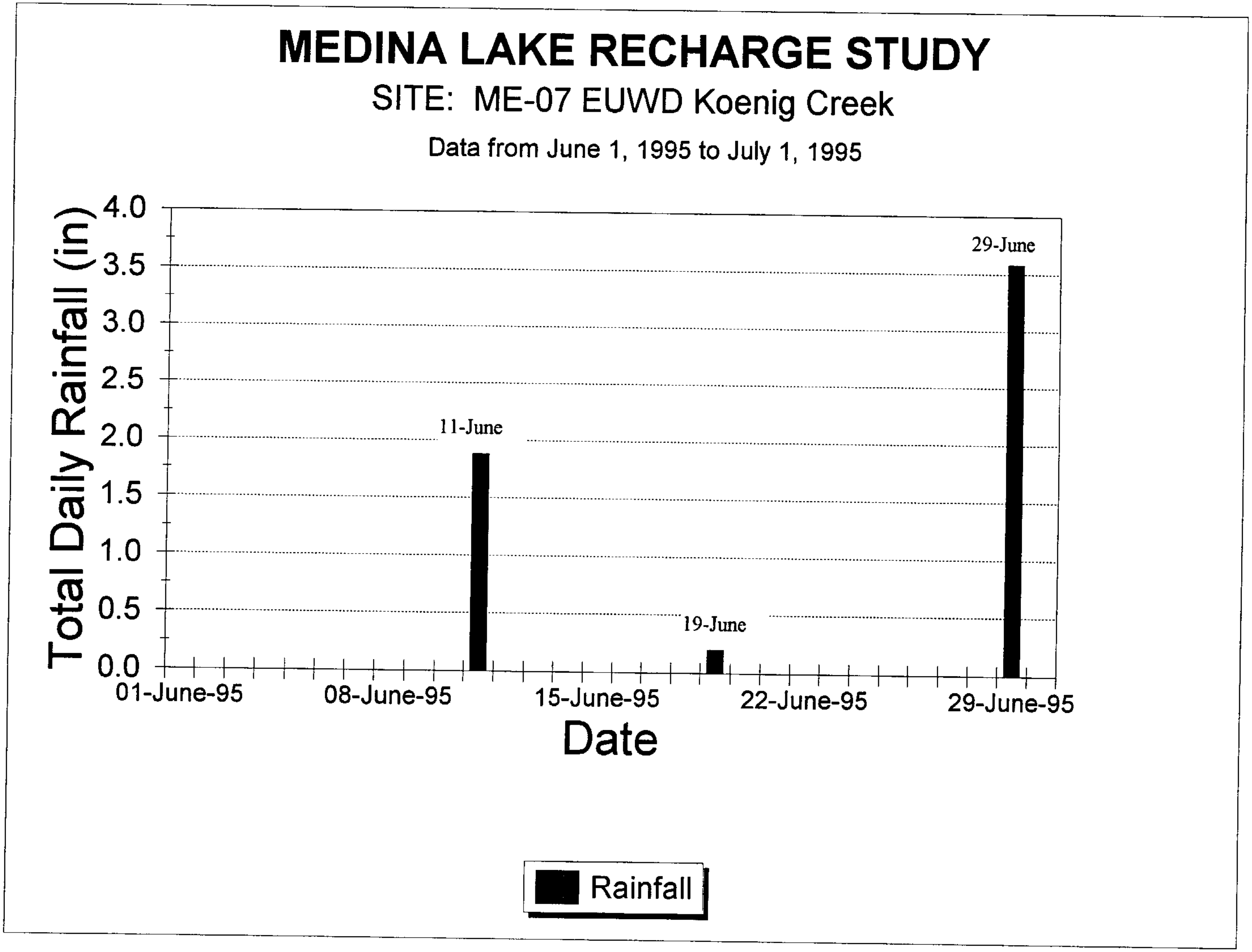

MEDINA LAKE RECHARGE STUDY
SITE 11: CYPRESS CREEK
Data from June 1, 1995 to July 1, 1995
Stage (feet)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
01-Jun-95
08-Jun-95
15-Jun-95
22-Jun-95
29-Jun-95
Date
Stage

MEDINA LAKE RECHARGE STUDY

Site: BMA 12 Bruins Creek

Data from June 1, 1995 to July 1, 1995

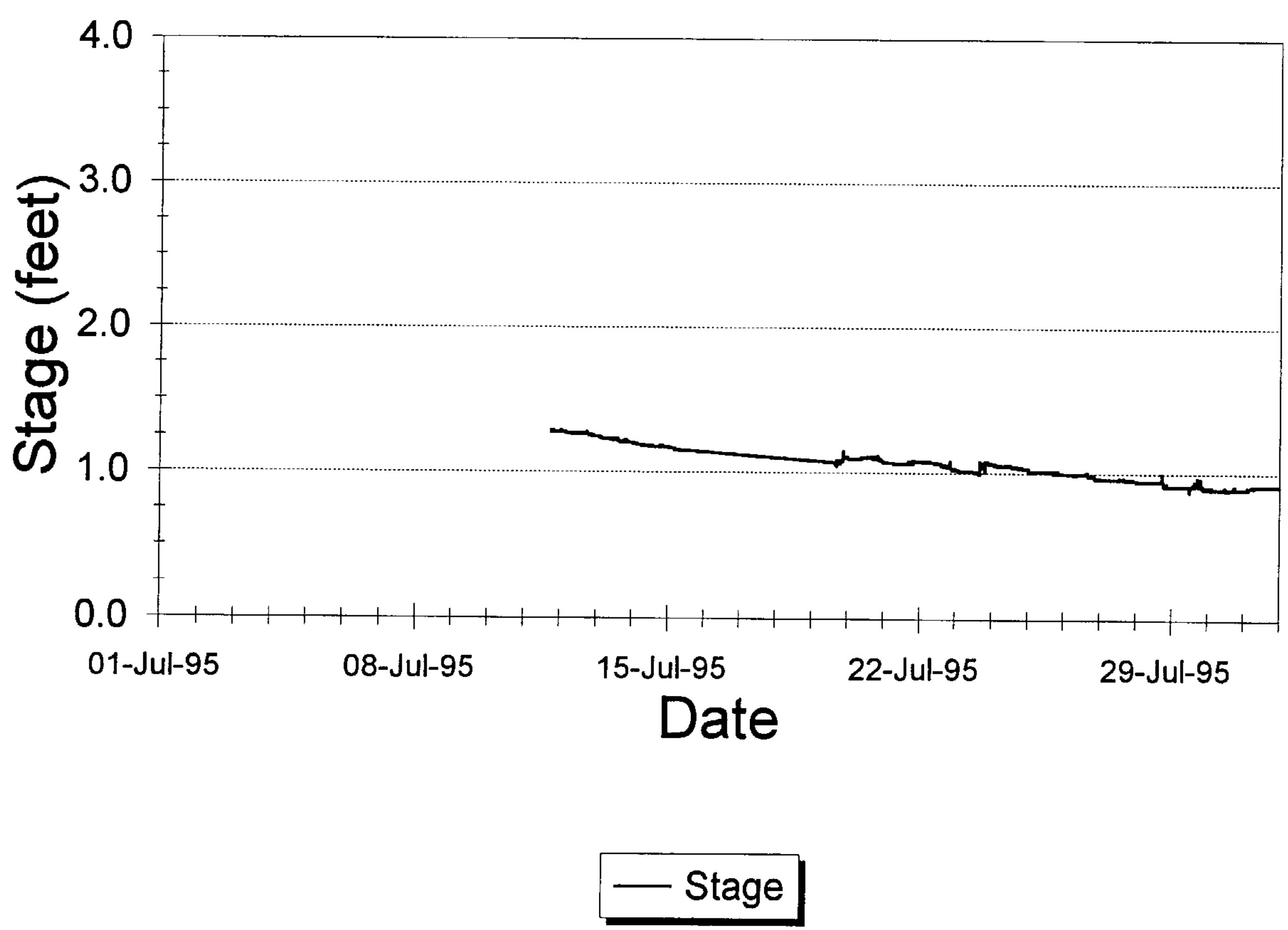


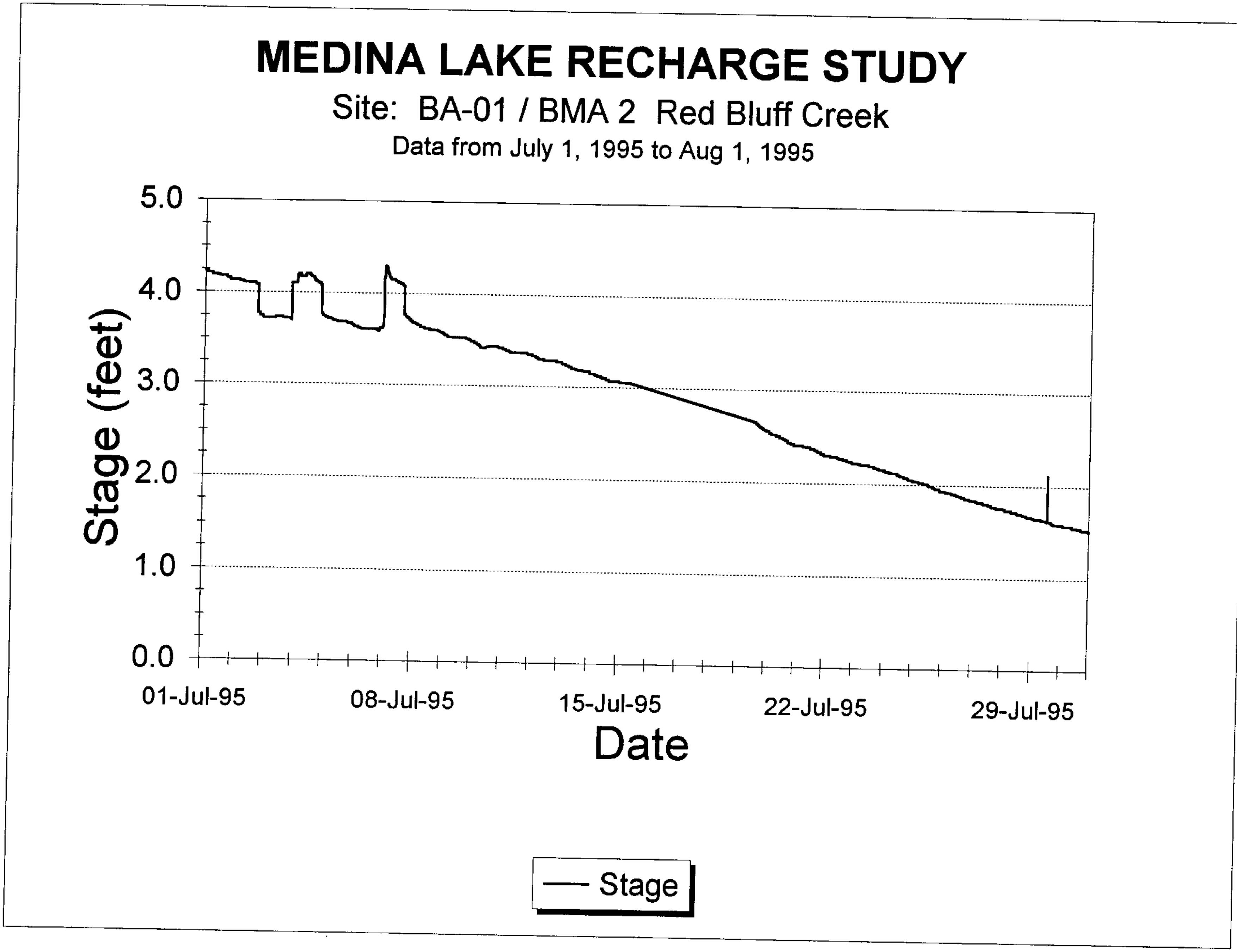

MEDINA LAKE RECHARGE STUDY
SITE: ME-07 EUWD Koenig Creek
Data from June 1, 1995 to July 1, 1995
Total Daily Rainfall (in)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
11-June
19-June
29-June
01-June-95
08-June-95
15-June-95
22-June-95
29-June-95
Date
Rainfall

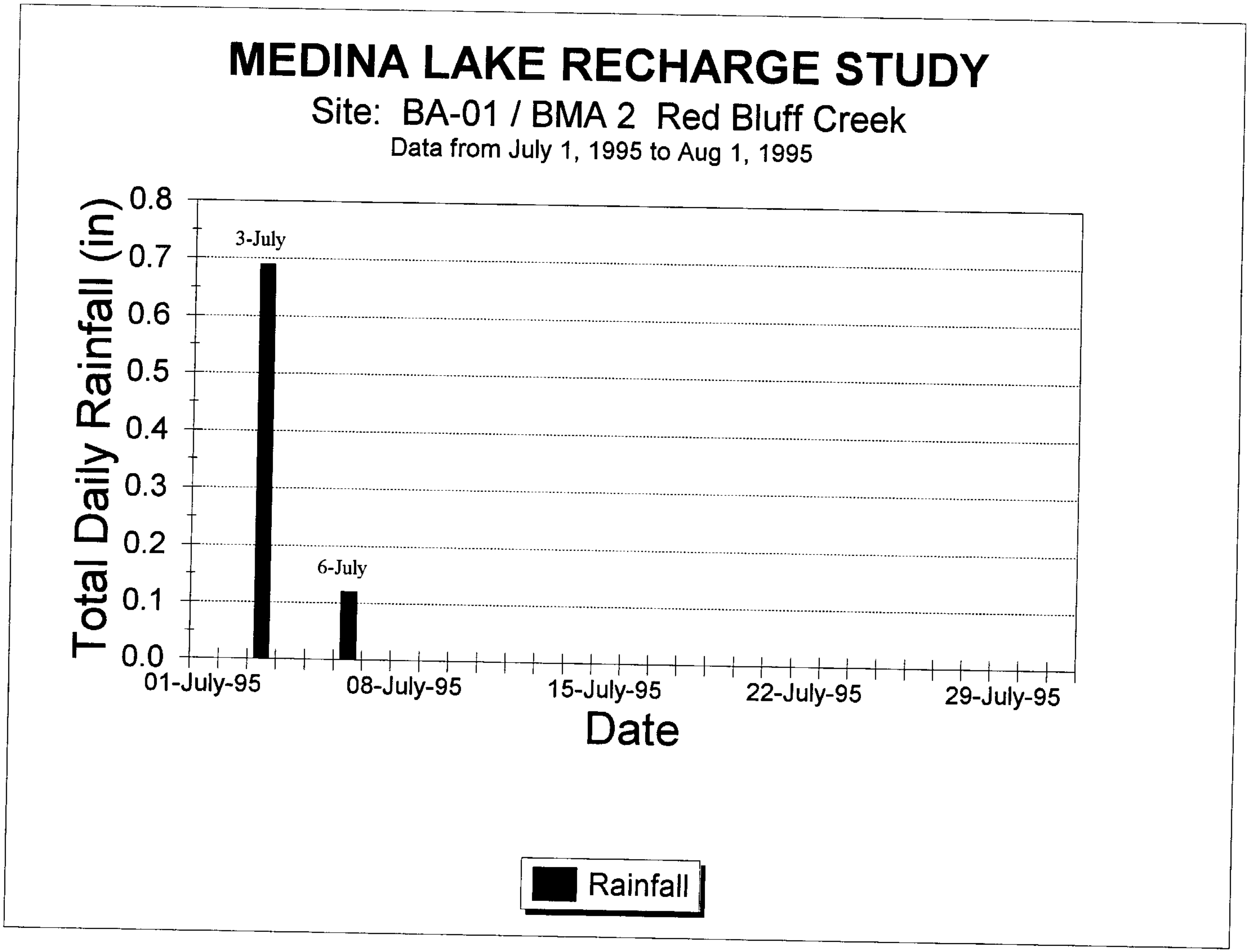
MEDINA LAKE RECHARGE STUDY

Site: BA-02 / BMA 1 English Crossing

Data from July 1, 1995 to Aug 1, 1995



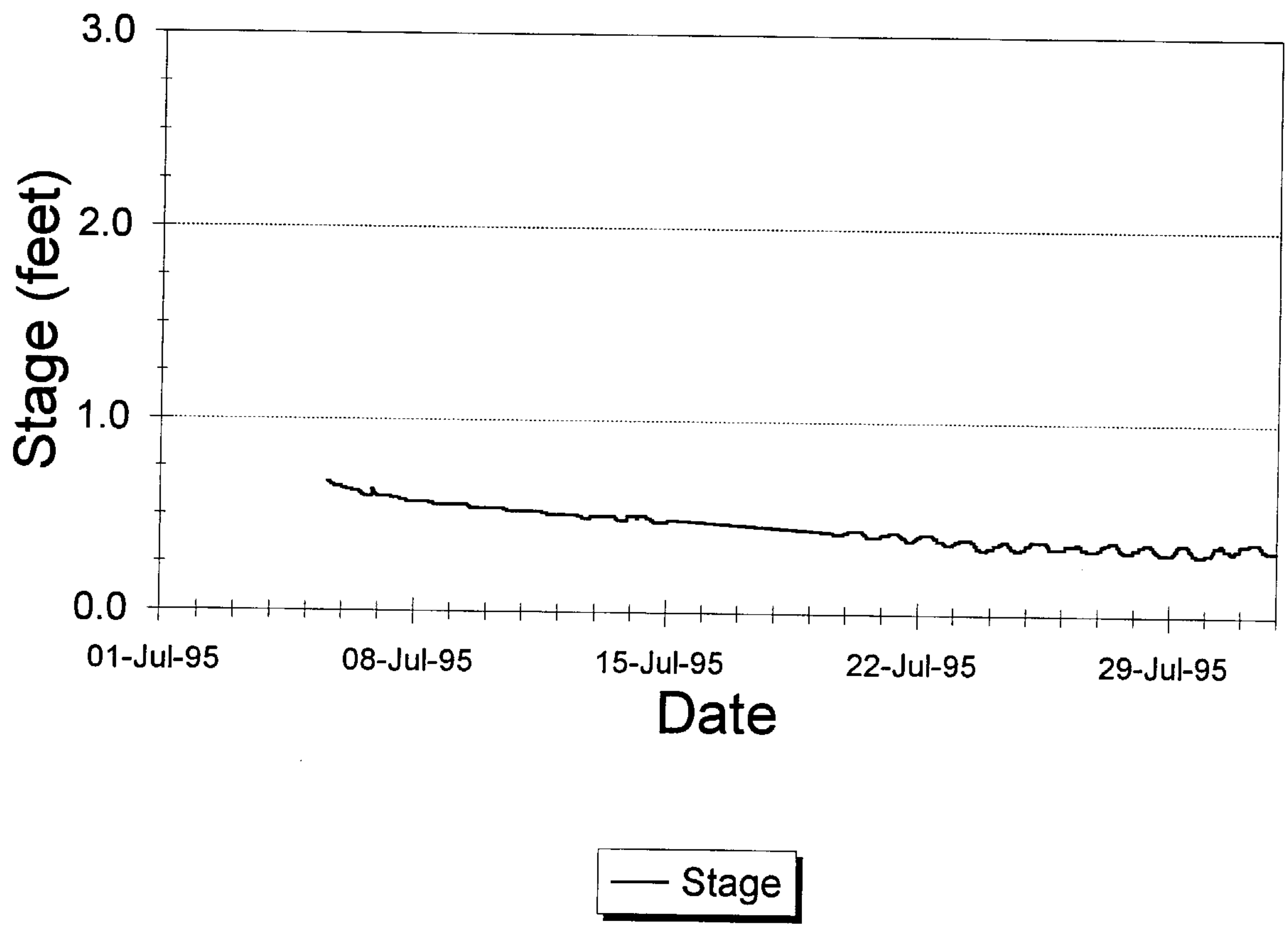

MEDINA LAKE RECHARGE STUDY
Site: BA-01 / BMA 2 Red Bluff Creek
Data from July 1, 1995 to Aug 1, 1995
Stage (feet)
5.0
4.0
3.0
2.0
1.0
0.0
01-Jul-95
08-Jul-95
15-Jul-95
22-Jul-95
29-Jul-95
Date
Stage


MEDINA LAKE RECHARGE STUDY
Site: BA-01 / BMA 2 Red Bluff Creek
Data from July 1, 1995 to Aug 1, 1995
Total Daily Rainfall (in)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
3-July
6-July
01-July-95
08-July-95
15-July-95
22-July-95
29-July-95
Date
Rainfall

MEDINA LAKE RECHARGE STUDY

Site: BMA 3 Elm Creek

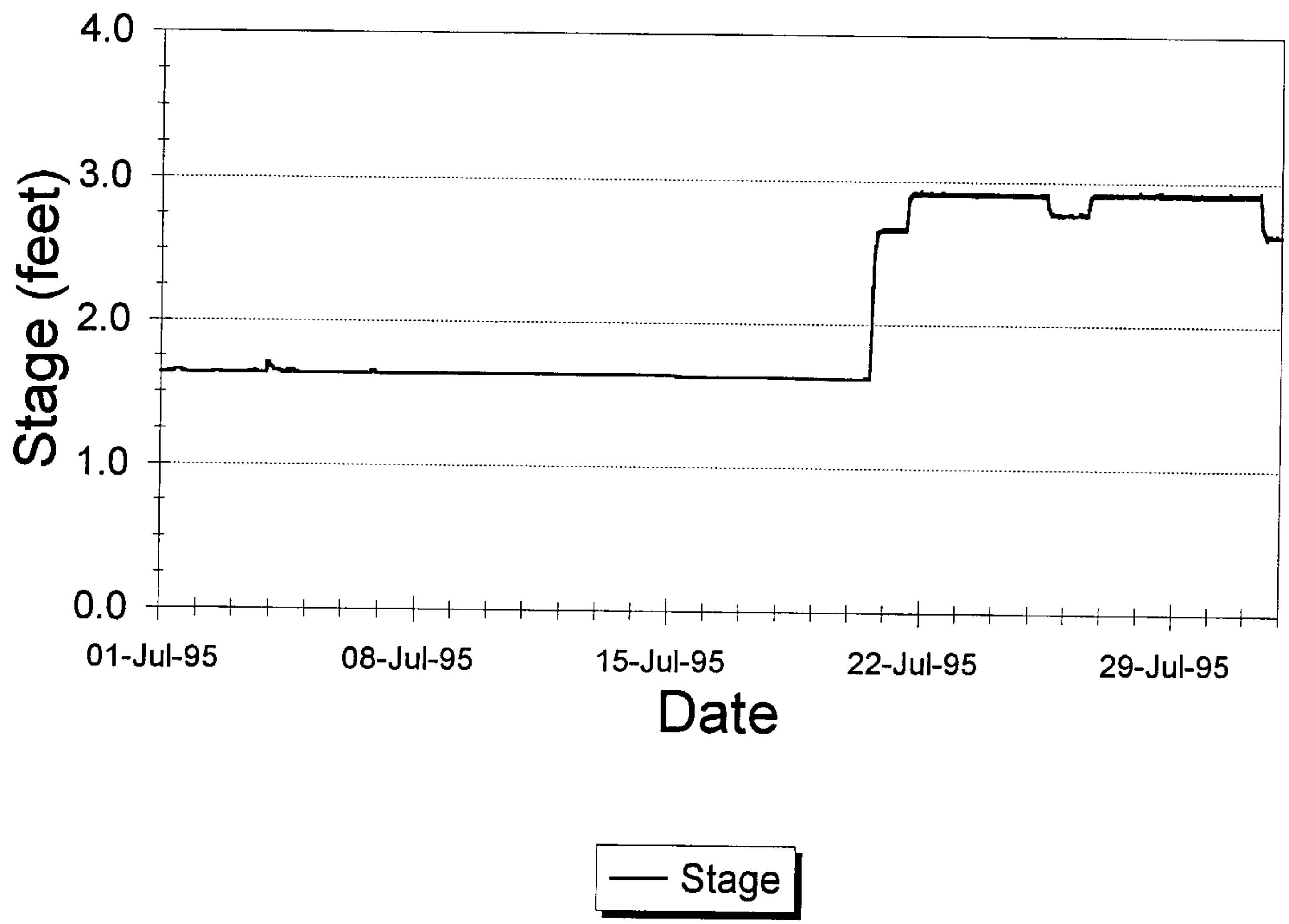
Data from July 1, 1995 to Aug 1, 1995

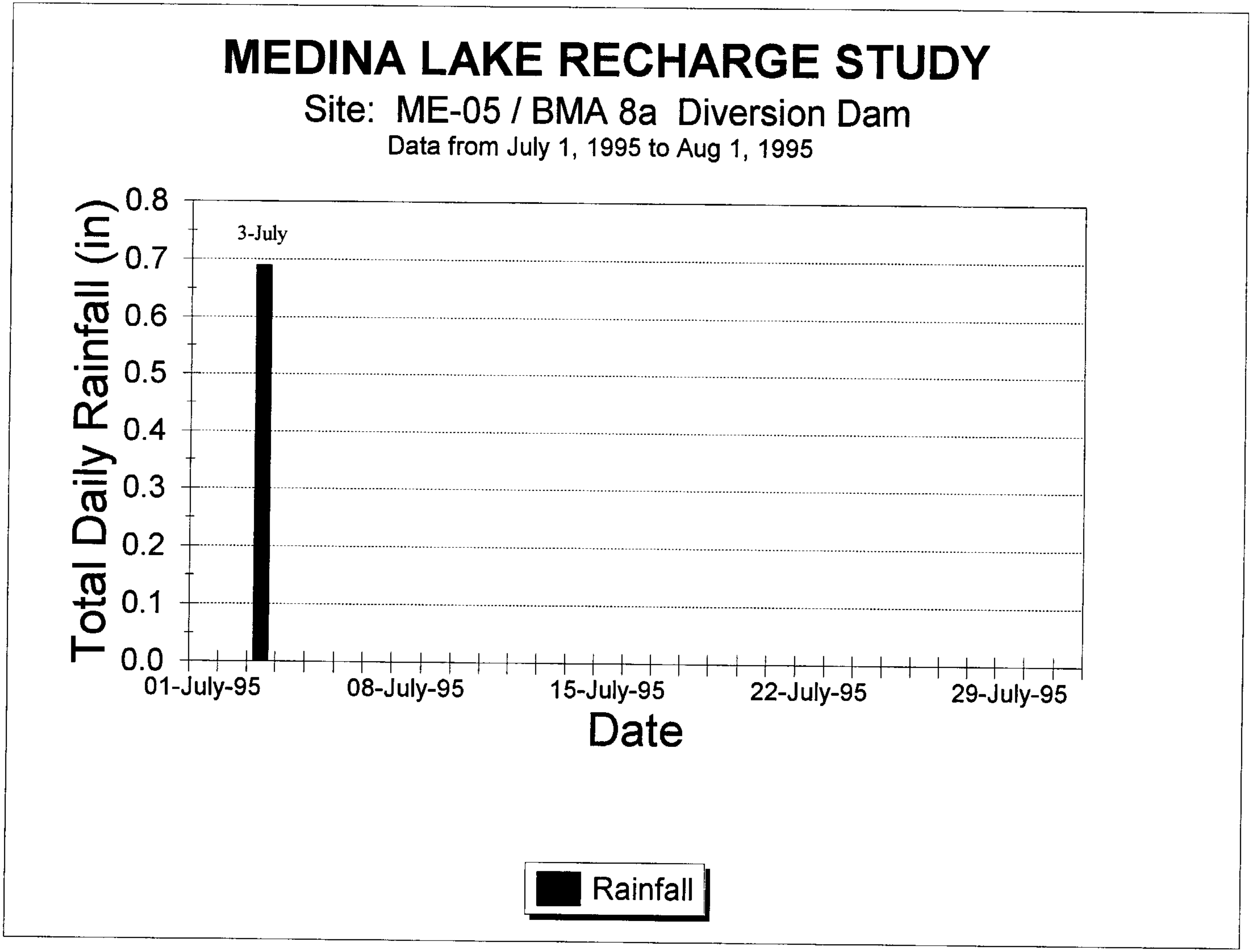


MEDINA LAKE RECHARGE STUDY

Site: BMA 7 Medina River Below Main

Data from July 1, 1995 to Aug 1, 1995

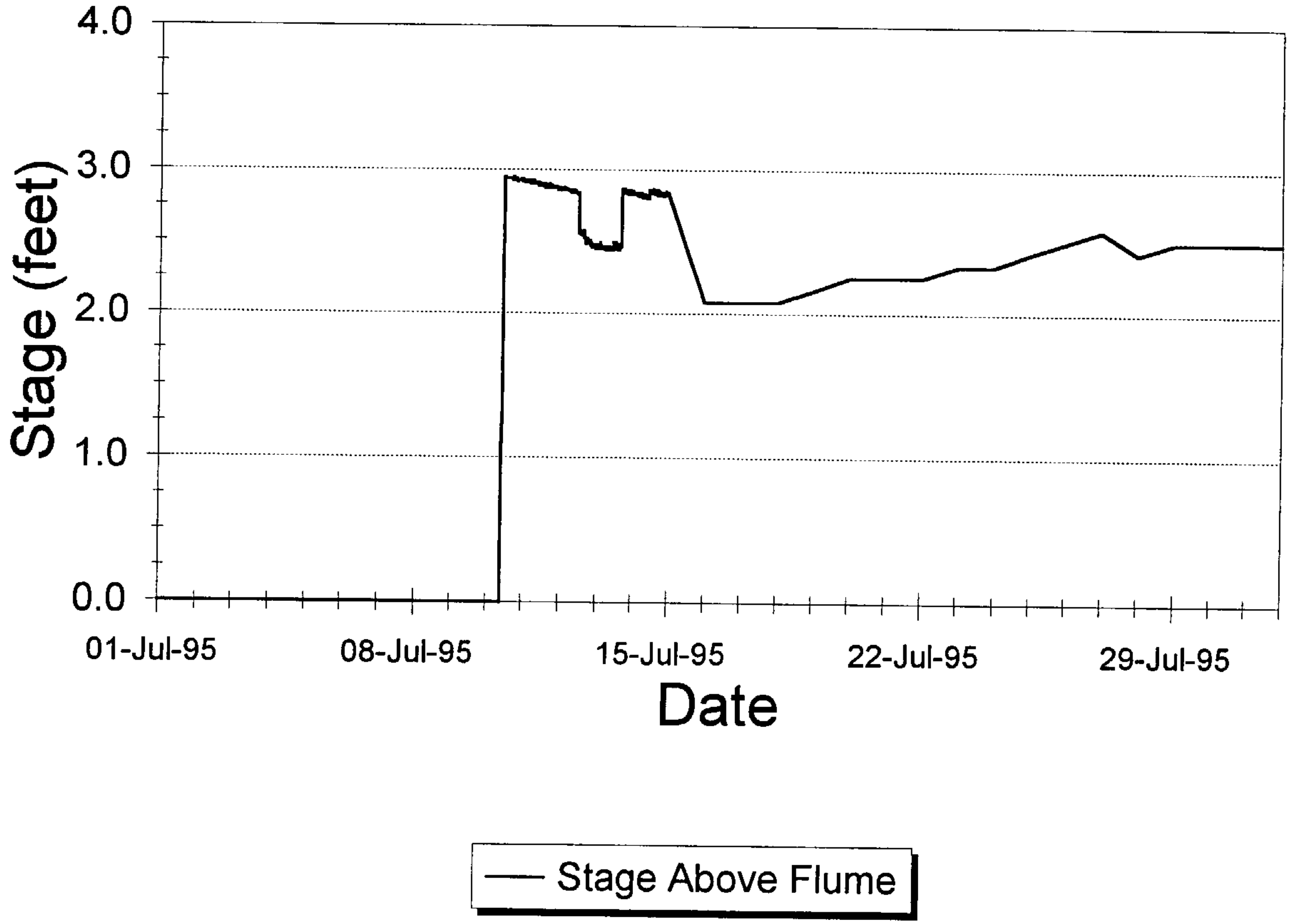


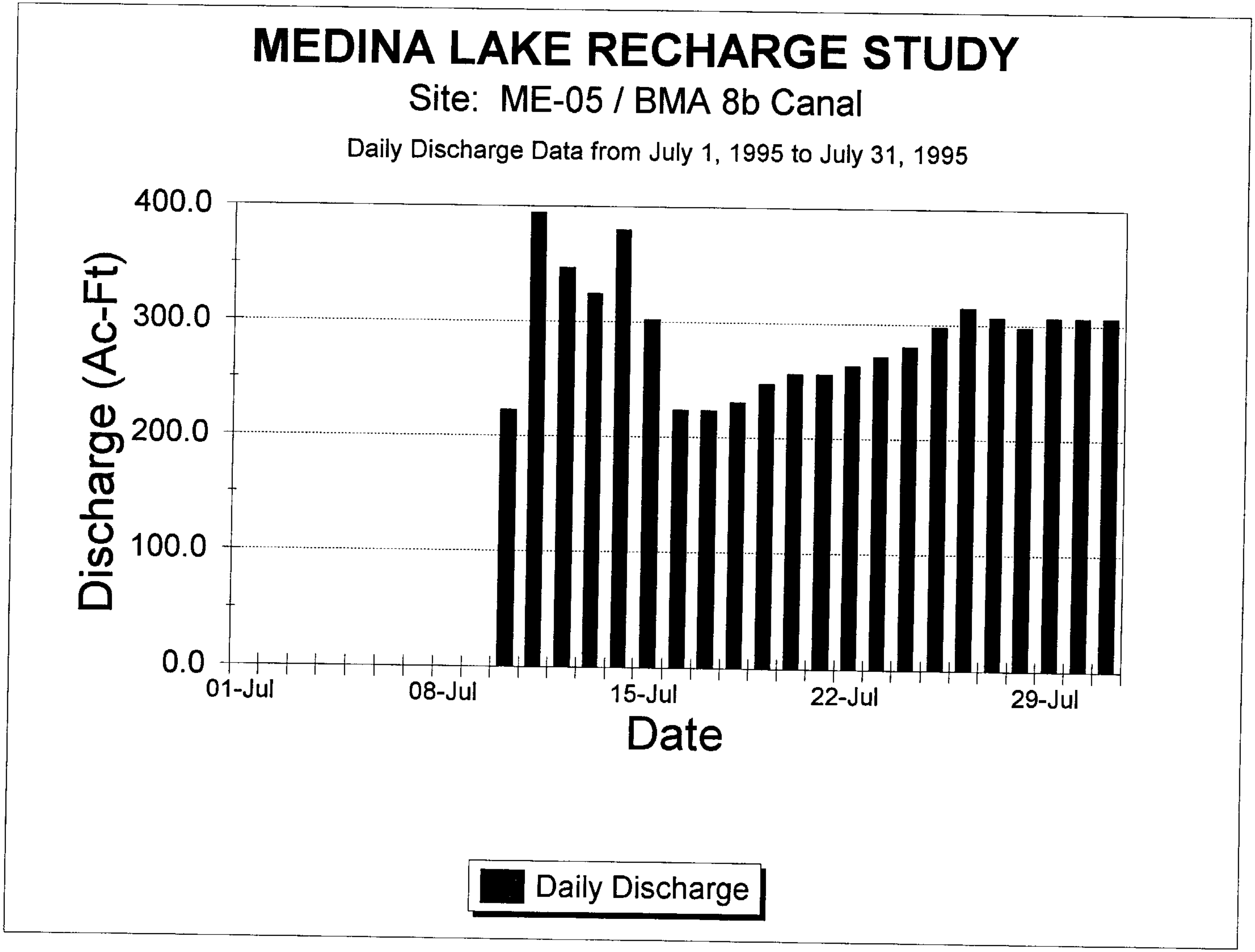

MEDINA LAKE RECHARGE STUDY
Site: ME-05 / BMA 8a Diversion Dam
Data from July 1, 1995 to Aug 1, 1995
Total Daily Rainfall (in)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
3-July
01-July-95
08-July-95
15-July-95
22-July-95
29-July-95
Date
Rainfall

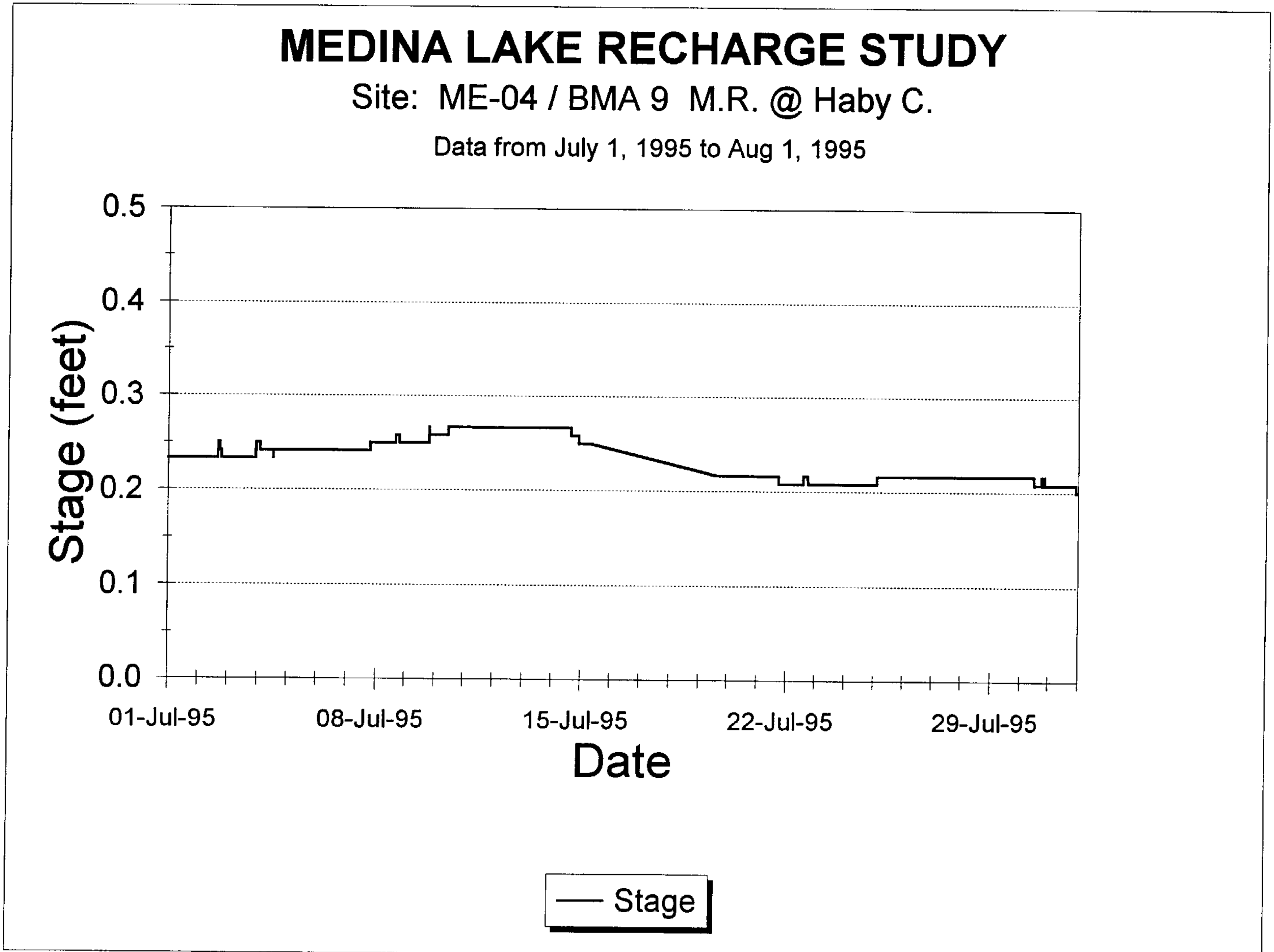
MEDINA LAKE RECHARGE STUDY

Site: ME-05 / BMA 8b Canal

Data from July 1, 1995 to Aug 1, 1995



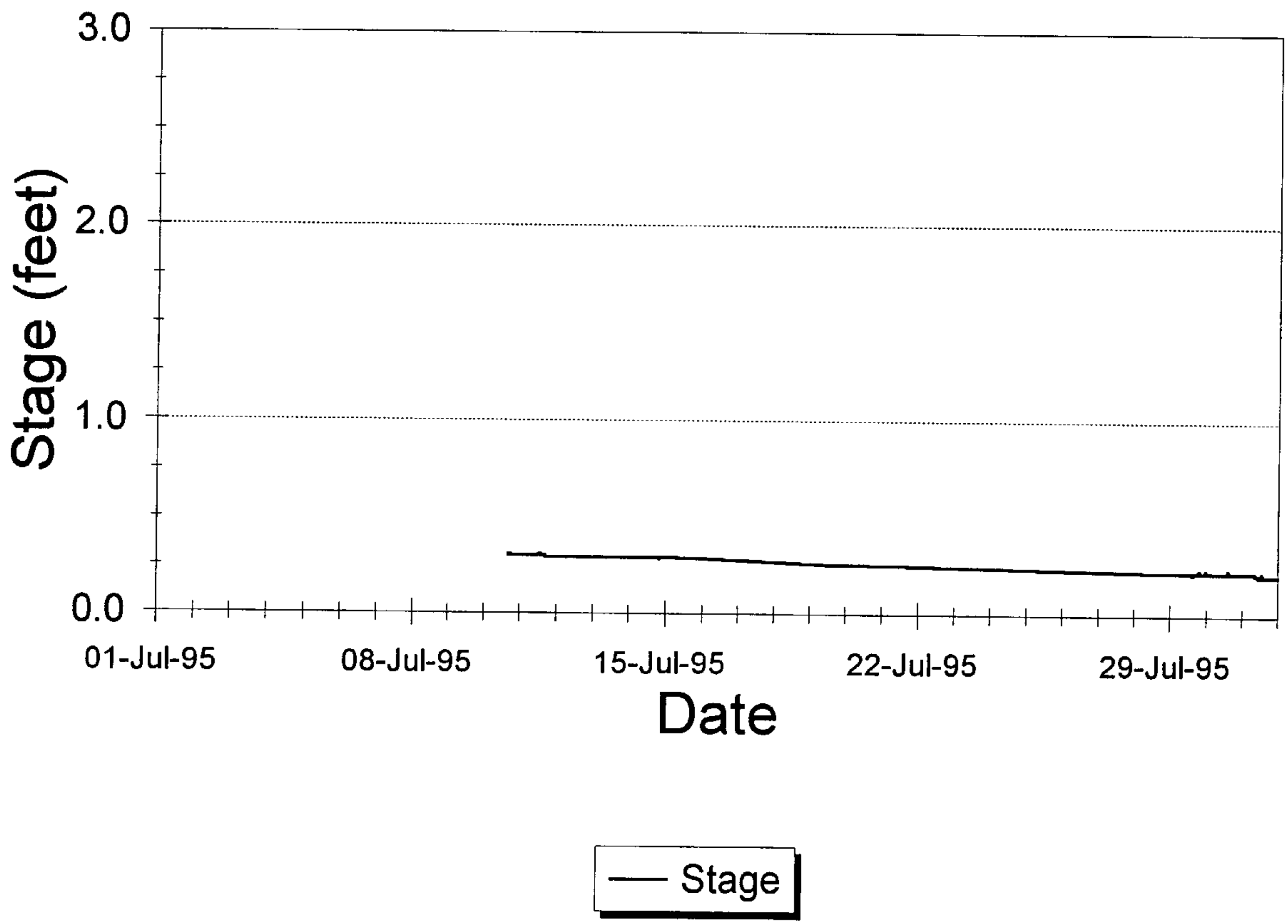

MEDINA LAKE RECHARGE STUDY
Site: ME-05 / BMA 8b Canal
Daily Discharge Data from July 1, 1995 to July 31, 1995
Discharge (Ac-Ft)
400.0
300.0
200.0
100.0
0.0
01-Jul
08-Jul
15-Jul
22-Jul
29-Jul
Date
Daily Discharge

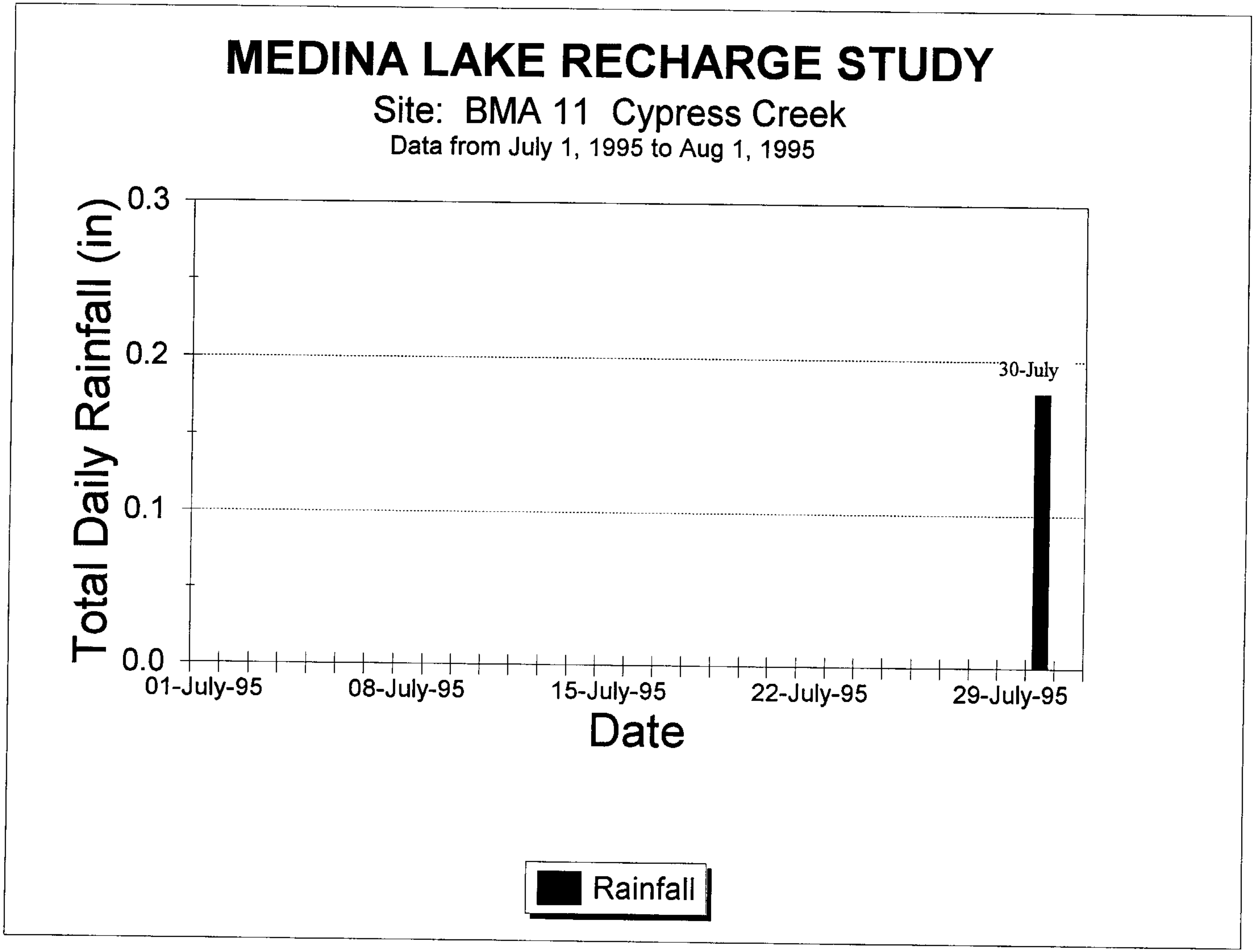

MEDINA LAKE RECHARGE STUDY
Site: ME-04 / BMA 9 M.R. @ Haby C.
Data from July 1, 1995 to Aug 1, 1995
Stage (feet)
0.5
0.4
0.3
0.2
0.1
0.0
01-Jul-95
08-Jul-95
15-Jul-95
22-Jul-95
29-Jul-95
Date
Stage

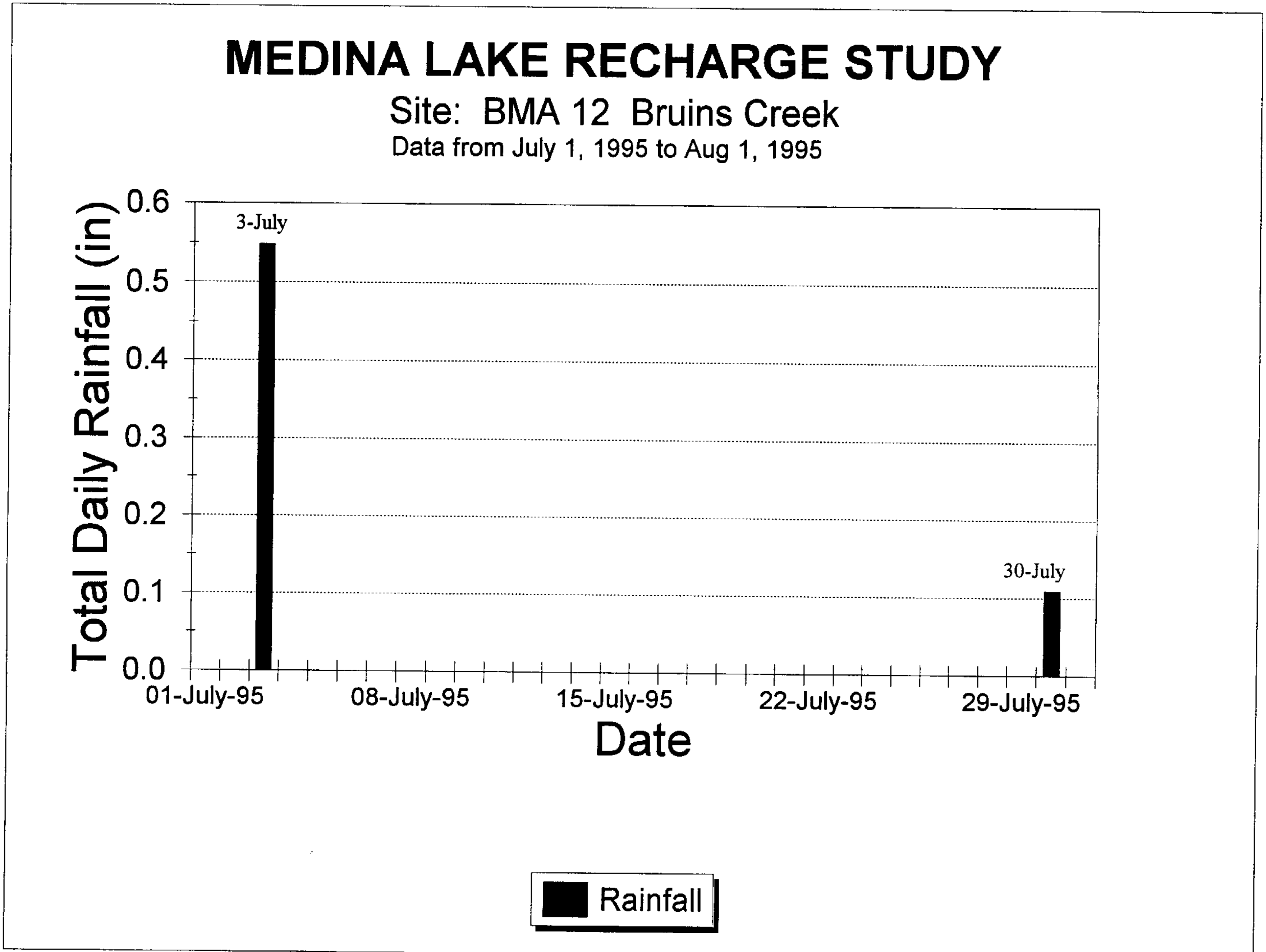
MEDINA LAKE RECHARGE STUDY

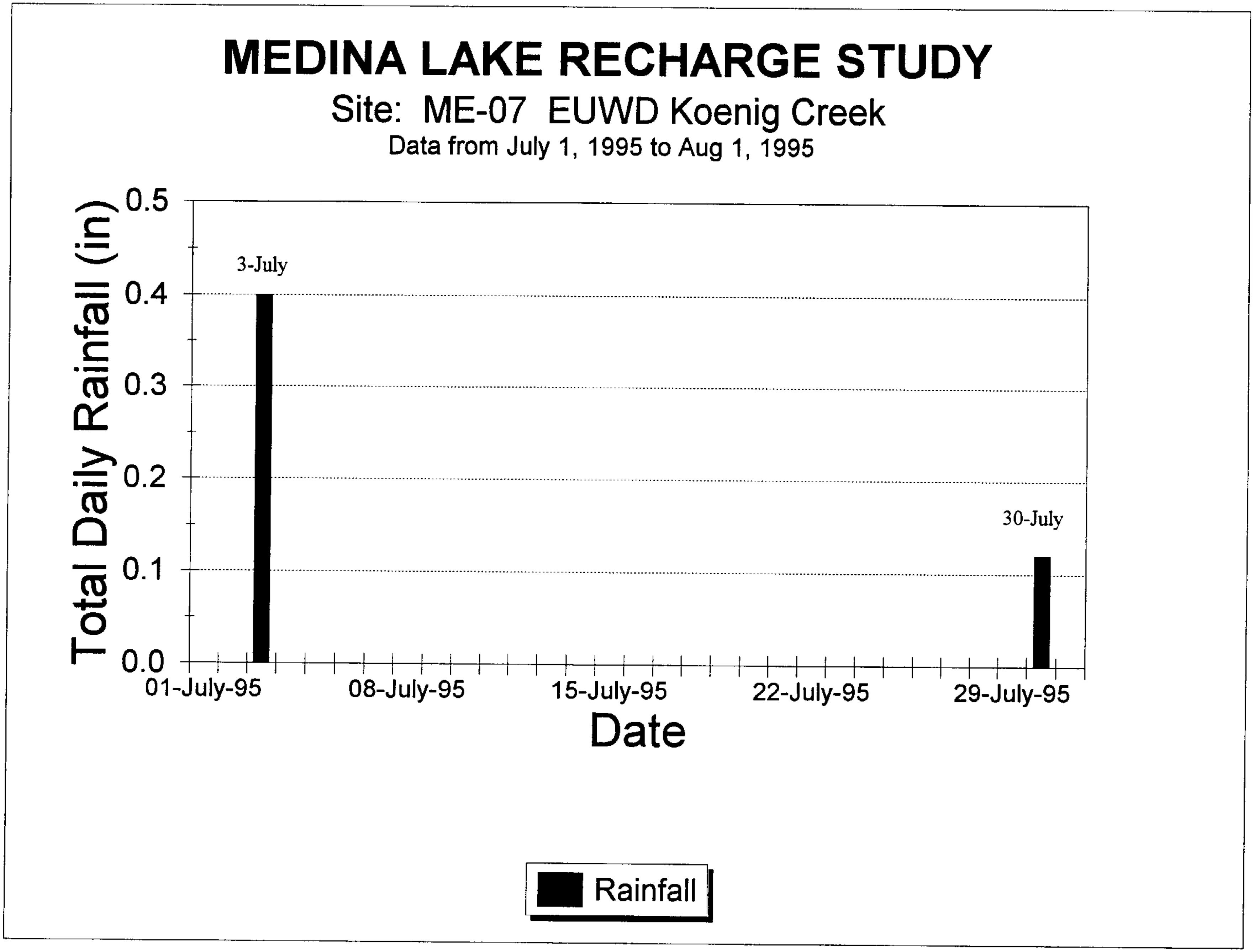
Site: BMA 11 Cypress Creek

Data from July 1, 1995 to Aug 1, 1995




MEDINA LAKE RECHARGE STUDY
Site: BMA 11 Cypress Creek
Data from July 1, 1995 to Aug 1, 1995
Total Daily Rainfall (in)
0.3
0.2
0.1
0.0
30-July
01-July-95
08-July-95
15-July-95
22-July-95
29-July-95
Date
Rainfall

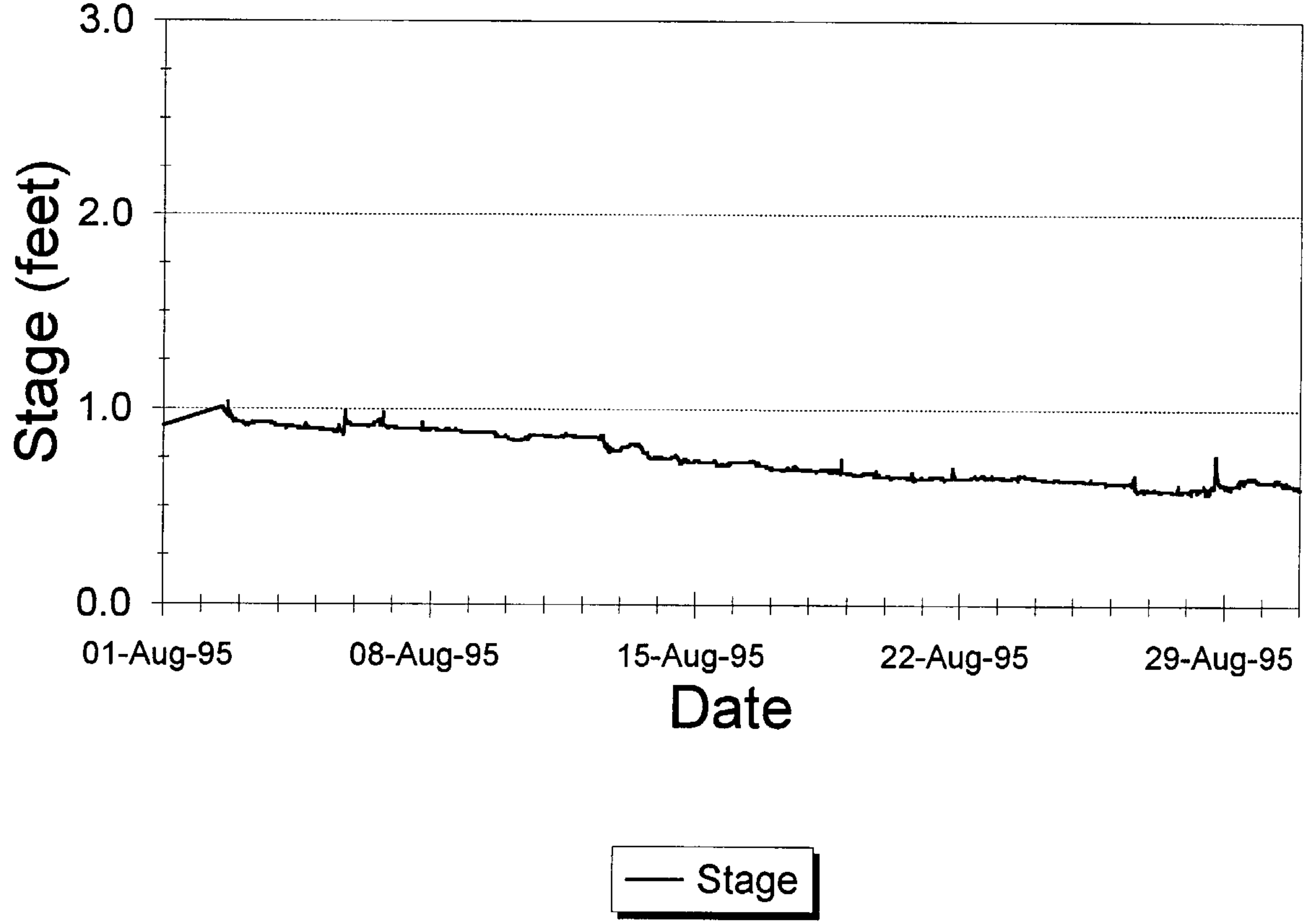

MEDINA LAKE RECHARGE STUDY
Site: BMA 12 Bruins Creek
Data from July 1, 1995 to Aug 1, 1995
Total Daily Rainfall (in)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
3-July
30-July
01-July-95
08-July-95
15-July-95
22-July-95
29-July-95
Date
Rainfall

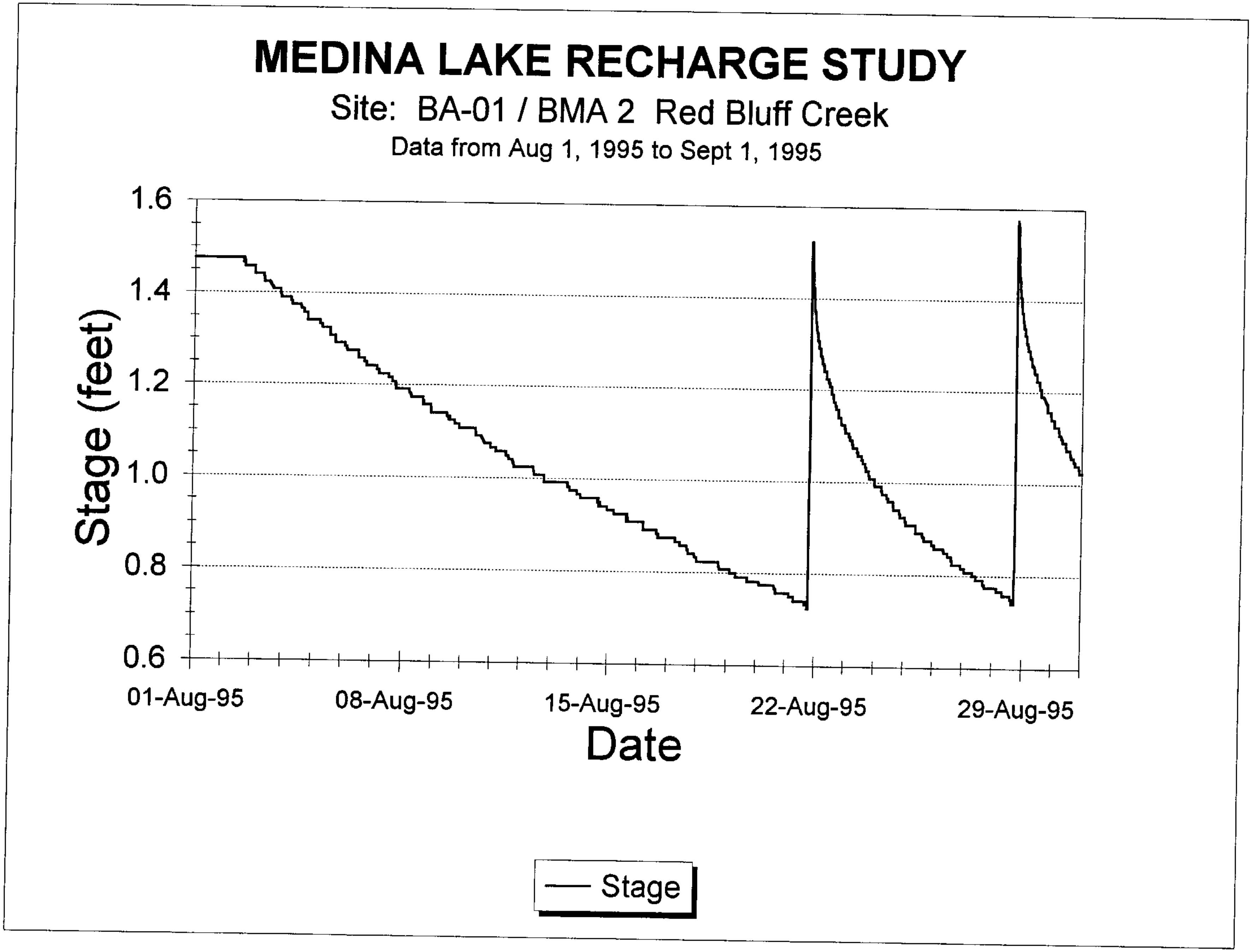

MEDINA LAKE RECHARGE STUDY
Site: ME-07 EUWD Koenig Creek
Data from July 1, 1995 to Aug 1, 1995
Total Daily Rainfall (in)
0.5
0.4
0.3
0.2
0.1
0.0
3-July
30-July
01-July-95
08-July-95
15-July-95
22-July-95
29-July-95
Date
Rainfall

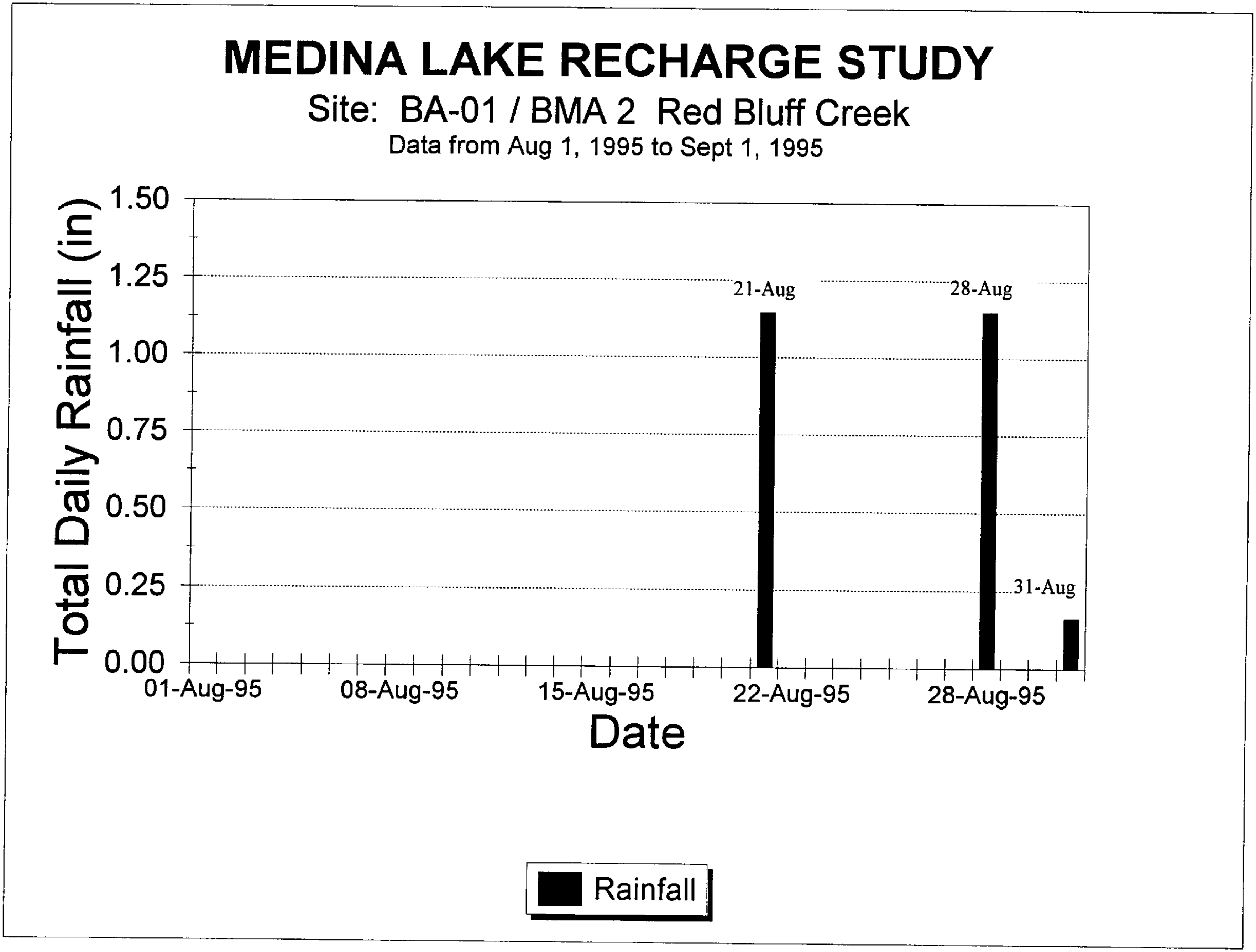
MEDINA LAKE RECHARGE STUDY

Site: BA-02 / BMA 1 English Crossing

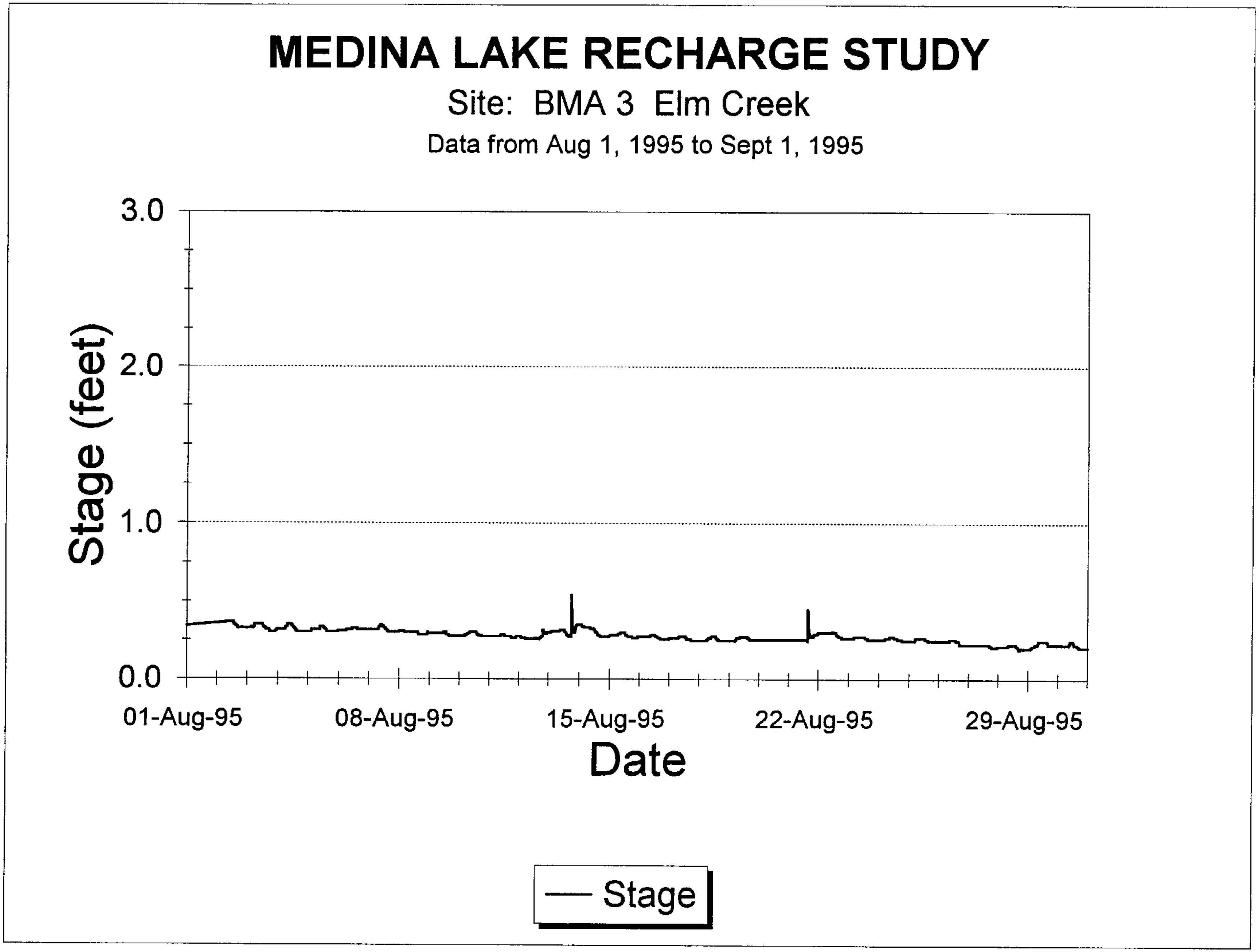
Data from Aug 1, 1995 to Sept 1, 1995




MEDINA LAKE RECHARGE STUDY
Site: BA-01 / BMA 2 Red Bluff Creek
Data from Aug 1, 1995 to Sept 1, 1995
Stage (feet)
1.6
1.4
1.2
1.0
0.8
0.6
01-Aug-95
08-Aug-95
15-Aug-95
22-Aug-95
29-Aug-95
Date
Stage



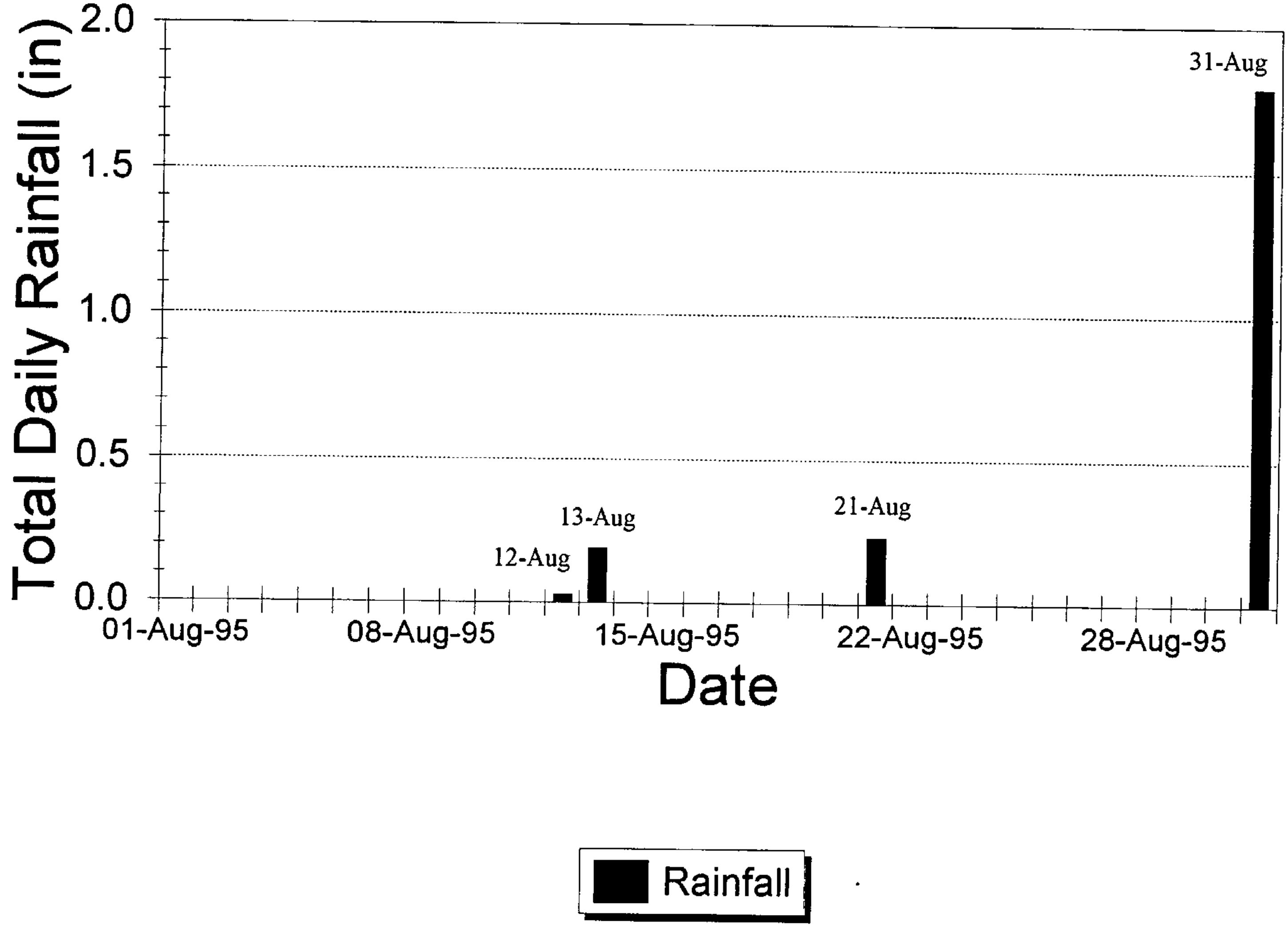
MEDINA LAKE RECHARGE STUDY
Site: BA-01 / BMA 2 Red Bluff Creek
Data from Aug 1, 1995 to Sept 1, 1995
Total Daily Rainfall (in)
1.50
1.25
1.00
0.75
0.50
0.25
0.00
21-Aug
28-Aug
31-Aug
01-Aug-95
08-Aug-95
15-Aug-95
22-Aug-95
28-Aug-95
Date
Rainfall


MEDINA LAKE RECHARGE STUDY
Site: BMA 3 Elm Creek
Data from Aug 1, 1995 to Sept 1, 1995
3.0
2.0
1.0
0.0
Stage (feet)
01-Aug-95
08-Aug-95
15-Aug-95
22-Aug-95
29-Aug-95
Date
Stage

MEDINA LAKE RECHARGE STUDY

Site: BMA 3 Elm Creek

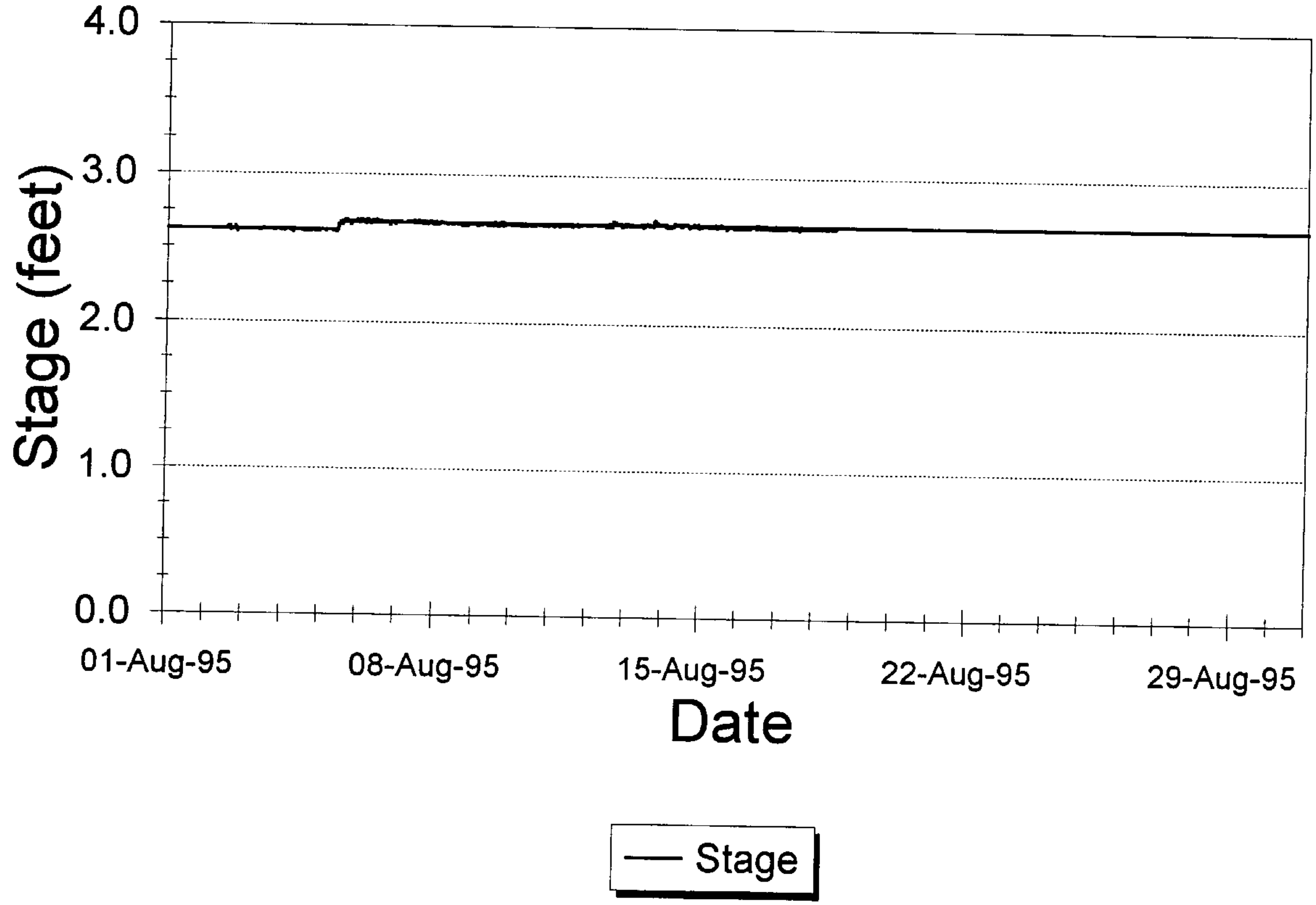
Data from Aug 1, 1995 to Sept 1, 1995

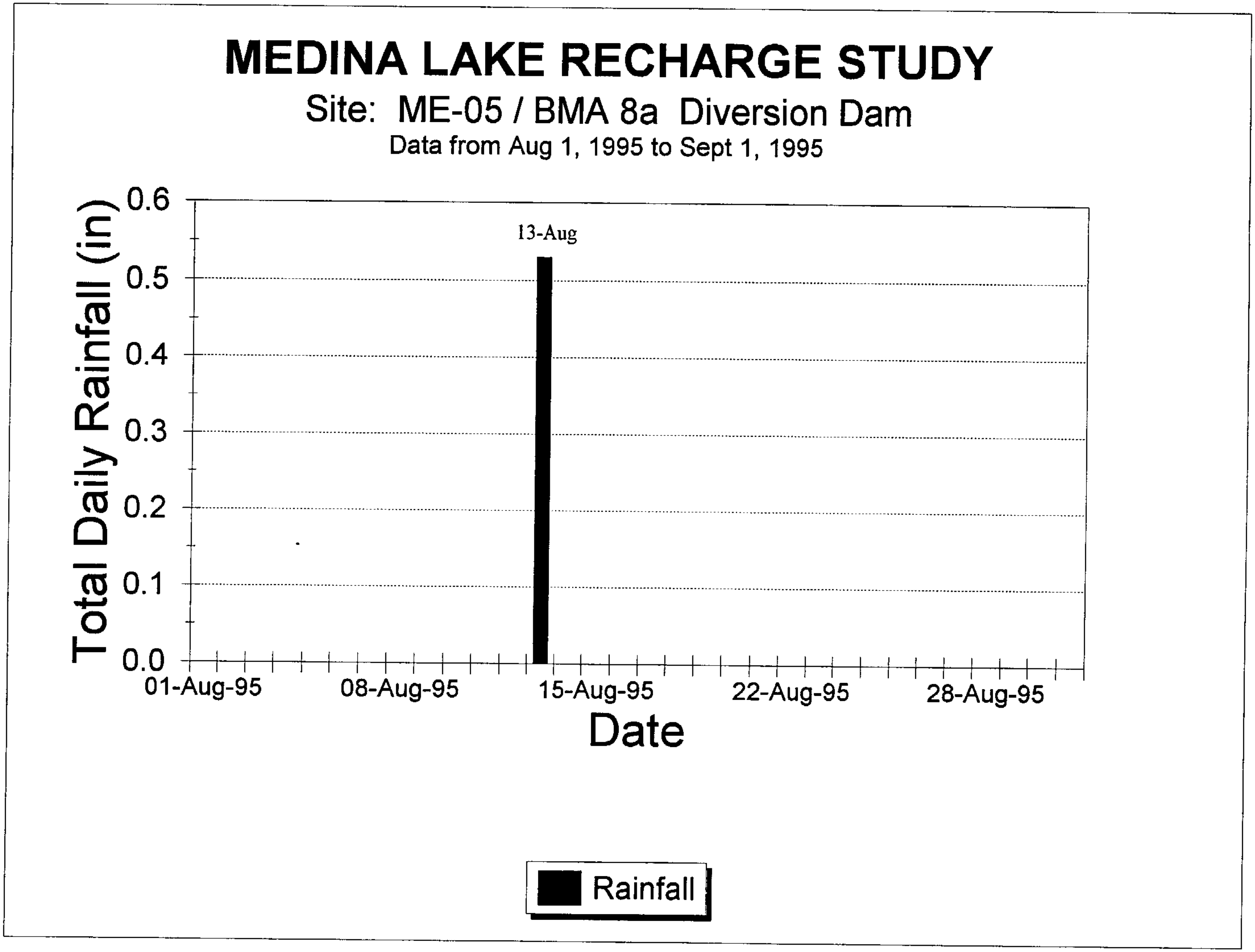


MEDINA LAKE RECHARGE STUDY

Site: BMA 7 M.R. Below Main

Data from Aug 1, 1995 to Sept 1, 1995

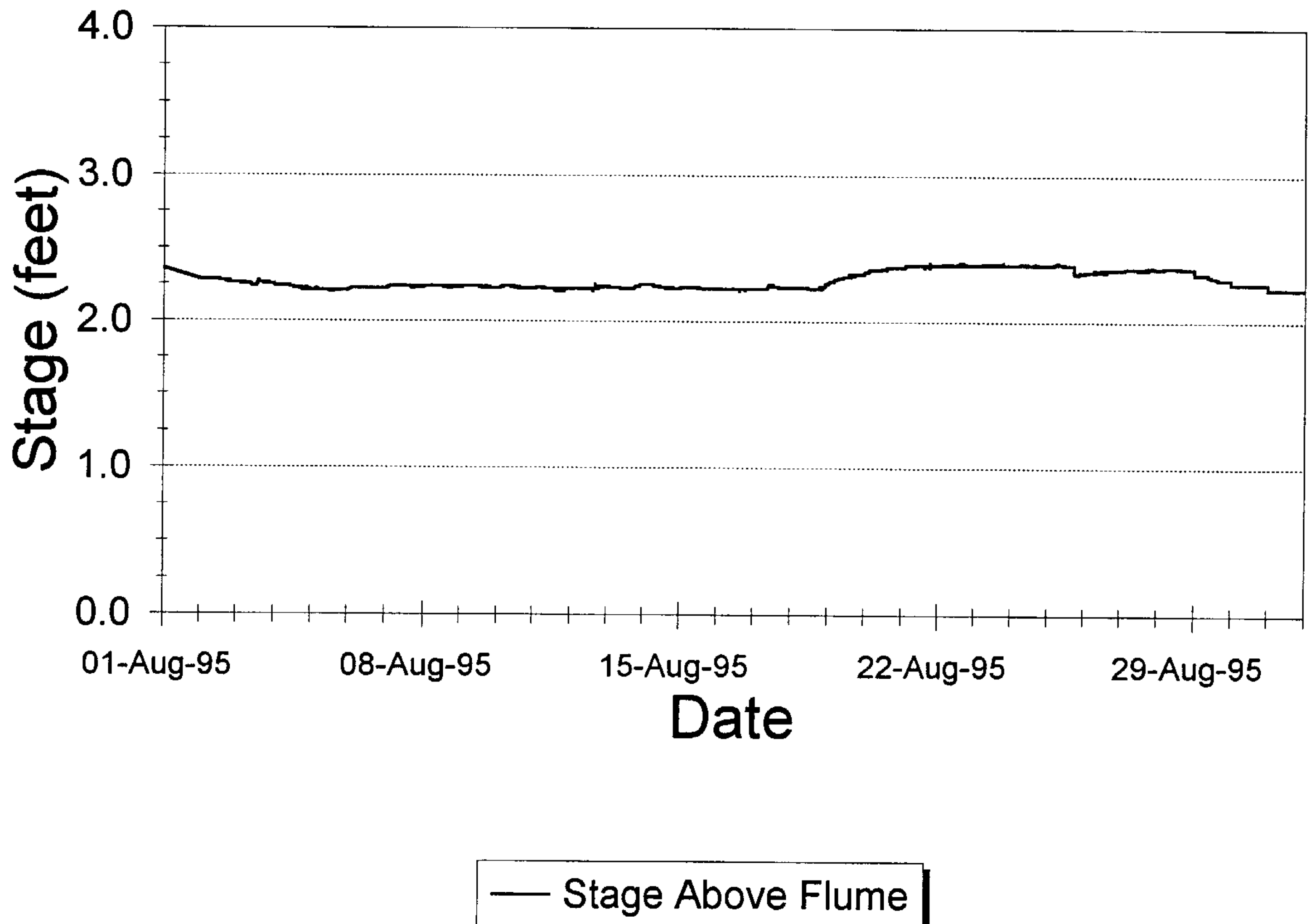



MEDINA LAKE RECHARGE STUDY
Site: ME-05 / BMA 8a Diversion Dam
Data from Aug 1, 1995 to Sept 1, 1995
Total Daily Rainfall (in)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
13-Aug
01-Aug-95
08-Aug-95
15-Aug-95
22-Aug-95
28-Aug-95
Date
Rainfall

MEDINA LAKE RECHARGE STUDY

Site: ME-05 / BMA 8b Canal

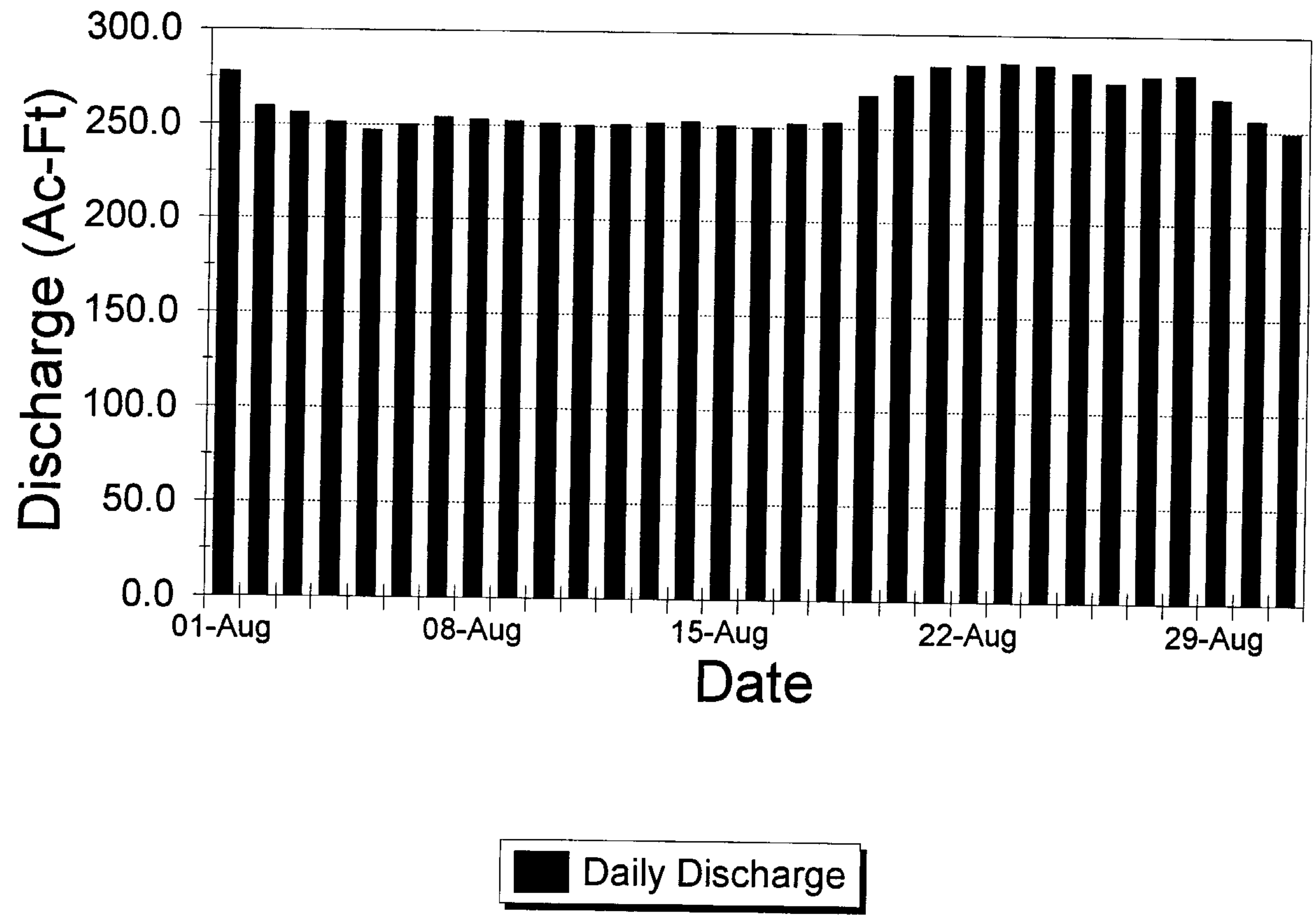
Data from Aug 1, 1995 to Sept 1, 1995



MEDINA LAKE RECHARGE STUDY

Site: ME-05 / BMA 8b Canal

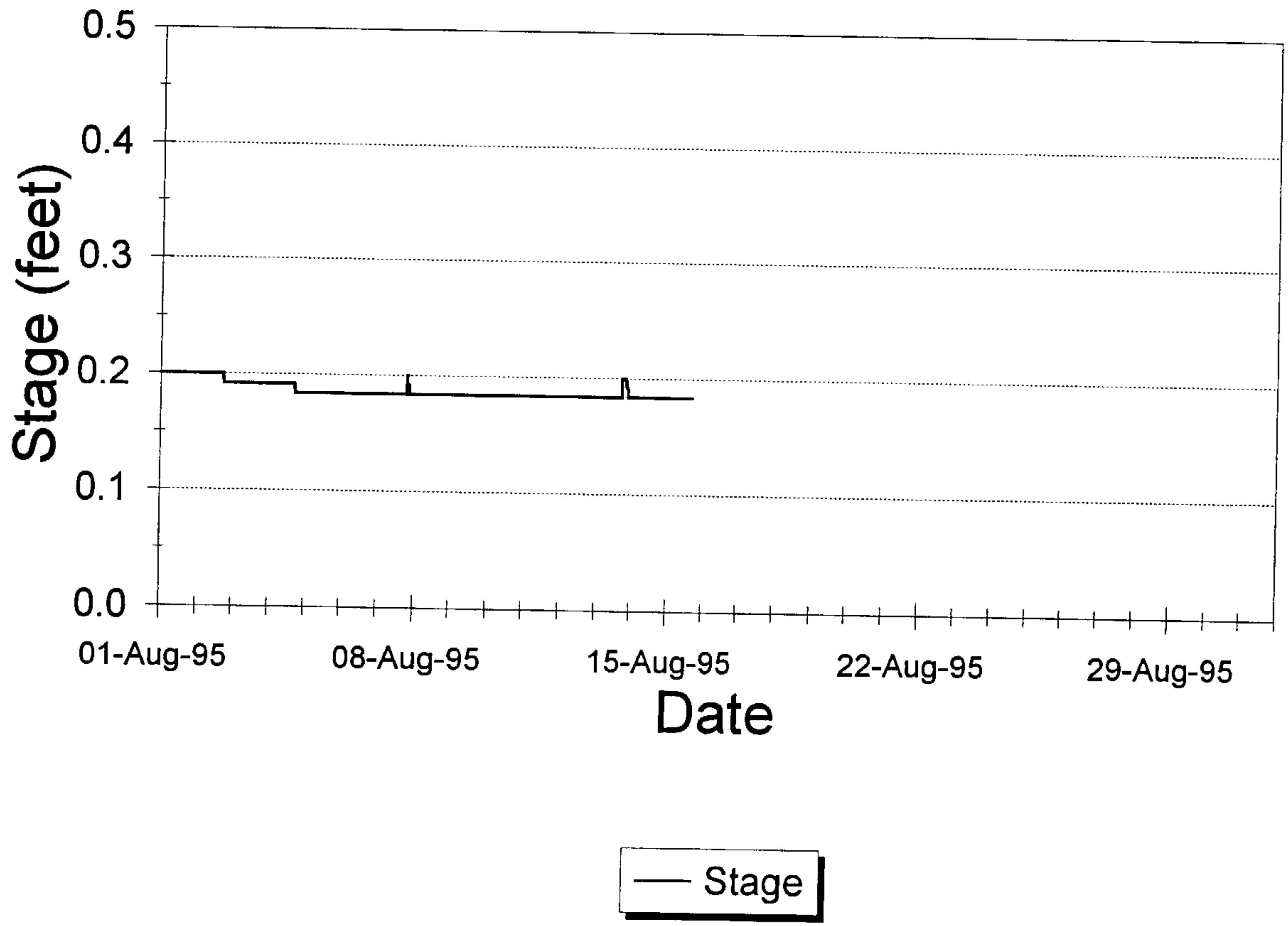
Daily Discharge Data from Aug 1, 1995 to Aug 31, 1995

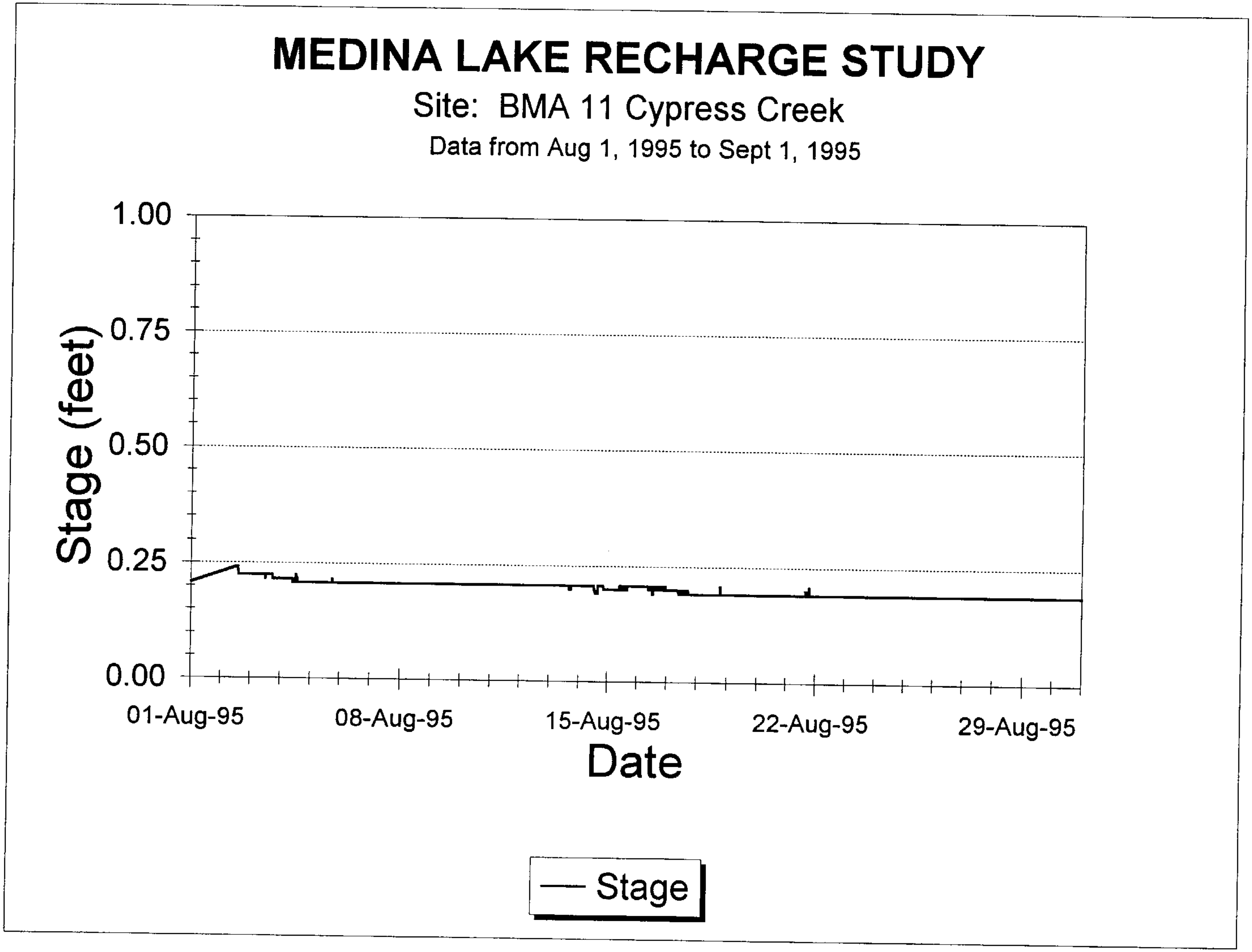


MEDINA LAKE RECHARGE STUDY

Site: ME-04 / BMA 9 M.R. @ Haby C.

Data from Aug 1, 1995 to Sept 1, 1995

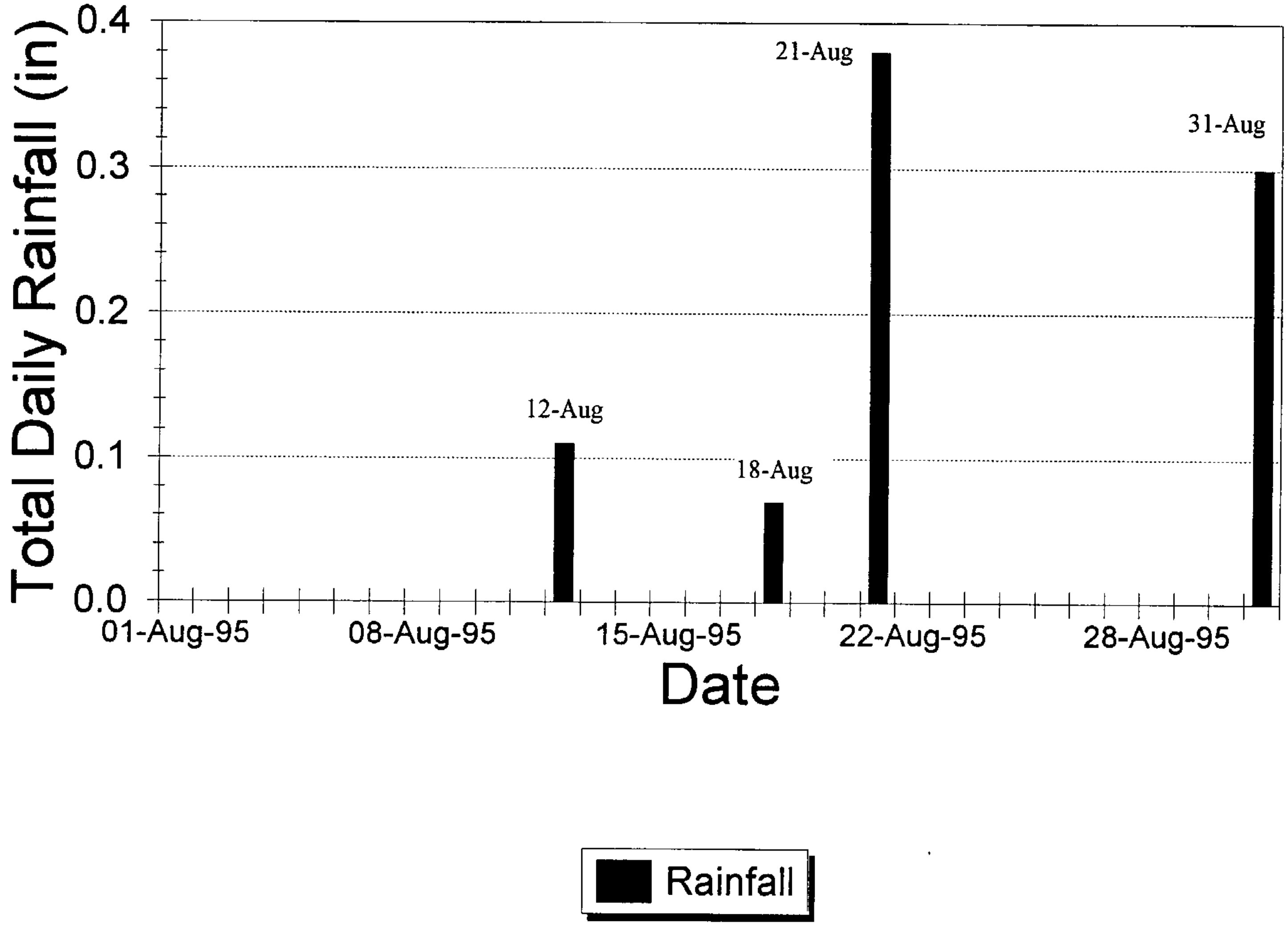


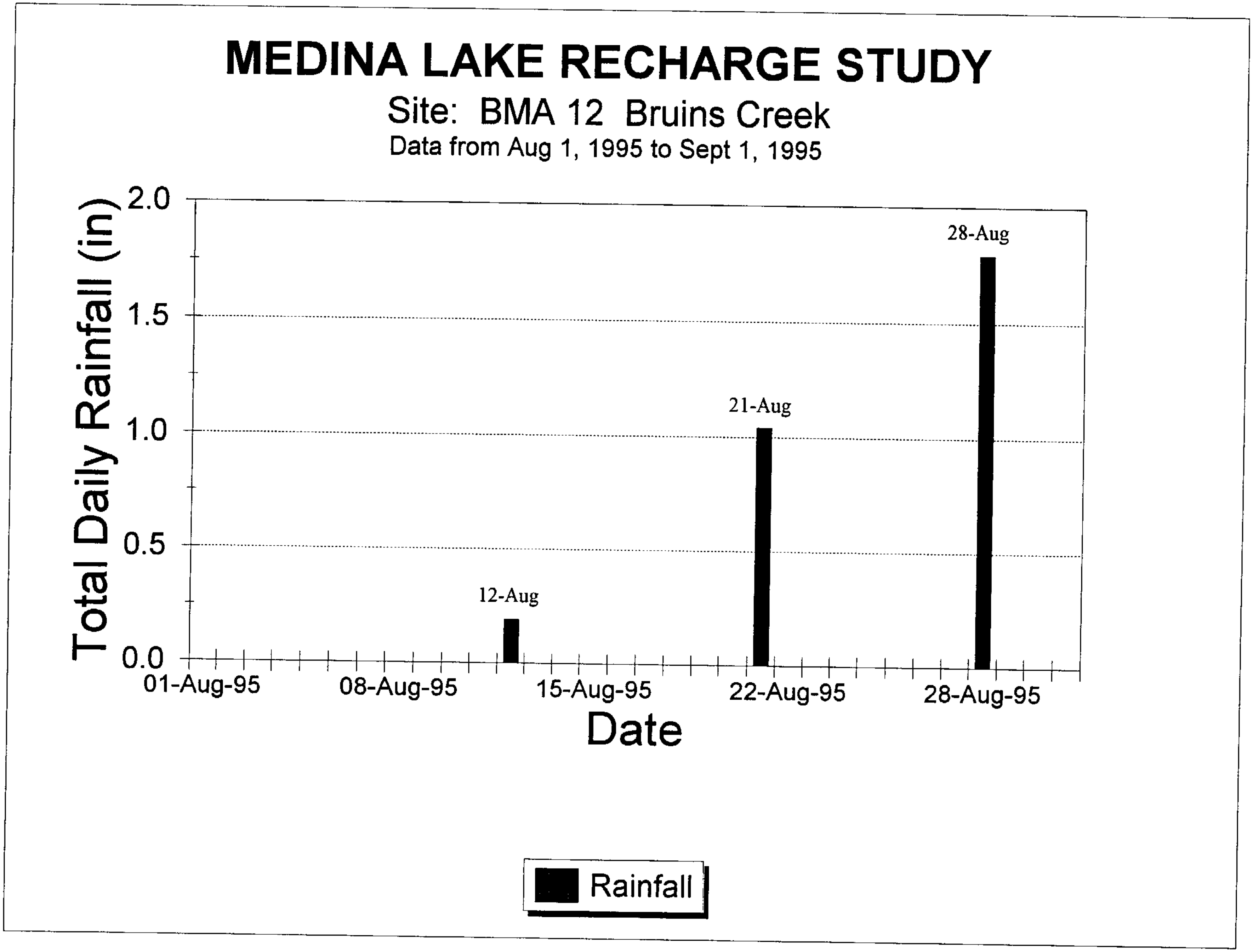

MEDINA LAKE RECHARGE STUDY
Site: BMA 11 Cypress Creek
Data from Aug 1, 1995 to Sept 1, 1995
1.00
0.75
0.50
0.25
0.00
Stage (feet)
01-Aug-95
08-Aug-95
15-Aug-95
22-Aug-95
29-Aug-95
Date
Stage

MEDINA LAKE RECHARGE STUDY

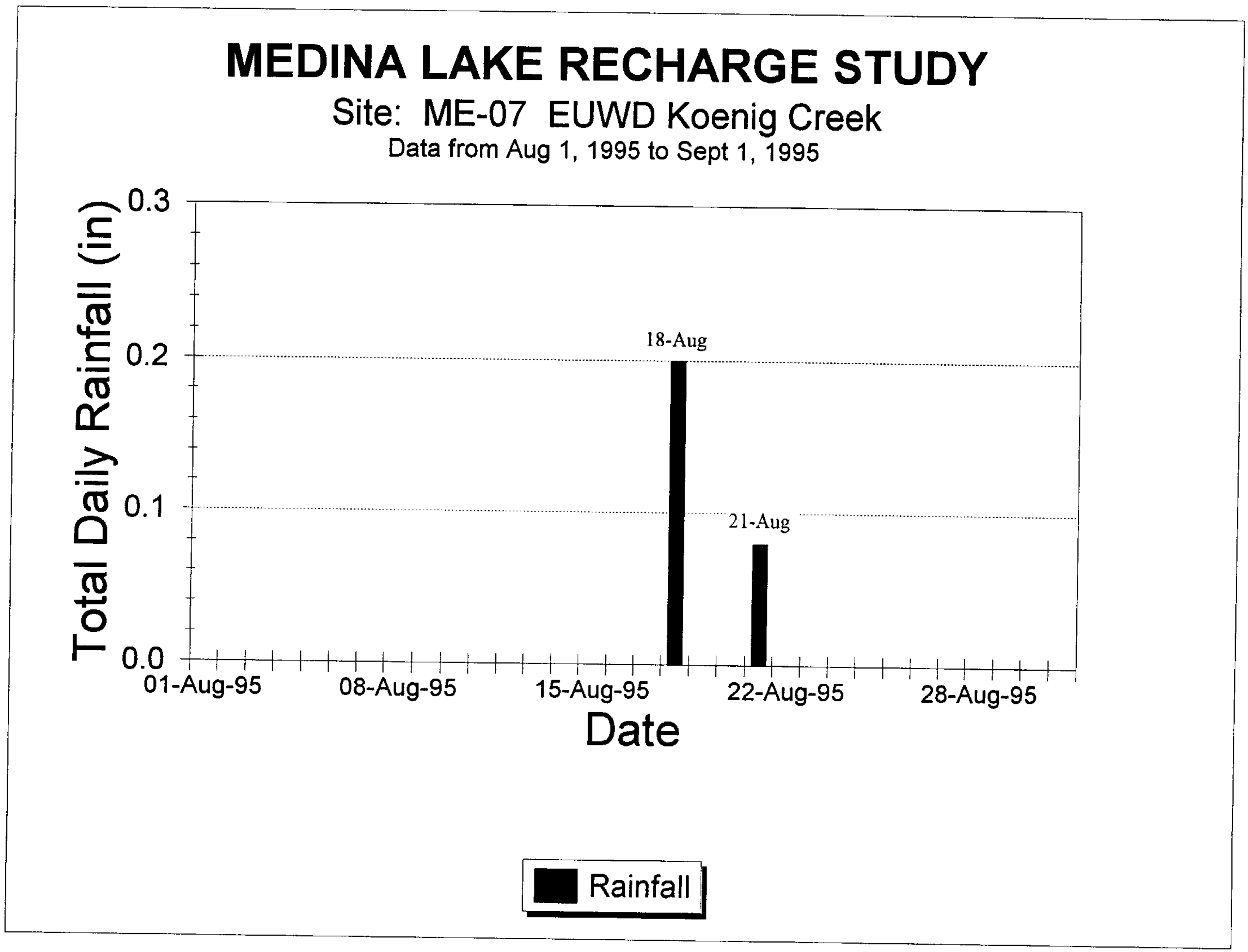
Site: BMA 11 Cypress Creek

Data from Aug 1, 1995 to Sept 1, 1995





MEDINA LAKE RECHARGE STUDY
Site: BMA 12 Bruins Creek
Data from Aug 1, 1995 to Sept 1, 1995
Total Daily Rainfall (in)
2.0
1.5
1.0
0.5
0.0
12-Aug
21-Aug
28-Aug
01-Aug-95
08-Aug-95
15-Aug-95
22-Aug-95
28-Aug-95
Date
Rainfall


MEDINA LAKE RECHARGE STUDY
Site: ME-07 EUWD Koenig Creek
Data from Aug 1, 1995 to Sept 1, 1995
Total Daily Rainfall (in)
0.3
0.2
0.1
0.0
18-Aug
21-Aug
01-Aug-95
08-Aug-95
15-Aug-95
22-Aug-95
28-Aug-95
Date
Rainfall

ATTACHMENT D

BATHYMETRIC SURVEY

TEXAS WATER DEVELOPMENT BOARD
RESERVOIR AREA TABLE

DRAFT

Oct 24 1995

MEDINA LAKE JULY 1995 SURVEY

AREA IN ACRES — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
933										
934										
935										
936										
937										
938										
939										
940										
941										
942										
943										
944										
945										
946										
947										
948										
949										
950										
951			1	3	5	6	8	10	11	12
952	14	15	16	18	20	22	24	25	27	28
953	30	31	32	34	35	36	37	38	39	40
954	41	42	42	43	44	45	46	47	50	52
955	55	57	58	60	62	63	65	66	68	69
956	71	72	73	75	76	77	79	80	81	82
957	83	84	85	86	87	88	88	89	90	91
958	92	93	94	95	96	97	98	99	100	102
959	103	104	105	106	107	108	109	110	111	113
960	114	115	116	118	119	120	121	122	123	124
961	126	127	128	130	131	132	134	135	136	138
962	139	140	141	143	144	145	146	147	149	150
963	151	152	154	155	157	158	160	161	163	164
964	165	167	168	170	171	172	174	175	176	178
965	180	182	184	185	187	189	190	192	194	196
966	197	199	201	203	205	207	209	211	213	215
967	217	220	222	225	227	230	232	235	238	240
968	243	245	248	250	253	255	258	260	263	266
969	268	271	274	277	279	282	285	288	291	294
970	297	300	303	306	309	312	314	317	320	322
971	325	327	329	332	334	337	339	342	344	347
972	350	352	355	357	360	362	365	368	371	373
973	376	379	381	384	386	389	392	394	397	400
974	402	405	407	410	412	415	417	420	422	425
975	428	430	434	437	440	443	446	450	454	457
976	461	465	469	472	476	480	483	487	491	495
977	499	503	507	512	516	521	527	532	537	541
978	545	548	551	555	558	561	564	567	570	573
979	576	579	582	584	587	590	593	595	598	601
980	604	607	610	613	616	619	622	625	628	630
981	633	636	639	641	644	647	649	652	655	657

MEDINA LAKE JULY 1995 SURVEY

AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
982	660	662	665	667	670	673	675	677	680	682
983	685	687	690	692	694	697	699	702	704	706
984	709	711	714	716	719	721	724	727	729	732
985	735	737	740	742	745	748	750	753	756	759
986	762	765	768	771	773	776	778	781	783	785
987	788	790	793	795	797	800	802	804	807	809
988	812	814	817	819	822	824	827	830	832	835
989	838	840	843	846	849	851	854	857	860	863
990	866	869	872	875	878	881	884	887	890	893
991	897	900	903	907	910	914	917	921	925	928
992	931	935	938	941	944	947	950	953	956	959
993	962	965	967	970	973	976	978	981	984	987
994	989	992	995	997	1000	1002	1005	1008	1010	1013
995	1016	1018	1021	1023	1026	1029	1031	1034	1036	1039
996	1042	1044	1047	1050	1053	1056	1058	1061	1064	1067
997	1070	1072	1075	1078	1080	1083	1086	1088	1091	1094
998	1096	1099	1102	1104	1107	1110	1113	1115	1118	1121
999	1124	1127	1129	1132	1135	1138	1141	1144	1147	1150
1,000	1153	1155	1158	1161	1164	1167	1170	1173	1177	1180
1,001	1183	1186	1189	1192	1195	1198	1202	1205	1208	1211
1,002	1214	1217	1221	1224	1227	1230	1233	1236	1239	1242
1,003	1246	1249	1252	1255	1258	1261	1264	1268	1271	1274
1,004	1277	1280	1283	1286	1290	1293	1296	1299	1302	1306
1,005	1309	1312	1315	1319	1322	1325	1328	1331	1334	1338
1,006	1341	1344	1347	1350	1353	1357	1360	1363	1366	1369
1,007	1373	1376	1379	1382	1386	1389	1392	1396	1399	1403
1,008	1406	1410	1413	1417	1421	1424	1428	1432	1435	1439
1,009	1443	1447	1451	1455	1459	1464	1468	1472	1476	1481
1,010	1486	1491	1496	1500	1505	1510	1515	1519	1524	1528
1,011	1533	1537	1542	1547	1551	1556	1560	1565	1569	1574
1,012	1579	1583	1588	1593	1597	1602	1607	1612	1616	1621
1,013	1626	1630	1635	1639	1644	1649	1653	1658	1662	1667
1,014	1671	1676	1680	1685	1689	1694	1699	1703	1708	1713
1,015	1717	1722	1727	1732	1736	1741	1746	1751	1756	1761
1,016	1766	1771	1776	1781	1785	1790	1795	1800	1805	1810
1,017	1815	1820	1824	1829	1834	1839	1844	1849	1854	1859
1,018	1864	1869	1874	1879	1884	1890	1895	1900	1906	1911
1,019	1917	1922	1928	1934	1940	1946	1952	1959	1965	1971
1,020	1980	1987	1993	1999	2005	2011	2016	2022	2027	2032
1,021	2038	2043	2048	2053	2058	2063	2068	2074	2079	2084
1,022	2090	2095	2100	2105	2110	2115	2120	2125	2131	2136
1,023	2141	2147	2152	2157	2162	2167	2172	2177	2183	2188
1,024	2193	2198	2203	2208	2213	2218	2224	2229	2234	2240
1,025	2245	2251	2256	2261	2267	2272	2278	2283	2289	2294
1,026	2300	2306	2311	2317	2323	2329	2335	2341	2348	2354
1,027	2361	2368	2376	2383	2390	2397	2404	2411	2419	2425
1,028	2433	2440	2447	2455	2462	2469	2476	2484	2491	2498
1,029	2505	2512	2519	2526	2533	2540	2547	2555	2561	2568
1,030	2580	2586	2593	2599	2605	2611	2617	2623	2629	2635
1,031	2641	2647	2653	2659	2664	2670	2676	2682	2687	2693

MEDINA LAKE JULY 1995 SURVEY

AREA IN ACRES

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1,032	2699	2705	2710	2716	2722	2727	2733	2739	2745	2750
1,033	2756	2761	2766	2772	2777	2783	2788	2793	2799	2804
1,034	2810	2815	2820	2826	2831	2837	2842	2848	2853	2859
1,035	2865	2870	2876	2881	2886	2892	2897	2903	2908	2914
1,036	2919	2925	2930	2936	2941	2947	2953	2959	2964	2970
1,037	2976	2983	2989	2995	3001	3007	3013	3019	3025	3031
1,038	3037	3044	3050	3056	3062	3068	3075	3081	3087	3094
1,039	3100	3106	3112	3119	3125	3132	3139	3145	3152	3158
1,040	3165	3172	3178	3185	3192	3198	3205	3212	3218	3225
1,041	3232	3239	3247	3254	3262	3269	3277	3284	3291	3299
1,042	3306	3313	3321	3328	3336	3344	3351	3359	3367	3374
1,043	3382	3389	3397	3405	3412	3419	3427	3434	3442	3449
1,044	3456	3464	3471	3479	3486	3493	3501	3508	3516	3524
1,045	3531	3539	3547	3555	3563	3571	3579	3587	3595	3604
1,046	3613	3622	3631	3640	3648	3657	3666	3675	3684	3693
1,047	3702	3711	3719	3728	3736	3745	3753	3762	3771	3779
1,048	3788	3797	3805	3814	3822	3830	3839	3847	3855	3863
1,049	3871	3879	3888	3896	3905	3914	3922	3931	3939	3948
1,050	3958	3967	3975	3984	3992	4000	4009	4018	4026	4035
1,051	4044	4053	4062	4071	4081	4090	4099	4108	4117	4127
1,052	4136	4146	4155	4165	4175	4185	4195	4206	4219	4235
1,053	4254	4288	4295	4302	4308	4314	4320	4325	4331	4337
1,054	4343	4349	4355	4361	4367	4373	4379	4385	4391	4397
1,055	4404	4410	4416	4422	4428	4434	4440	4446	4452	4458
1,056	4464	4470	4476	4482	4488	4494	4500	4506	4512	4518
1,057	4524	4530	4536	4542	4548	4554	4560	4566	4573	4579
1,058	4585	4591	4597	4603	4609	4615	4621	4627	4634	4640
1,059	4646	4652	4658	4664	4670	4676	4683	4689	4695	4701
1,060	4735	4741	4747	4754	4760	4766	4772	4779	4785	4791
1,061	4798	4804	4810	4817	4823	4829	4836	4842	4849	4855
1,062	4861	4868	4874	4880	4887	4893	4900	4906	4913	4919
1,063	4926	4932	4939	4945	4952	4958	4965	4971	4978	4984
1,064	4993	5001	5009	5016	5024	5032	5039	5047	5054	5062
1,065	5070	5077	5084	5091	5098	5105	5113	5120	5127	5134
1,066	5141	5148	5155	5162	5169	5177	5184	5191	5198	5205
1,067	5214	5221	5228	5235	5243	5250	5257	5264	5271	5278
1,068	5301	5309	5317	5325	5333	5341	5349	5357	5365	5373
1,069	5380	5388	5396	5403	5411	5418	5426	5433	5441	5448
1,070	5542	5542	5543	5543	5544	5544	5544	5545	5545	5545
1,071	5545	5546	5546	5546	5547	5547	5547	5547	5548	5548
1,072	5549									

DRAFT

TEXAS WATER DEVELOPMENT BOARD

RESERVOIR VOLUME TABLE

Oct 24 1995

MEDINA LAKE JULY 1995 SURVEY

VOLUME IN ACRE-FEET

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
933										
934										
935										
936										
937										
938										
939										
940										
941										
942										
943										
944										
945										
946										
947										
948										
949										
950										
951					1	1	2	3	4	5
952	6	8	9	11	13	15	17	20	22	25
953	28	31	34	38	41	44	48	52	56	60
954	64	68	72	76	81	85	90	94	99	104
955	110	115	121	127	133	139	146	152	159	166
956	173	180	187	195	202	210	218	225	233	242
957	250	258	267	275	284	293	301	310	319	328
958	337	347	356	366	375	385	395	404	414	425
959	435	445	456	466	477	487	498	509	520	532
960	543	554	566	578	589	601	613	625	638	650
961	663	675	688	701	714	727	740	754	767	781
962	795	809	823	837	851	866	880	895	910	925
963	940	955	970	986	1001	1017	1033	1049	1065	1082
964	1098	1115	1132	1148	1165	1183	1200	1217	1235	1253
965	1271	1289	1307	1325	1344	1363	1382	1401	1420	1440
966	1459	1479	1499	1519	1540	1560	1581	1602	1623	1645
967	1666	1688	1710	1733	1755	1778	1801	1824	1848	1872
968	1896	1921	1945	1970	1995	2021	2046	2072	2098	2125
969	2151	2178	2206	2233	2261	2289	2317	2346	2375	2404
970	2434	2464	2494	2524	2555	2586	2617	2649	2681	2713
971	2745	2778	2811	2844	2877	2911	2944	2978	3013	3047
972	3082	3117	3152	3188	3224	3260	3296	3333	3370	3407
973	3445	3482	3520	3559	3597	3636	3675	3714	3754	3794
974	3834	3874	3915	3955	3997	4038	4079	4121	4163	4206
975	4248	4291	4335	4378	4422	4466	4510	4555	4600	4646
976	4692	4738	4785	4832	4879	4927	4975	5024	5073	5122
977	5172	5222	5272	5323	5375	5427	5479	5532	5585	5639
978	5694	5748	5803	5858	5914	5970	6026	6083	6140	6197
979	6255	6312	6370	6429	6487	6546	6605	6665	6724	6784
980	6845	6905	6966	7027	7089	7150	7212	7275	7337	7400
981	7463	7527	7591	7655	7719	7783	7848	7913	7979	8044

DRAFT

MEDINA LAKE JULY 1995 SURVEY

VOLUME IN ACRE-FEET ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
982	8110	8176	8243	8309	8376	8443	8511	8578	8646	8714
983	8783	8851	8920	8989	9058	9128	9198	9268	9338	9409
984	9479	9550	9622	9693	9765	9837	9909	9982	10055	10128
985	10201	10274	10348	10422	10497	10571	10646	10721	10797	10873
986	10949	11025	11102	11179	11256	11333	11411	11489	11567	11646
987	11724	11803	11882	11962	12041	12121	12201	12281	12362	12443
988	12524	12605	12687	12768	12850	12933	13015	13098	13181	13265
989	13348	13432	13516	13601	13685	13770	13856	13941	14027	14113
990	14200	14286	14374	14461	14549	14636	14725	14813	14902	14991
991	15081	15171	15261	15351	15442	15533	15625	15717	15809	15902
992	15995	16088	16182	16276	16370	16464	16559	16654	16750	16846
993	16942	17038	17135	17231	17329	17426	17524	17622	17720	17818
994	17917	18016	18116	18215	18315	18415	18516	18616	18717	18818
995	18920	19021	19123	19226	19328	19431	19534	19637	19741	19844
996	19948	20053	20157	20262	20367	20473	20578	20684	20791	20897
997	21004	21111	21218	21326	21434	21542	21650	21759	21868	21977
998	22087	22197	22307	22417	22527	22638	22749	22861	22973	23085
999	23197	23309	23422	23535	23648	23762	23876	23990	24105	24220
1,000	24335	24450	24566	24682	24798	24915	25032	25149	25266	25384
1,001	25502	25621	25739	25858	25978	26098	26217	26338	26458	26579
1,002	26701	26822	26944	27066	27189	27312	27435	27558	27682	27806
1,003	27931	28055	28180	28306	28431	28557	28684	28810	28937	29064
1,004	29192	29320	29448	29576	29705	29834	29964	30093	30223	30354
1,005	30485	30616	30747	30879	31011	31143	31276	31409	31542	31676
1,006	31809	31944	32078	32213	32348	32484	32620	32756	32892	33029
1,007	33166	33303	33441	33579	33718	33856	33995	34135	34275	34415
1,008	34555	34696	34837	34979	35120	35263	35405	35548	35692	35835
1,009	35979	36124	36269	36414	36560	36706	36853	37000	37147	37295
1,010	37443	37592	37741	37891	38042	38192	38343	38495	38647	38800
1,011	38953	39106	39260	39415	39570	39725	39881	40037	40194	40351
1,012	40509	40667	40825	40984	41144	41304	41464	41625	41786	41948
1,013	42111	42273	42437	42600	42765	42929	43094	43260	43426	43592
1,014	43759	43926	44094	44263	44431	44600	44770	44940	45111	45282
1,015	45453	45625	45798	45971	46144	46318	46492	46667	46842	47018
1,016	47195	47371	47549	47727	47905	48084	48263	48443	48623	48804
1,017	48985	49167	49349	49532	49715	49899	50083	50267	50452	50638
1,018	50824	51011	51198	51386	51574	51762	51952	52141	52332	52523
1,019	52714	52906	53098	53291	53485	53679	53874	54070	54266	54463
1,020	54660	54859	55058	55257	55458	55658	55860	56062	56264	56467
1,021	56671	56874	57079	57284	57490	57696	57902	58109	58317	58525
1,022	58734	58943	59153	59363	59574	59785	59997	60209	60422	60635
1,023	60849	61064	61279	61494	61710	61926	62143	62361	62579	62798
1,024	63017	63236	63456	63677	63898	64119	64341	64564	64787	65011
1,025	65235	65460	65685	65911	66138	66364	66592	66820	67049	67278
1,026	67507	67738	67968	68200	68432	68665	68898	69131	69366	69601
1,027	69837	70073	70310	70549	70787	71026	71266	71507	71749	71991
1,028	72234	72477	72722	72967	73213	73459	73707	73955	74204	74453
1,029	74703	74954	75205	75458	75711	75964	76218	76474	76730	76986
1,030	77243	77501	77760	78020	78280	78541	78802	79064	79327	79590
1,031	79854	80118	80383	80649	80915	81182	81449	81717	81986	82255

DRAFT

MEDINA LAKE JULY 1995 SURVEY

VOLUME IN ACRE-FEET ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1,032	82524	82794	83065	83337	83608	83881	84154	84427	84702	84976
1,033	85252	85527	85804	86081	86358	86636	86915	87194	87474	87754
1,034	88034	88315	88597	88880	89162	89446	89730	90014	90299	90585
1,035	90871	91158	91445	91733	92021	92310	92600	92889	93180	93471
1,036	93763	94055	94348	94641	94935	95229	95524	95820	96116	96413
1,037	96710	97008	97306	97606	97906	98206	98507	98808	99111	99414
1,038	99717	100021	100325	100631	100937	101243	101550	101858	102167	102476
1,039	102785	103096	103406	103718	104030	104343	104657	104971	105286	105601
1,040	105917	106234	106552	106870	107189	107508	107828	108149	108471	108793
1,041	109116	109439	109764	110089	110415	110741	111068	111396	111725	112055
1,042	112385	112716	113047	113380	113713	114047	114382	114717	115054	115391
1,043	115729	116067	116406	116747	117087	117429	117771	118114	118458	118803
1,044	119148	119494	119840	120188	120536	120885	121235	121585	121937	122289
1,045	122641	122995	123349	123704	124060	124417	124774	125132	125492	125852
1,046	126212	126574	126937	127300	127665	128030	128396	128763	129131	129500
1,047	129870	130240	130612	130984	131357	131731	132106	132482	132859	133236
1,048	133615	133994	134374	134755	135137	135519	135903	136287	136672	137058
1,049	137445	137832	138220	138610	139000	139391	139783	140175	140569	140963
1,050	141358	141754	142151	142550	142948	143348	143748	144150	144552	144955
1,051	145359	145764	146169	146577	146984	147392	147802	148212	148624	149036
1,052	149449	149863	150278	150694	151111	151529	151948	152368	152790	153212
1,053	153636	154063	154492	154922	155353	155784	156215	156647	157080	157514
1,054	157948	158382	158817	159254	159690	160127	160564	161002	161442	161881
1,055	162321	162761	163202	163645	164087	164530	164974	165418	165863	166308
1,056	166754	167201	167648	168096	168545	168994	169443	169894	170345	170796
1,057	171248	171701	172154	172608	173063	173518	173973	174430	174887	175344
1,058	175803	176261	176720	177181	177641	178102	178564	179027	179490	179954
1,059	180418	180882	181348	181814	182281	182748	183216	183685	184154	184624
1,060	185094	185568	186042	186518	186993	187469	187946	188424	188902	189381
1,061	189860	190340	190821	191303	191785	192267	192750	193234	193719	194204
1,062	194690	195176	195663	196151	196640	197128	197618	198108	198600	199091
1,063	199583	200076	200569	201064	201559	202054	202550	203047	203545	204043
1,064	204541	205041	205541	206043	206545	207047	207551	208055	208561	209066
1,065	209573	210080	210588	211097	211606	212116	212627	213139	213651	214164
1,066	214678	215192	215707	216224	216740	217257	217775	218294	218814	219334
1,067	219855	220376	220898	221422	221946	222470	222996	223521	224049	224576
1,068	225104	225634	226166	226698	227231	227765	228299	228834	229371	229908
1,069	230445	230983	231522	232063	232604	233145	233687	234230	234774	235318
1,070	235863	236417	236972	237526	238081	238635	239189	239743	240298	240853
1,071	241407	241962	242516	243071	243626	244180	244735	245289	245845	246399
1,072	246954									

TEXAS WATER DEVELOPMENT BOARD
RESERVOIR AREA TABLE

DRAFT

Oct 25 1995

DIVERSION LAKE JULY 1995 SURVEY

AREA IN ACRES | ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
880										
881										
882										
883		1	1	1	1	1	1	1	1	1
884	1	1	1	1	1	1	1	1	1	1
885	1	1	2	2	2	2	2	2	2	2
886	2	2	2	2	2	2	2	2	2	2
887	2	3	3	3	3	3	3	3	3	3
888	3	4	4	4	4	4	4	4	4	4
889	5	5	5	5	5	5	5	5	6	6
890	9	9	9	9	9	9	9	10	10	10
891	10	10	10	10	10	10	11	11	11	11
892	11	11	11	11	11	12	12	12	12	12
893	12	12	12	12	13	13	13	13	13	13
894	13	13	14	14	14	14	14	14	14	14
895	16	16	16	17	17	17	17	18	18	18
896	18	19	19	19	19	20	20	20	20	21
897	21	21	21	22	22	22	22	22	23	23
898	23	23	24	24	24	24	25	25	25	25
899	26	26	26	26	26	27	27	27	27	28
900	30	30	31	31	31	32	32	32	32	33
901	33	33	34	34	34	35	35	35	35	36
902	36	36	37	37	37	37	38	38	38	39
903	39	39	39	40	40	40	41	41	41	42
904	42	42	42	43	43	43	44	44	44	45
905	47	47	48	48	49	49	50	50	50	51
906	51	52	52	53	53	53	54	54	55	55
907	56	56	56	57	57	58	58	59	59	59
908	60	60	61	61	61	62	62	63	63	64
909	64	64	65	65	66	66	66	67	67	68
910	70	70	71	71	72	72	73	74	74	75
911	75	76	76	77	77	78	78	79	80	80
912	81	81	82	82	83	83	84	84	85	85
913	86	87	87	88	88	89	89	90	90	91
914	91	92	92	93	94	94	95	95	96	96
915	97	97	98	98	99	99	100	101	101	102
916	102	103	103	104	104	105	105	106	106	107
917	107	108	108	109	109	110	110	111	111	112
918	112	113	113	114	114	115	115	116	116	117
919	117	118	118	119	119	120	121	121	122	122
920	124	124	125	126	126	127	127	128	128	129
921	129	130	130	131	131	132	133	133	134	134
922	135	135	136	136	137	137	138	139	139	140
923	140	141	141	142	142	143	144	144	145	145
924	146	146	147	148	148	149	149	150	150	151
925	154	155	156	156	157	158	159	160	161	162
926	163	164	165	166	167	169				

TEXAS WATER DEVELOPMENT BOARD
RESERVOIR VOLUME TABLE

DRAFT

Oct 25 1995

DIVERSION LAKE JULY 1995 SURVEY

VOLUME IN ACRE-FEET — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
880										
881										
882						1	1	1	1	1
883	1	1	1	1	1	1	1	1	1	1
884	1	1	2	2	2	2	2	2	2	2
885	2	3	3	3	3	3	3	4	4	4
886	4	4	5	5	5	5	5	6	6	6
887	6	7	7	7	7	8	8	8	9	9
888	9	10	10	10	11	11	11	12	12	13
889	13	14	14	15	15	16	16	17	17	18
890	18	19	20	21	22	23	24	25	26	27
891	28	29	30	31	32	33	34	35	36	37
892	38	39	40	41	43	44	45	46	47	48
893	50	51	52	53	55	56	57	58	60	61
894	62	64	65	66	68	69	71	72	73	75
895	76	78	79	81	83	84	86	88	90	91
896	93	95	97	99	101	103	105	107	109	111
897	113	115	117	119	121	124	126	128	130	133
898	135	137	140	142	144	147	149	152	154	157
899	159	162	164	167	170	172	175	178	180	183
900	186	189	192	195	198	201	204	208	211	214
901	217	221	224	228	231	234	238	241	245	248
902	252	256	259	263	267	270	274	278	282	286
903	289	293	297	301	305	309	313	317	322	326
904	330	334	338	342	347	351	355	360	364	369
905	373	378	383	387	392	397	402	407	412	417
906	422	427	433	438	443	448	454	459	465	470
907	476	481	487	493	498	504	510	516	522	528
908	533	539	546	552	558	564	570	576	583	589
909	595	602	608	615	621	628	635	641	648	655
910	661	668	675	683	690	697	704	712	719	726
911	734	741	749	757	764	772	780	788	796	804
912	812	820	828	836	844	853	861	870	878	887
913	895	904	912	921	930	939	948	957	966	975
914	984	993	1002	1011	1021	1030	1040	1049	1059	1068
915	1078	1088	1097	1107	1117	1127	1137	1147	1157	1167
916	1177	1188	1198	1208	1219	1229	1239	1250	1261	1271
917	1282	1293	1303	1314	1325	1336	1347	1358	1369	1380
918	1392	1403	1414	1426	1437	1448	1460	1471	1483	1495
919	1506	1518	1530	1542	1554	1566	1578	1590	1602	1614
920	1626	1639	1651	1664	1676	1689	1702	1715	1727	1740
921	1753	1766	1779	1792	1805	1818	1832	1845	1858	1872
922	1885	1899	1912	1926	1939	1953	1967	1981	1995	2009
923	2023	2037	2051	2065	2079	2093	2108	2122	2136	2151
924	2166	2180	2195	2210	2224	2239	2254	2269	2284	2299
925	2314	2330	2345	2361	2376	2392	2408	2424	2440	2456
926	2472	2489	2505	2522	2538	2555				

HYDROLOGIC, RECHARGE AND WATER QUALITY ASSESSMENT OF MEDINA LAKE

Contract No. 95-483-071

The following map is not attached to this report. It is located in the official file and may be copied upon request.

Map No. 1
Figure 6 Medina Lake Contour Map

Please contact Research and Planning Fund Grants Management Division at (512) 463-7926 for copies.

BLACKWELL & ASSOCIATES INC.

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December 18, 1996

Mr. Alfredo Rodriguez
Project Manager
Texas Water Development Board
1700 N. Congress Avenue
Austin, Texas 78745

RE: **FINAL** Interim Report, FY 1996 - Medina Lake Recharge Study
TWDB Contract No. 95-483-071

Dear Alfredo:

Please find enclosed seven (7) **FINAL** copies of the Hydrologic, Recharge and Water-Quality Analysis Report for the above mentioned study. As discussed with you previously, the Final Interim Report consists of a letter from the USGS responding to review comments received from the Texas Water Development Board (TWDB) on the DRAFT report, as well as new covers (including inside cover sheet) that state "Final Interim Report for Fiscal Year 1996". These covers are to be inserted in place of the "Draft Interim Report for Fiscal Year 1996" covers present in the reports submitted to you from Blackwell & Associates on September 23, 1996.

Please feel free to contact me at (512) 251-6169 if you have any questions regarding this submittal for if I may be of any further assistance.

Sincerely,
BLACKWELL & ASSOCIATES INC.

James Blackwell

James E. Blackwell, P.E.

cc: John Ward, BMA
Tom Moreno, BMWD
Ed McCarthy, MLK
Lou Rosenberg, P.C.
Rebecca Lambert, USGS

Comments from J. Ashworth (TWDB) By 12/15/95

GEOLOGIC FRAMEWORK AND HYDROGEOLOGIC CHARACTERISTICS OF THE EDWARDS AND TRINITY AQUIFERS, MEDINA LAKE AREA, MEDINA AND BANDERA COUNTIES, TEXAS

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95-____

Prepared in cooperation with the
BEXAR-MEDINA-ATASCOSA COUNTIES WATER CONTROL AND IMPROVEMENT DISTRICT NO. 1

GEOLOGIC FRAMEWORK AND HYDROGEOLOGIC CHARACTERISTICS OF THE EDWARDS AND TRINITY AQUIFERS, MEDINA LAKE AREA, MEDINA AND BANDERA COUNTIES, TEXAS

By Ted A. Small and Rebecca B. Lambert

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations 95-XXXX

Prepared in cooperation with the
BEXAR-MEDINA-ATASCOSA COUNTIES WATER CONTROL AND IMPROVEMENT DISTRICT NO. 1

Austin, Texas
1995

CONTENTS

PLATE

[Plate is in pocket]

FIGURE

TABLE

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
mile (mi)	1.609	kilometer

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Geologic Framework and Hydrogeologic Characteristics of the Edwards and Trinity Aquifers, Medina Lake Area, Medina and Bandera Counties, Texas

By Ted A. Small *and* Rebecca B. Lambert

Abstract

The Edwards aquifer is one of the most productive carbonate aquifers in the nation. In addition to providing a public water supply to more than 1 million people in a six-county region in south-central Texas, the Edwards aquifer supplies large quantities of water to agriculture, industry, and major springs. The Medina Lake watershed contributes an average of 61,300 acre-ft per year recharge to the Edwards aquifer.

Medina and Diversion Lakes are located on the Medina River in northeastern Medina and southeastern Bandera County. The Medina Lake system, completed in 1912, was constructed to supplement existing irrigation supplies. Most of the reservoir area of Medina Lake is assumed to overlie the Glen Rose Limestone, which is the upper unit of the Trinity aquifer (Holt, 1959, p. 58), while Diversion Lake possibly lies on rocks of the Kainer Formation in the Edwards aquifer recharge zone. Seepage losses from Medina and Diversion Lakes have been documented by the USGS and other sources since completion of the irrigation structures in 1912. All of the water lost from the lakes has been assumed to enter the Edwards aquifer, either directly or indirectly through the Trinity aquifer.

Geologic and hydrogeologic information was compiled and included historical geologic and hydrogeologic maps, geologic cross-sections, geophysical and driller's logs, and aerial photos. The hydrogeologic units of the Edwards and Trinity aquifers and other geologic features exposed in outcrop were mapped. The outcrop porosity and permeability characteristics of each of the hydrogeologic units of the Edwards and Trinity aquifers were also described. Most of the faults in the study area trend northeast, some cross-faults trend northwest. Generally, the faults are en echelon and normal, with the downthrown blocks typically toward the coast.

The Edwards aquifer recharge zone has relatively large permeability resulting, in part, from the development of secondary porosity. Lithology, stratigraphy, diagenesis, and karstification account for the effective porosity and permeability in the Edwards aquifer outcrop. Karst features that greatly enhance effective porosity in the outcrop area include sinkholes, dolines, and caves. In the Medina Lake study area, Hydrogeologic subdivision VI, the Kirschberg evaporite member, appears to be the most porous and permeable subdivision within the Kainer Formation. Hydrogeologic subdivision III, the leached and collapsed members, undivided, is the most porous and permeable subdivision within the Person Formation. Hydrogeologic subdivision II, the cyclic and marine members, undivided, is moderately permeable, with both fabric and not fabric selective porosity. The porosity and permeability of Glen Rose Limestone (Trinity aquifer) is much less than that observed in the most porous and permeable units of the Edwards aquifer.

Results from the field mapping confirmed the conclusion reached by previous investigations - that Medina Lake lies mainly on rocks of the Upper Glen Rose Limestone. However, the channel downstream of Medina Dam along the intervening canyon to the upper end of Diversion Lake lies on the Upper Glen Rose Limestone, not on rocks of the Edwards Group as previously assumed. The lower end of Diversion Lake (near Diversion dam) lies on a thin section of the lowermost unit in the Edwards Group - the Basal Nodular member. Rocks of the Edwards Group form the caps and bluffs on the hills surrounding the lakes. Most of the Edwards rocks that may be hydrologically connected with the lake system at higher lake stages are primarily from the Basal Nodular and Dolomitic members of the Kainer Formation (table 1), stratigraphically the lowest formation in the Edwards Group.

INTRODUCTION

The Edwards aquifer is one of the most productive carbonate aquifers in the nation. In addition to providing a public water supply to more than 1 million people in a six-county region in south-central Texas, the Edwards aquifer supplies large quantities of water to agriculture, industry, and major springs. The major springs, in turn, support recreational activities and businesses, provide flow to downstream users, and provide habitat for several threatened or endangered species. The aquifer is extremely complex - with intensely faulted and fractured, karstic limestone outcrops that are recharged by local streams and precipitation.

Medina and Diversion Lakes are located on the Medina River in northeastern Medina and southeastern Bandera County (fig. 1). Medina Lake, completed in 1912, was constructed to supplement existing irrigation supplies. The Medina River is impounded behind the upper dam at Medina Lake. Water from the upper dam is discharged down a 4-mile canyon to a small impoundment (Diversion Lake) where it is then diverted into a system of irrigation canals. Previous mapping investigations (Sayre, 1936; Guyton and Associates, 1955; Holt, 1956; Barnes and others, 1992) showed Medina Lake overlying the Glen Rose Limestone, the upper unit of the Trinity aquifer (Holt, 1959, p. 58), and Diversion Lake overlying rocks of the Edwards Limestone.

Figure 1 near here.

Seepage losses from Medina and Diversion Lakes have been documented by the USGS and other sources since completion of the irrigation structures in 1912. Most of the water lost from the lakes has been assumed to enter the Edwards aquifer, either directly or indirectly through the Trinity aquifer.

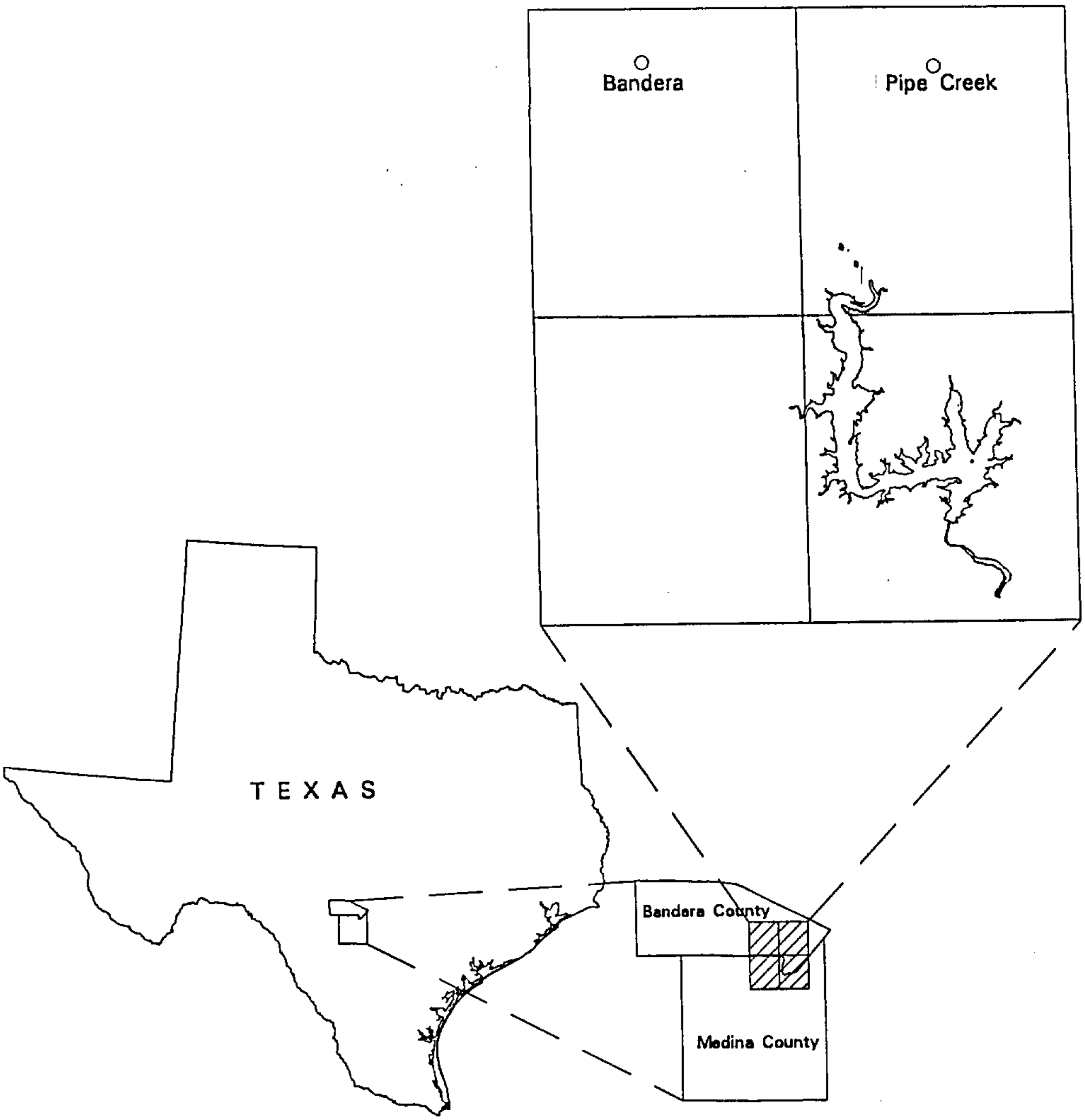


Figure 1. Location of Medina Lake Study Area.

Most recharge to the Edwards aquifer is from direct infiltration of precipitation and streamflow loss in the recharge zone. After entering the aquifer, the water generally moves from west to east through Medina County, where it is discharged by wells. U.S. Geological Survey estimate of recharge to the Edwards aquifer from 1934-94 averaged 677,600 acre-ft per year (D.S. Brown, USGS, oral commun.). Of this total, the estimated contribution of the Medina Lake watershed ranged from 6,800 to 104,000 acre-ft per year, with an average of 61,300 acre-ft per year for 1934-94 (D.S. Brown, USGS, oral commun.). Most of ? The contribution of recharge to the Edwards aquifer from the Medina Lake watershed is assumed to be seepage losses from Medina and Diversion Lakes.

Previous hydrogeologic investigations in the area mapped individual rock units only to the group or formation level, separating the Edwards Group (Edwards aquifer) from the Glen Rose Limestone (Trinity aquifer). Sayre (1936) completed a field map for a report describing the geology and ground-water resources in Uvalde and Medina Counties. The Edwards and Georgetown Limestones in the Medina Lake Study area were mapped together by Sayre as a single unit. Sayre also mapped the Glen Rose Limestone in the areas to the northwest and east of Medina Lake. Very few faults in the Medina Lake area were reported by Holt (1956). Should this be put with Holt paragraph on next page?

W.F. Guyton & Associates (1955) described the characteristics of the "Edwards Limestone Reservoir" in the San Antonio area and produced a map showing the distribution of rocks of the Edwards and associated limestones (Edwards Group), rocks older than the Edwards and rocks younger than the Edwards. This map is very similar to the map previously published by Sayre (1936) but does not show any additional detail of the stratigraphy or structure in the Medina Lake study area.

Holt (1956) further refined the work previously done by Sayre (1936) mapping the Glen Rose Limestone and the Edwards Limestone in the Medina Lake study area. Holt mapped the Glen Rose Limestone, the Edwards Limestone, and the Georgetown Limestone in the Medina Lake area, without differentiating the units into individual members. Holt's published map shows that the distribution of the Edwards Limestone is not as widespread as Sayre had mapped - the Glen Rose Limestone comprises a greater portion of the outcrop and the Edwards Limestone appears to be more discontinuous and dissected.

One of the most recent maps, the geologic map of Texas published by the Bureau of Economic Geology (BEG) in 1992, is also to this scale (Barnes and others, 1992). The BEG map shows that Medina Lake is underlain by the Glen Rose Limestone, and that the intervening canyon between the two dams and Diversion Lake are underlain by rocks of the Edwards Group. Although a few additional structural features have been added, the spatial distribution of rock units for the Edwards and Trinity Groups on the BEG map are approximately the same as the previously published maps.

Purpose and Scope

The purpose of this report is to document the results from mapping the hydrogeologic subdivisions of the Edwards aquifer in the vicinity of Medina and Diversion Lakes. Seepage losses from Medina and Diversion Lake have been documented by the USGS and other sources since completion of the irrigation structures in 1912. All of the water lost from the lakes has been assumed to enter the Edwards aquifer, either directly or indirectly through the Trinity aquifer. Previous hydrogeologic investigations mapped the geology only to the formation level. Further refinement of the stratigraphy was needed to show the spatial distribution of individual members in the Glen Rose Limestone and the Edwards Group and the location of faults.

Some of this Trinity water recharged from the lake is probably lost to local domestic pumpage.

This report describes the geologic framework and the hydrogeologic characteristics of the Edwards and Trinity aquifers in the Medina Lake area in Medina and Bandera Counties (Maclay and Small, 1976; Stricklin, Smith and Lozo, 1971). This information will help to provide a better understanding of the processes controlling the spatial distribution of recharge and the flow of water into the aquifer. The study area, as defined, includes the watershed area encompassing Medina and Diversion Lakes and an area for several miles or more down gradient from both lakes (fig. 1)

Methods of Investigation

Information was compiled from historical geologic and hydrogeologic maps, geologic cross-sections, geophysical and driller's logs, aerial photos, and other available pertinent information on Medina and Bandera Counties for use in field mapping the hydrogeologic units in the Medina and Diversion Lakes watershed. The mapping units were based on the hydrogeologic units defined in Maclay and Small (1976) for the Edwards aquifer and the geologic units modified from those defined in Stricklin, Smith, and Lozo (1971) for the Trinity deposits comprising the Trinity aquifer (table 1). Distinct marker beds, such as the regional dense member of the Person Formation (Edwards aquifer), and the *Corbula* bed and the evaporite zones in the Glen Rose Limestone (Trinity aquifer), were used as stratigraphic identifiers of the Glen Rose Limestone when possible. The porosity and permeability characteristics of each mappable unit were described. Structural and karst features, including faults and fractures, caverns, and sinkholes were also recorded. Field identification of the various members in the Kainer and Person Formations of the Edwards Group and the members of the Trinity Group was based on their characteristic lithologies and fossils (table 1). The hydrogeologic subdivisions of the Edwards and Trinity aquifers in the Medina Lake study area are shown on plate 1.

Table 1.

Plate 1.

Table 1. Summary of the lithologic and hydrologic properties of the hydrogeologic subdivisions of the Edwards and Trinity aquifers outcrop, Medina and Bandera Counties, Texas

[Hydrogeologic subdivisions modified from Maclay and Small (1976); groups, formations, and members modified from Rose (1972), Stricklin, Smith, and Lozo (1971), Holt (1956), Asworth (1983); lithology modified from Dunham (1962); and porosity type modified from Choquette and Pray (1970). CU, confining unit; AQ, aquifer]

Hydrogeologic subdivision	Group, formation, or member	Hydro-logic function	Thickness (feet)	Lithology	Field identification	Cavern development	Porosity/ permeability type (M outcrop)
Upper confining units	Anacacho Limestone	CU	240 - 450	Argillaceous, light gray to buff, fossiliferous limestone	Soft, marly limestone	None	Low permeability
Upper confining units	Austin Group	CU	225-300	Chalk, marl, and hard limestone	Soft, marly limestone	None	Low permeability
Upper Cretaceous; Upper confining units	Eagle Ford Group	CU	30 - 50	Brown, flaggy shale and argillaceous limestone	Not observed in field	None	Primary porosity lost/ low permeability
Upper Cretaceous; Upper confining units	Buda Limestone	CU	40 - 50	Buff, light gray, dense mudstone	Not observed in field	Minor surface karst	Low porosity/low permeability
Upper Cretaceous; Upper confining units	Del Rio Clay	CU	40 - 50	Blue-green to yellow-brown clay	Not observed in field	None	None/primary upper confining unit
Lower Cretaceous; Edwards aquifer; I	Georgetown Formation	Karst AQ; not karst CU	2 - 20	Reddish-brown, gray to light tan marly limestone	Not observed in field	None	Low porosity/low permeability
Lower Cretaceous; Edwards aquifer; II	Edwards Group *; Person Formation; Cyclic and marine members, undivided	AQ	80 - 90	Mudstone to packstone; *miliolid* grainstone; chert	Massive beds to relatively thin beds; crossbeds	Many subsurface; may be associated with earlier karst development	Laterally extensive; both fabric and not fabric/ water-yielding
Lower Cretaceous; Edwards aquifer; III	Edwards Group *; Person Formation; Leached and collapsed members, undivided	AQ	70 - 90	Crystalline limestone; mudstone to grainstone; chert; collapsed breccia	Bioturbated iron-stained beds separated by massive limestone beds; stromatolitic limestone	Extensive lateral development; large rooms	Majority not fabric/one of the most permeable
Lower Cretaceous; Edwards aquifer; IV	Edwards Group *; Person Formation; Regional dense member	CU	16-20	Dense, argillaceous mudstone	Wispy iron-oxide stains	Very few; only vertical fracture enlargement	Not fabric/low permeability; vertical barrier
Lower Cretaceous; Edwards aquifer; V	Edwards Group *; Kainer Formation; Grainstone member	AQ	50 - 60	*Miliolid* grainstone; mudstone to wackestone; chert	White crossbedded grainstone	Few	Not fabric/ recrystallization reduces permeability
Lower Cretaceous; Edwards aquifer; VI	Edwards Group *; Kainer Formation; Kirschberg evaporite member	AQ	50 - 60	Highly altered crystalline limestone; chalky mudstone; chert	Boxwork voids, with neospar and travertine frame	Probably extensive cave development	Majority fabric/one of the most permeable
Lower Cretaceous; Edwards aquifer; VII	Edwards Group *; Kainer Formation; Dolomitic member	AQ	110 - 140	Mudstone to grainstone; crystalline limestone; chert	Massively bedded light gray, *Toucasia* abundant	Caves related to structure or bedding planes	Mostly not fabric; some bedding plane-fabric/ water-yielding
Lower Cretaceous; Edwards aquifer; VIII	Edwards Group *; Kainer Formation; Basal nodular member	Karst AQ; not karst CU	50 - 60	Shaly, nodular limestone; mudstone and *miliolid* grainstone	Massive, nodular and mottled, abundant gastropods and *Exogyra texana*	Large lateral caves at surface; a few caves near Koenig Creek	Fabric; stratigraphically controlled/large conduit flow at surface; no permeability in subsurface
Lower Cretaceous; U. Trinity aquifer	Trinity Group; Glen Rose Formation; Upper member	CU; evaporite beds AQ	350 - 500	Yellowish tan, thinly bedded limestone and marl	Stair-step topography; alternating limestone and marl	Some surface cave development	Some water production at evaporite beds/ relatively impermeable
Lower Cretaceous; M. Trinity aquifer	Trinity Group; Glen Rose Formation; Lower member	AQ;	300-320	Massive fossiliferous limestone, rudistid reefs and caves, few thin beds of marl and dolomitic limestone	Massive, reefal limestone with *Corbula martinae, Orbitolina*	Some cave development	Small to moderate quantities of water from caves and reefs

*equivalent to the Devils River Limestone (undivided)

Well logs and geologic map data were compiled and used in mapping the hydrogeologic subdivisions and determining the thickness of the Edwards aquifer in the study area. The lower confining unit of the Edwards aquifer, the upper member of the Glen Rose Limestone of Lower Cretaceous age (table 1), was mapped where it is adjacent to the recharge zone. The Anacacho Limestone and the Austin Group, the upper confining units which are juxtaposed against the Edwards Group on the southeast side of the Habys Crossing Fault (plate 1), were mapped along the southern boundary of the recharge zone.

Caves and other karst features were located during mapping using information from Elliot and Veni (1994, p. 231-233) and local residents. Aerial photographs at a scale of 1:24,000 (1" = 2,000 ft) were used to locate the most recent rock exposures so that relatively fresh outcrops could be examined. Original land-surface topography of excavated quarries was interpolated from exposed outcrops and 7-1/2-minute quadrangles. Edwards and Trinity aquifer outcrop mapping also was interpolated through areas that were covered by alluvial deposits.

Determination of fault displacement often is difficult in carbonate rocks. Fault traces commonly are obscured and difficult to identify in the field. Fault displacements were postulated and estimated on the basis of abrupt lithologic or stratigraphic dissimilarities and at least one of the following: fault scarps, fault breccia, long linear travertine or sparry calcite deposits, or steeply dipping strata thought to represent fault-bend folds. Fault-bend folds are bedding deformation associated with fault-block movement (Suppe, 1985, p. 343). The strike of these features was measured with a compass in order to determine the orientation of the faults. The lengths of many of the faults were projected on the basis of lineaments visible on land surface or in aerial photographs. Faults were inferred based on the location of lineaments on photographs in areas where only slight stratigraphic dissimilarities were indicated, or where the faults extended beyond the mapped area.

Acknowledgments

The authors express their thanks to all the property owners who granted permission to enter their property. Also thanks are given to the Edwards Underground Water District (EUWD), Medina County Underground Water Conservation District, Springhills Water Management District, Armadigger Inc., D&K Drilling Co., Marion Heisler, and M and E Enterprises, Inc. for well information, drillers logs, and geophysical logs in the study area.

GEOLOGIC FRAMEWORK

General Features

The regional dip of rocks of the Edwards Group was reported to be 15 to 20 ft/mile to the southeast in Medina County by Holt (1956, p. 14) and thicknesses reported by Rose (1972, table 1). The faults in northern Medina County are part of the Balcones fault zone (fig. 1). Although most of the faults in the area trend southwest to northeast, a few cross-faults trend southeast to northwest. Generally, the faults are en echelon and normal, with the downthrown blocks typically toward the coast (southeast). Topographic relief is not visible at all of the faults, partly because the rocks on both sides of the fault have similar weathering characteristics, and possibly because the rate of movement is no faster than the rate of erosion.

Maclay and Small (1984, p. 33) define flow-barrier faults as faults that have vertical displacement greater than 50 percent of the total thickness of the aquifer, sufficient to juxtapose permeable layers against relatively less permeable layers. The approximate thickness of the Edwards aquifer in Medina County is 450 ft; 50 percent of this is 225 ft. Thus, faults in the study area with a vertical displacement of about 225 ft or greater were designated as flow-barrier faults. A series of flow-barrier faults extends from the southwest part of the study area toward the northeast.

Some of the faults in Medina County are similar to those in Bexar County described by Arnow (1959, p. 20) and mark the trace of shatter zones, where the faults are not single, sharp breaks as shown by a single line placed on a map. Field observations of features associated with faults included linear sparry travertine (a clear to translucent secondarily precipitated calcite) deposits within many of the fault shatter zones, and of caliche-like fault gouge, sometimes containing small boulders, as well as actual displacement of beds.

Stratigraphy

The Glen Rose Formation of the Trinity Group is about 820 feet thick in the study area and is composed of two members. George and others (1952) divided the Glen Rose Limestone into lower and upper members separated by a thin, resistive *Corbula* limestone bed. The lower member is the topmost unit of the Middle Trinity aquifer (Asworth, 1983) consisting of thick-bedded, massive rudistid limestones and thin beds of limestone, marl, and shale (Stricklin and others, 1971). Overlying the basal unit is a fossiliferous shale and nodular marl capped by the flaggy limestone *Corbula* bed at the top.

The lower Glen Rose Limestone is composed of beds of massive fossiliferous limestone, characterized in the study area part of Bandera County by rudist patch reefs (Petta, 1977). The rudist reef complex on Red Bluff Creek is part of what Petta (1977, p. 138) refers to as "probably the best exposed rudist reef in the world." Overlying the limestone beds are thin, locally fossiliferous marly limestone and limestone beds. The fossil clam *Corbula martinae* (Whitney, 1952) is common to abundant in one of these beds and this bed is considered to be at the boundary between the upper and lower member of the Glen Rose Limestone.

The upper Glen Rose limestone is about 320 feet thick (Ashworth, 1983, p. 27) in the study area and is characterized by alternating beds of shale and nodular marl interbedded with thin beds of impure limestone and two evaporite zones (Reeves, 1967). The upper member can be recognized by the development of terrace (or stair-step) type of topography caused by the uneven weathering of those beds. The two evaporite beds are found near the middle and at the base of the upper member. At the outcrop, the evaporites have been leached by downward-percolating ground waters, producing uneven settling of claystone beds formerly between or overlying the gypsum bed (Ashworth, 1983). Concurrent with the dissolution of evaporite is the development of collapse breccia zones of increased porosity and permeability as evidence by the numerous sinkholes and caverns that are exposed along stream beds where the Lower Glen Rose Limestone crops out (Reeves, 1967). The upper member of the Glen Rose Limestone is divided from the lower member by the presence of the small clam *Corbula martinae*. Profuse numbers of these clams commonly occur in a thin bed at the top of the lower member of the Glen Rose limestone. However, this bed is not always easily found.

Because the Lower Glen Rose Limestone is massive, it is more susceptible than the upper member to the development of secondary porosity which results from jointing, faulting, and the dissolving action of ground, and hence is generally the more prolific water-producing zone (Ashworth, 1983).

Overlying the Trinity Group is the Edwards Group, which includes the Edwards Limestone and equivalent rocks. On the San Marcos Platform in Medina and Bandera Counties, the Edwards Group is divided into the Kainer and Person Formations (Rose, 1972). Massive nodular beds at the base of the Kainer Formation, the oldest formation of the Edwards Group, conformably overlie the alternating marl and limestone beds of the upper member of the Glen Rose limestone. The rock units of the Kainer and Person Formations form the basis of the eight hydrostratigraphic units of the Edwards aquifer defined by Maclay and Small (1984). The basal member of the Person Formation, a shaley mudstone known as the regional dense member, is laterally extensive and easily mapped (Maclay and Small, 1984).

In the vicinity of Medina Lake, the Edwards aquifer consists of approximately 450 ft of cherty limestone (table 1). The major formal lithostratigraphic units of the Edwards aquifer are the Kainer, Person, and Georgetown Formations (Maclay and Small, 1976). The Kainer and Person Formations are subdivided into informal members by Rose (1972). The rocks of these members, or subdivisions, were deposited in shallow to very shallow marine waters (Rose, 1972) and reflect depositional environments resulting from slight changes in water level, water chemistry, temperature, and circulation. All of these factors can cause subtle to not-so-subtle changes in the overall lithology of the various members and some changes within the individual members.

The Kainer Formation (Rose, 1972, p. 18) is approximately 260 to 310 ft thick in the Edwards Plateau. A geophysical log from a well in the study area in Medina County contains 312 ft of Kainer Formation (table 1). The lithology of the Kainer Formation includes marine sediments consisting of fossiliferous (most commonly rudistids) mudstones and wackestones that grade upward into intertidal and supratidal dolomitic mudstones with evaporites, and terminate in a shallow marine *miliolid* grainstone. The lower part of the dolomitic member of the Kainer Formation in Medina County is distinctly burrowed, similar to the facies equivalents of the burrowed member of the Fort Terrett Formation (Rose, 1972, p. 30, 46; Miller, p. 15, 22) northwest of the study area. Major collapsed features noted elsewhere by Rose (1972) in the Kirschberg evaporite member are not evident in Medina County. This might indicate fewer massive gypsum deposits and more interbedded limestone that would have prevented major collapses after evaporite removal.

The Person Formation (Rose, 1972, p. 19) is about 160-180 ft thick in Medina County (table 1). The regional dense member at the base of the Person Formation is a dense, argillaceous mudstone, which is easily recognized in cores and usually recognizable on geophysical logs (Small, 1985). Deposition of the Person Formation above the regional dense member continued with dolomitic biomicrite, which contains layers of collapsed breccias, burrowed mudstones, and stromatolitic limestone. The cyclic and marine members, undivided, consist of small upward-grading cycles of mudstones to grainstones that range from massive to thin beds and occasionally are crossbedded. According to Rose (1972), all of the cyclic and much of the marine members in Medina County might have been removed by erosion prior to the deposition of the Georgetown Formation.

The Kainer and Person Formations change facies into the Devils River Limestone in the far southwest corner of the study area (Plate 1). The Devils River Limestone is equivalent to the Edwards Group, but discerning and mapping hydrogeologic subdivisions in the Devils River Limestone is beyond the scope of this work.

The Georgetown Formation was not observed in the study area during field mapping, but may be present in some of the areas that were inaccessible. However, nearby in western Bexar County, an outcrop in a quarry near Helotes Creek contains an unweathered tannish-yellow biomicrite sequence of Georgetown Formation that is approximately 20 ft thick.

The Upper Cretaceous Del Rio Clay, Buda Limestone, Eagle Ford Group, Austin Group and Anacacho Formation overlie the Georgetown Formation (plate 1, table 1). However, only the Anacacho Formation and Austin Group crop out in the study area. In the study area, the upper Cretaceous Austin Group and Anacacho Formation are exposed south of the Haby Crossing Fault (plate 1) and were not mapped. The underlying upper confining units do not crop out in the study area.

HYDROGEOLOGIC CHARACTERISTICS

General Features

The Trinity aquifer is comprised of Cretaceous-aged rocks of the Trinity Group, underlying the Edwards Group. The Glen Rose Limestone, stratigraphically the youngest formation in the Trinity aquifer, crops out over the northern part of Medina and Bandera Counties. Wells completed in the Glen Rose Limestone in Medina County supply fresh to slightly saline water from the lower Glen Rose (Ashworth, 1983, p. 12) and potable, but highly mineralized water sufficient for stock and domestic use (Holt, 1959).

The Edwards aquifer, composed of rocks of the Edwards Group in the Balcones fault zone, is a hydraulically independent regional aquifer system with a very great transmissive capacity within the artesian zone. The Edwards aquifer is multilayered, consisting of highly solutioned and porous honeycombed strata separated by hard, dense, massive limestone (Jorgensen and others, 1988). The Edwards aquifer in Medina County supplies abundant quantities water of good quality for pubic supply, industry, irrigation, and domestic and stock use for more than half of the county (Holt, 1959, p. 22). Recharge to the Edwards aquifer occurs in the Balcones fault zone where streams draining the Edwards Plateau lose their base flow and much of their storm runoff by infiltration through porous and fractured limestones (Maclay and Small, 1984). Water is discharged naturally from springs that occur along major faults east of the study area or induced by pumping of wells located in, to the south, and to the east of, the study area.

The Edwards aquifer has relatively large permeability resulting, in part, from the development or redistribution of secondary porosity (Maclay and Small, 1976). Lithology, stratigraphy, diagenesis, and selective dissolution (karstification) account for the effective porosity and permeability in the Edwards aquifer outcrop. Karst features that can greatly enhance the effective porosity in the outcrop include sinkholes, dolines, and caves. The dry-subhumid climate (Thornthwaite, 1952) is not favorable for rapid karst development. The presence of caves in the Edwards Group limestone in Medina County is random and the morphology is controlled by the local stratigraphy.

Porosity and Permeability

According to Choquette and Pray (1970, p. 212), porosity in sedimentary carbonates is either fabric selective or not fabric selective. Fabric selective porosity is secondary porosity that preferentially developed along specific sedimentary structures, strata, or mineralogy. Not fabric selective porosity is secondary porosity that developed generally without the influence of sedimentary structures as well as secondary porosity that developed preferentially along fractures or faults not associated with the original sedimentary or diagenetic processes. Effective, or drainable, porosity consists of pores that are well-connected by sufficiently large openings, generally greater than 0.1 micrometer in diameter. In the Edwards aquifer, effective porosity is more closely associated with large permeability than with total porosity, which includes unconnected or dead-end pores (Maclay and Small, 1976).

Permeability is the capacity of a porous rock to transmit water. According to Ford and Williams (1989, p. 130), permeability depends on the physical properties of the rock, particularly pore size, shape, and distribution. Ford and Williams (1989, p. 150) further state that, "As a consequence of the effects of fissuring and differential solution, permeability may be greater in some directions than in others as well as in certain preferred stratigraphic horizons."

The lower and upper members of the Glen Rose Limestone and the eight hydrogeologic subdivisions and the names of the corresponding members, and the type of porosity and permeability observed in the field within the subdivisions are discussed below in ascending order.

The lower member of the Glen Rose Limestone exposed in outcrop in the Medina Lake Study has good permeability and porosity associated with patch reefs and caves. Most of the porosity associated with the patch reefs is fabric selective moldic porosity. The porosity associated with caves is not fabric selective. The upper member of the Glen Rose Limestone is relatively impermeable and usually acts as a lower confining unit of the Edwards aquifer. However, in most of the study area, the Glen Rose Limestone yields small to moderate quantities of water to wells.

Hydrogeologic subdivision VIII (basal nodular member) has negligible porosity and permeability in the subsurface, and can be regarded as part of the lower confining unit (Maclay and Small, 1984). In the outcrop, this subdivision is extensively karstified and has secondary (mostly not fabric selective) porosity in the form of large undercut caves. The lateral cave development might result from dissolution associated with perching of infiltrating meteoric water on the underlying relatively impermeable upper member of the Glen Rose Limestone (Kastning, 1986). The perching would allow time for dissolution to occur within this subdivision. Many seeps and springs discharge from the lower part of this hydrogeologic subdivision in Medina and Bexar County.

Hydrogeologic subdivision VII (dolomitic member) generally is porous and relatively permeable. Some of the evaporite beds within this subdivision are burrowed and dissolved to the extent of being honeycombed and, therefore, permeable. Many of the beds contain isolated molds, casts, and burrows with large secondary (fabric selective) porosity but little permeability because the openings rarely are connected. Therefore, the permeable layers are restricted to solution-enlarged bedding planes. A small, but relatively deep, cave was found in this subdivision near Medina Lake.

Hydrogeologic subdivision VI (Kirschberg evaporite member) appears to be the most porous and permeable subdivision of the Kainer Formation. The porosity, chiefly fabric selective, has been described as boxwork (Maclay and Small, 1976) because of the configuration of voids and the secondary neospar and travertine deposits. The boxwork porosity does not prevail throughout hydrogeologic subdivision VI, but is interbedded with massive limestone beds.

Hydrogeologic subdivision V (grainstone member) is widely recrystallized. The recrystallization greatly reduces the effective porosity and permeability of this subdivision; however, there is local interparticle and intraparticle porosity and local fracture porosity and permeability.

Hydrogeologic subdivision IV (regional dense member) is probably an effective vertical confining unit between the underlying Kainer Formation and the overlying members of the Person Formation. However, caves, faults, and fractures, primarily not fabric selective porosity, and fracture-associated permeability, might greatly reduce the confining effects of this subdivision in some areas.

Hydrogeologic subdivision III (leached and collapsed members, undivided) is the most porous and permeable subdivision within the Person Formation. The predominant type of porosity in this subdivision is fabric selective where evaporite minerals have been dissolved. However, breccia porosity resulting from evaporite dissolution can be either fabric selective or not fabric selective (Choquette and Pray, 1970). Cave porosity and permeability associated with faulting and (or) evaporite dissolution also is common. Haby Bat Cave and Boehm Cave are in this subdivision.

Hydrogeologic subdivision II (cyclic and marine members, undivided) is moderately permeable, with both fabric and not fabric selective porosity. Field observations indicate that this subdivision has only slightly less porosity and permeability than subdivision III.

Hydrogeologic subdivision I (Georgetown Formation) was not observed in the study area. The thickness of the Georgetown in the subsurface of the Medina Lake area is estimated to be 2-20 ft (table 1). In Bexar County, the Georgetown is approximately 20 ft thick (Stein and Ozuna, 1995). Generally wells completed in this unit yield little water. This subdivision has negligible porosity and permeability, especially in the subsurface.

The upper confining units consist of the Del Rio Clay, Buda Limestone, Eagle Ford Group, Austin Group, and Anacacho Limestone (Rose, 1972). Because the Del Rio Clay consists mostly of clay and has negligible effective porosity and permeability, it forms the primary upper confining unit of the Edwards aquifer.

SUMMARY AND CONCLUSIONS

The Edwards aquifer is one of the most productive carbonate aquifers in the nation. It is the sole source of public water supply for San Antonio and for most of southern Medina County. In addition, the Edwards aquifer provides large quantities of water to agriculture, industry, and major springs. The major springs support recreational activities and businesses, provide water to downstream users, and provide habitat for several threatened or endangered species. However, it is not a reliable aquifer in the Medina Lake area.

The dissolution-modified, faulted limestone aquifer is recharged in its outcrop area in the Balcones fault zone. The Edwards aquifer comprises the Kainer and Person Formations of the Edwards Group and the overlying Georgetown Formation. The Kainer and the Person Formations consist of seven informal members. These seven members, together with the overlying Georgetown Formation, compose the eight informal hydrogeologic subdivisions of the aquifer.

The Edwards aquifer has relatively large permeability resulting, in part, from the development or redistribution of secondary porosity. Lithology, stratigraphy, diagenesis, and karstification account for the effective porosity and permeability in the Edwards aquifer outcrop. Karst features that greatly enhance effective porosity and permeability include sinkholes, dolines, and caves.

Hydrogeologic subdivision VI (Kirschberg evaporite member) appears to be the most porous and permeable subdivision in the Kainer Formation. Hydrogeologic subdivision III (leached and collapsed members, undivided) is the most permeable subdivision in the Person Formation. Hydrogeologic subdivision II (cyclic and marine members, undivided) is moderately porous and permeable.

Results from the field mapping confirmed the conclusion reached by previous investigations (add citation) that Medina Lake lies mainly on rocks of the Upper Glen Rose Limestone. However, the channel downstream of Medina Dam along the intervening canyon to the upper end of Diversion Lake lies on the Upper Glen Rose Limestone, not on rocks of the Edwards Group as previously assumed (citations). The lower end of Diversion Lake (near Diversion dam) lies on a thin section of the lowermost unit in the Edwards Group - the Basal Nodular member. Rocks of the Edwards Group form the caps and bluffs on the hills surrounding the lakes. Most of the Edwards rocks that may be hydrologically connected with the lake system at higher lake stages are primarily from the Basal Nodular and Dolomitic members of the Kainer Formation (table 1), stratigraphically the lowest formation in the Edwards Group. strike from report.

REFERENCES CITED

Arnow, Ted, 1959, Ground-water geology of Bexar County, Texas: Texas Board of Water Engineers Bulletin 5911, 62 p.

Ashworth, J.B., 1983, Ground-water availability of the Lower Cretaceous Formations in the Hill County of south-central Texas: Texas Department of Water Resources, Report 273, 172 p.

Barnes, V.E., and others, 1992, Geologic map of Texas: Bureau of Economic Geology, The Univerisyt of Texas, Austin, Texas.

Choquette, P.W., and Pray, L.C., 1970, Geologic nomenclature and classification of porosity in sedimentary carbonates: American Association of Petroleum Geologists Bulletin, v. 54, no. 2, p. 207-250.

Dunham, R.J., 1962, Classification of carbonate rocks according to depositional texture, *in* Classification of Carbonate Rocks Symposium: American Association of Petroleum Geologists Memoir 1, p. 108-121.

Elliot, W.R. and Veni, George, eds., 1994, The caves and karst of Texas: A Guidebook for the 1994 Convention of the National Speleological Society with emphasis on the southwestern Edwards Plateau, Brackettville, Texas, June19-24, 1994, National Speleological Society, Huntsville, Alabama, p. 231-238.

Ford, D.C., and Williams, P.W., 1989, Karst geomorphology and hydrology: London, Chapman and Hall, 601 p.

George, W.O., S.D. Breeding, and W.W. Hastings, 1952, Geology and Ground-water Resources of Comal County, Texas: U.S. Geological Survey Water-Supply Paper 1138, 126 p.

Guyton, W.F. and Associates, 1955, The Edwards Limestone Reservoir: Private consultant's report to the City Water Board, San Antonio, Texas by W.R. Guyton and Associates, Austin, Texas, 30 p.

Holt, C.L.R., 1956, Geology and ground water resources of Medina County, Texas: Texas Board of Water Engineers, Bulletin 5601, 283 p.

Holt, C.L.R., 1959, Geology and ground-water resources of Medina County, Texas: U.S. Geological Survey Water-Supply Paper 1422, 213 p.

Jorgensen, D.G., J. Downey, A.R. Dutton, and R.W. Macaly, 1988, Region 16, Central Nonglaciated Plains in Back, W., J.S. Rosenshein, and P.R. Seaber, eds., Hydrogeology: Geological Society of Ameria, Volume O-2, p. 141-156.

Kastning, E.H., 1986, Cavern development in the New Braunfels area, central Texas, in Abbott, P.L., and Woodruff, C.M., Jr., eds., The Balcones escarpment - geology, hydrology, ecology and social development in central Texas: Geological Society of America, p. 91-100.

Maclay, R.W., and Small, T.A., 1976, Progress report on geology of the Edwards aquifer, San Antonio area, Texas, and preliminary interpretation of borehole geophysical and laboratory data on carbonate rocks: U.S. Geological Survey Open-File Report 76-627, 65 p.

______1984, Carbonate geology and hydrology of the Edwards aquifer in the San Antonio area, Texas: U.S. Geological Survey Open-File Report 83-537, 72 p.

Miller, B.C., Smith, C.I., Rose, P.R., Humbphreys, C.H., and R.E.Webster, eds., 1984, Stratigraphy and structure of the Maverick Basin and Devils River Trend, Lower Cretaceous, Southwest Texas: San Antonio Geological Society Guidebook, San Antonio, Texas, 128 p.

Petta, T.J., 1977, Diagensis and geochemistry of a Glen Rose patch reef complex, Bandera County, Texas: in Cretaceous Carbonates of Texas and Mexico, Application to subsurface exploration, Bebout and Loucks, eds., University of Texas Bureau of Economic Geology Report of Investigation No. 89, 332 p.

Reeves, R.D., 1967, Ground-water resources of Kendall County, Texas: Texas Water Development Board Report No. 60, 100 p.

Rose, P.R., 1972, Edwards Group, surface and subsurface, central Texas: Austin, University of Texas, Bureau of Economic Geology Report of Investigations 74, 198 p.

Sayre, A.N., 1936, Geology and ground-water resources of Uvalde and Medina Counties, Texas: U.S. Geological Survey Water-Supply Paper 678, 146 p.

Small, T.A., 1985, Identification and tabulation of geological contacts in the Edwards aquifer, San Antonio area, Texas: Texas Department of Water Resources LP-199, 54 p.

Stricklin, F.L., C.I. Smith, and F.E. Lozo, 1971, Stratigraphy of Lower Cretaceous Trinity Deposits of Central Texas: University of Texas Bureau of Economic Geology Report of Investigations No. 71, 63 p.

Suppe, J., 1985, Principles of structural geology: Englewood Cliffs, N. J., Prentice-Hall, 537 p.

Thornthwaite, C.W., 1952, Evapotranspiration in the hydrologic cycle, *in* The physical and economic foundation of natural resources, v. II, The physical basis of water supply and its principal uses: U.S. Congress, House of Representatives, Committee on Interior and Insular Affairs, p. 25-35.

Young, Keith, 1986, The Pleistocene terra rossa of central Texas, *in* Abbott, P.L., and Woodruff, C.M., Jr., eds., The Balcones escarpment, central Texas: Geological Society of America, p. 63-70.

THE MEDINA LAKE PROJECT

BRINGING MEDINA LAKE WATER EAST
A REGIONAL PARTNERSHIP TO SUBSTITUTE
MEDINA LAKE SURFACE WATER FOR
PRESENT MUNICIPAL DEMAND ON THE EDWARDS AQUIFER

SPONSORED BY:

BEXAR-MEDINA-ATASCOSA COUNTIES WCID NO. 1

October 27, 1993

BMA TOUR FOR TWDB STAFF

Packet Contents

1. Tour Agenda
2. Medina Lake Map
3. BMA/BMWD Relationship Map
4. Medina Lake Photographs
5. Diversion Lake Photographs
6. Map locating BMA/BMWD existing meters to monitor canal system losses (TWDB grant funded)
7. Map locating proposed additional meters (TWDB application pending)
8. SB 1477 §1.44
9. Summary of benefits under §1.44
10. Photographs of Canal Refurbishing Work
11. Dam Stability Study letters
12. 1993 SCS Annual Report - BMA Article

G:\B\BMA\TOURS\TOC.5

BMA MEDINA/DIVERSION LAKES & CANAL SYSTEM FIELD TOUR
FOR TEXAS WATER DEVELOPMENT BOARD

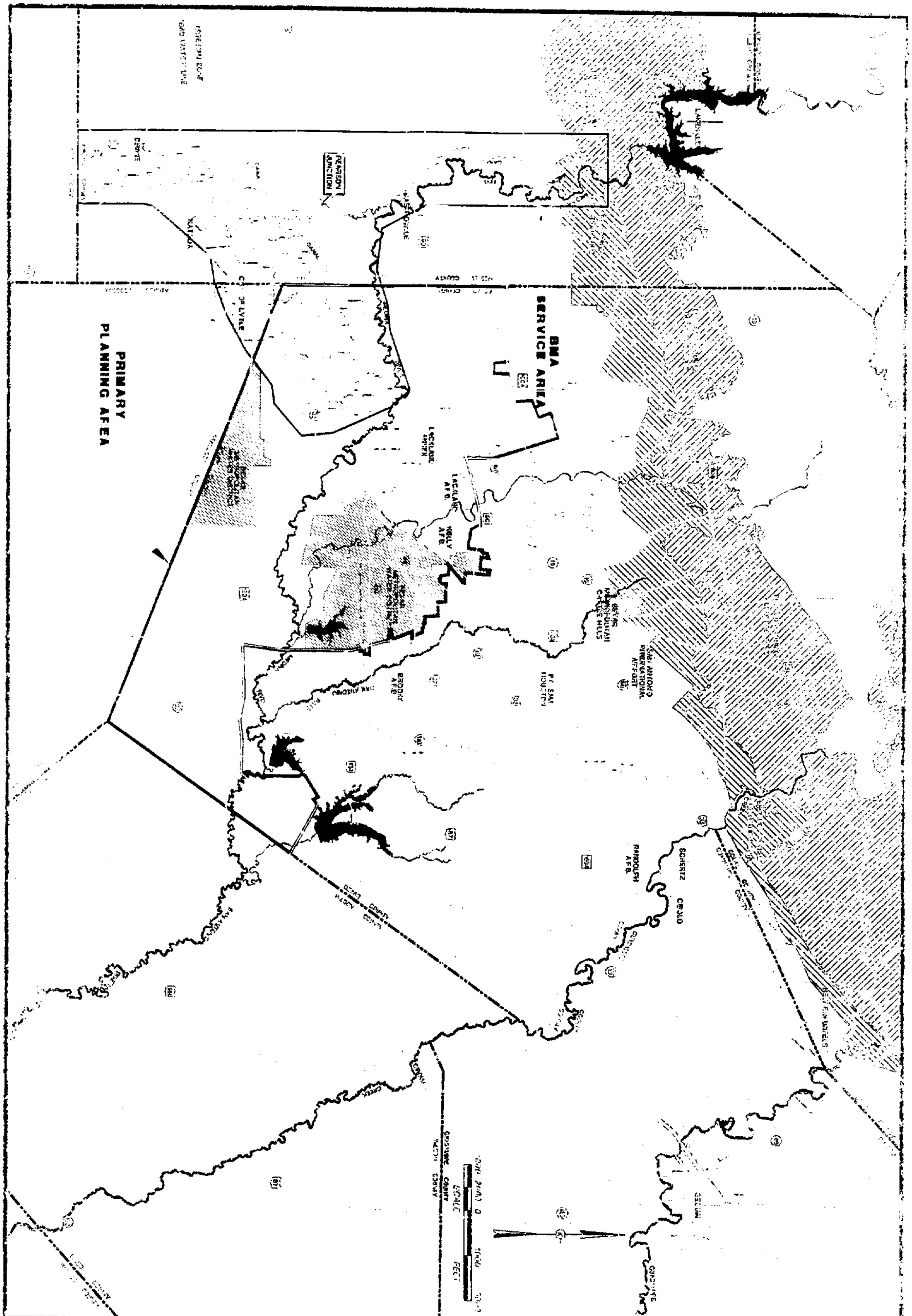
Wednesday, October 27, 1993

Hosted By

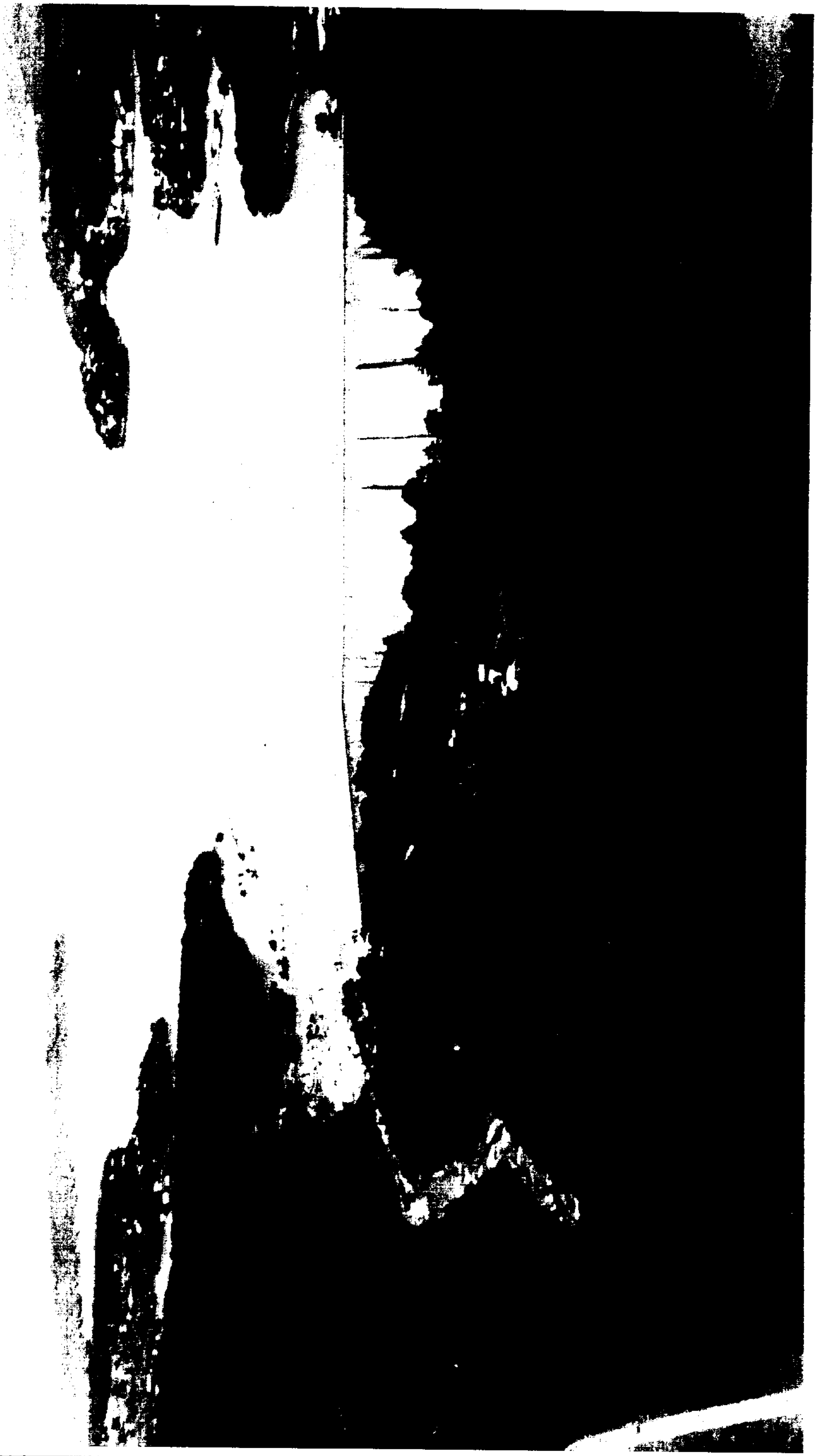
BEXAR-MEDINA-ATASCOSA COUNTIES WCID NO. 1
P.O. Box 170
Highway 132
Natalia, Texas 78059
Telephone: (210) 663-2132
Telecopier: (210) 663-3519

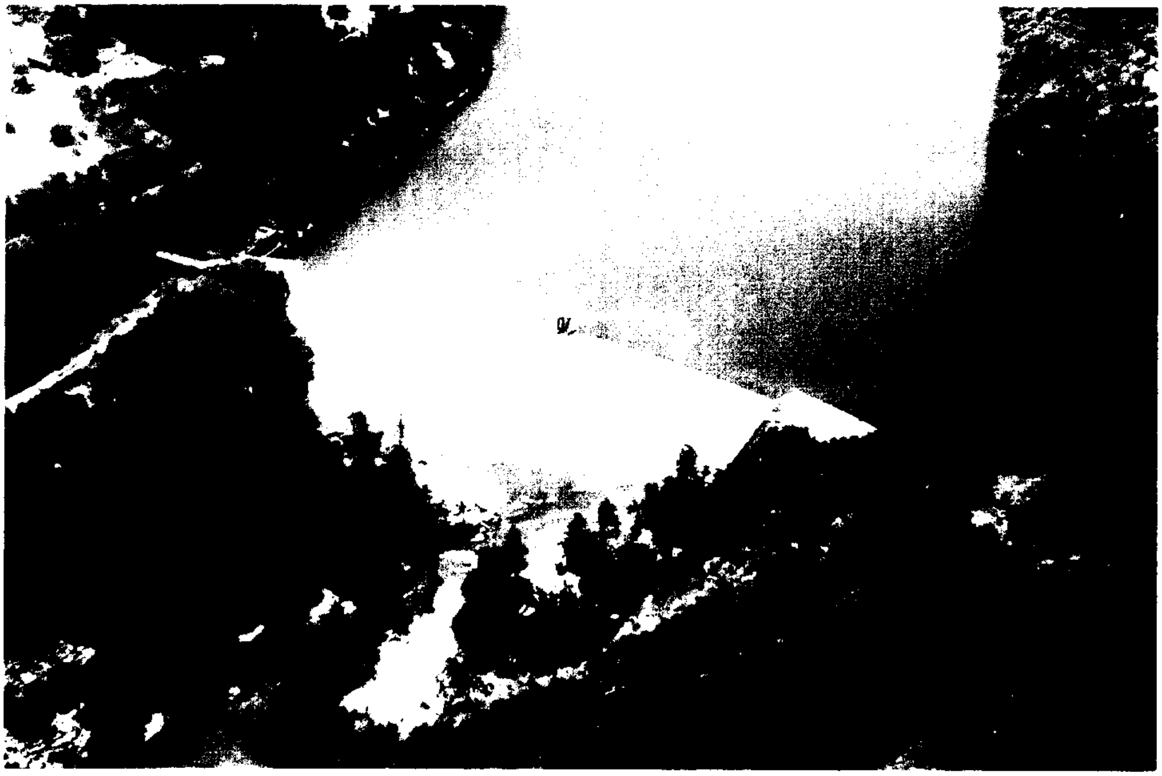
Stop 1	8:30	Meet at the Alsatian Inn, Highway 90, Castroville, Texas
Stop 2		Tour Medina Lake - Main Dam
Stop 3		Tour Diversion Lake - Diversion Dam and beginning of BMA Canal System, BMA Metering Program
Stop 4		Tour canal refurbishing sites, BMA syphon, and potential wetlands park near Castroville
Stop 5		Tour canal other BMA canals and meter sites as time allows
Stop 6	12:30	Lunch at the Alsatian Inn, Castroville, Texas, and return to Austin


MEDINA
LAKE
Elm Cove
Plum Creek Cove
DIVERSION
LAKE

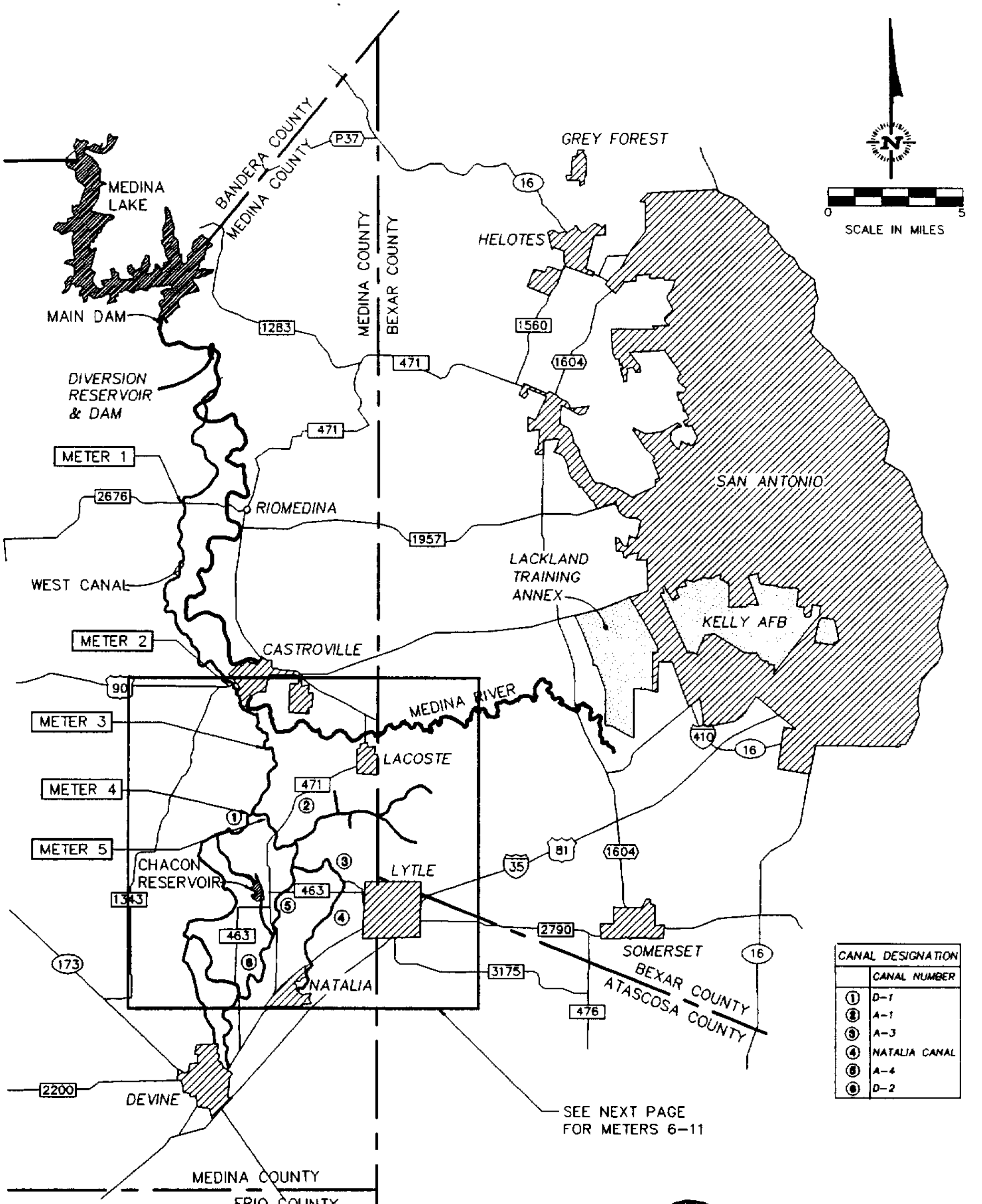


MICHAEL SULLIVAN & ASSOC., INC. Engineering & Environmental Consultants Air - Water Quality - Water Resources	BMWD and BMA Service Areas and Primary Planning Area	SUBMITTED TO: Bexar Metropolitan Water District FOR: Southern Bexar County Medina Valley Surface Water Supply Study	DATE: JULY 1990 DRAWN BY: DWH





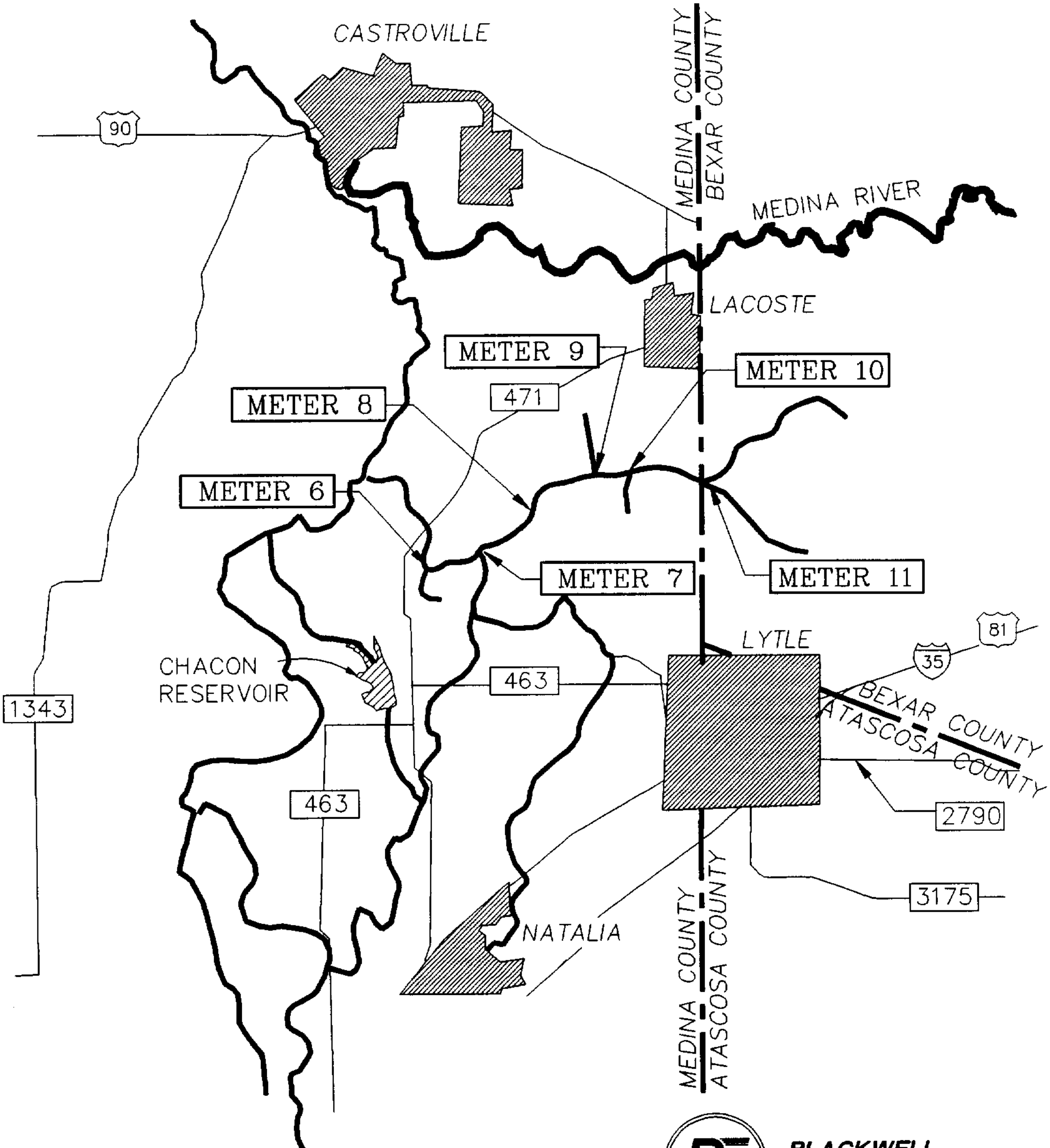
BEXAR - MEDINA - ATASCOSA
WATER IMPROVEMENT DISTRICT #1



CANAL DESIGNATION	CANAL NUMBER
①	D-1
②	A-1
③	A-3
④	NATALIA CANAL
⑤	A-4
⑥	D-2

BLACKWELL ENVIRONMENTAL INC.

BEXAR – MEDINA – ATASCOSA WATER IMPROVEMENT DISTRICT #1



BLACKWELL ENVIRONMENTAL INC.

of those rules and orders. The authority shall provide to the district notice that the delegation of authority to it has been terminated. After the termination notice is given, the authority of the district to manage or control water in the aquifer is limited to the authority granted by Subsection (b) of this section.

SECTION 1.43. CREATION OF UNDERGROUND WATER CONSERVATION DISTRICT. An underground water conservation district may be created in any county affected by this article as provided by Subchapter B, Chapter 52, Water Code.

SECTION 1.44. COOPERATIVE CONTRACTS FOR ARTIFICIAL RECHARGE. (a) The authority may contract with any political subdivision of the state under Chapter 791, Government Code, to provide for artificial recharge of the aquifer, through injection wells or with surface water subject to the control of the political subdivision, for the subsequent retrieval of the water by the political subdivision or its authorized assignees for beneficial use within the authority.

(b) The authority may not unreasonably deny a request to enter into a cooperative contract under this section if the political subdivision agrees to:

(1) file with the authority records of the injection or artificial recharge of the aquifer; and

(2) provide for protection of the quality of the aquifer water and of the rights of aquifer users in designating the location of injection wells or recharge dams, the methods of

injection or recharge, and the location and type of retrieval wells.

(c) The political subdivision causing artificial recharge of the aquifer is entitled to withdraw during any 12-month period the measured amount of water actually injected or artificially recharged during the preceding 12-month period, as demonstrated and established by expert testimony, less an amount determined by the authority to:

(1) account for that part of the artificially recharged water discharged through springs; and

(2) compensate the authority in lieu of users' fees.

(d) The amounts of water withdrawn under this section are not subject to the maximum total permitted withdrawals provided by Section 1.14 of this article.

SECTION 1.45. RECHARGE DAMS. (a) The authority may build or operate recharge dams in the recharge area of the aquifer if the recharge is made to increase the yield of the aquifer and the recharge project does not impair senior water rights or vested riparian rights.

(b) The commission shall determine the historic yield of the floodwater to the Nueces River basin. The historic yield is equal to the lesser of:

(1) the average annual yield for the period from 1950 to 1987; or

(2) the annual yield for 1987.

SECTION 1.44 (S.B. 1477)
SUMMARY OF POTENTIAL BENEFITS TO THE REGION

Implementation of Section 1.44 of Senate Bill 1477 authorizing political subdivisions to contract with the new Edwards Aquifer Authority to use the Aquifer to "transport" surface water via the Aquifer provides the following substantial benefits, at a minimum:

- Avoid $50 million estimated cost to build a pipeline from Medina Lake to San Antonio to transport Medina Lake surface water to Bexar County.

- The Aquifer as a transport mechanism is already in place and immediately available - avoids 5 to 10 year minimum delay to construct a pipeline.

- Avoid the potential environmental impact associated with construction of a conventional surface pipeline from Medina Lake to San Antonio, or anywhere else where the Aquifer can be used to transport surface water.

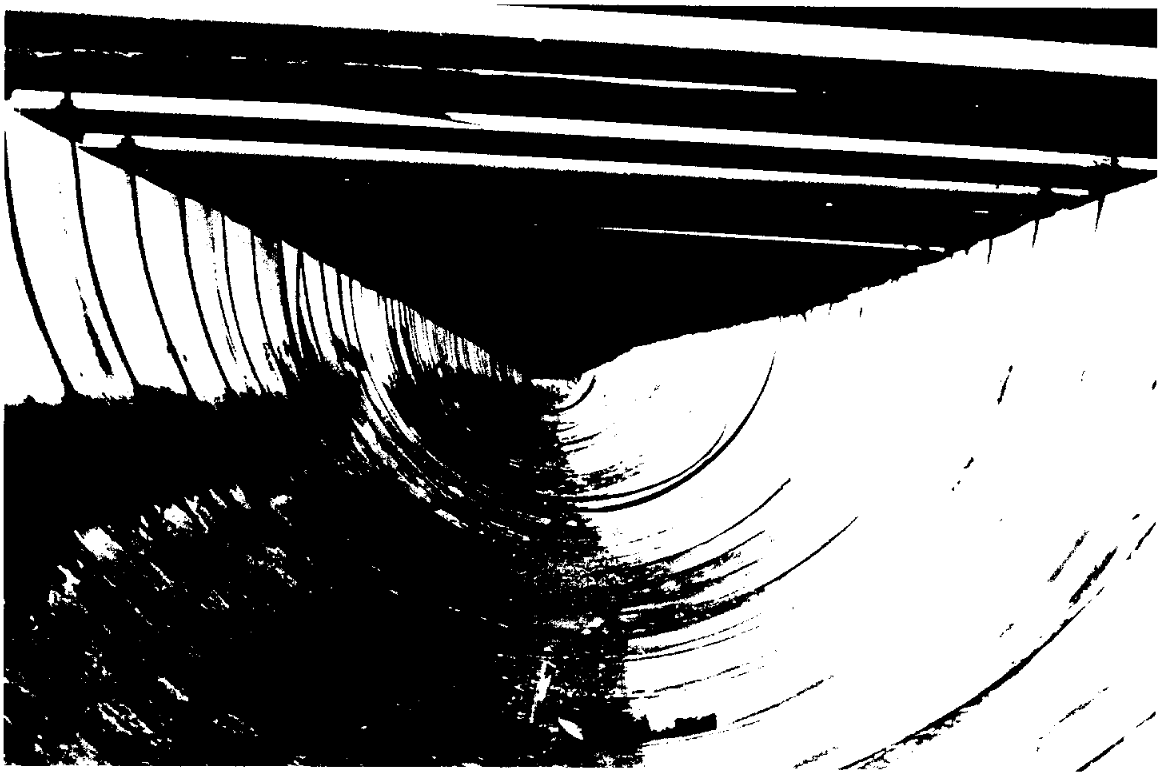
- Result in increased contributions to the Aquifer, as a portion of surface water injected into the Aquifer for transport must remain in the Aquifer for the benefit of the "common whole."

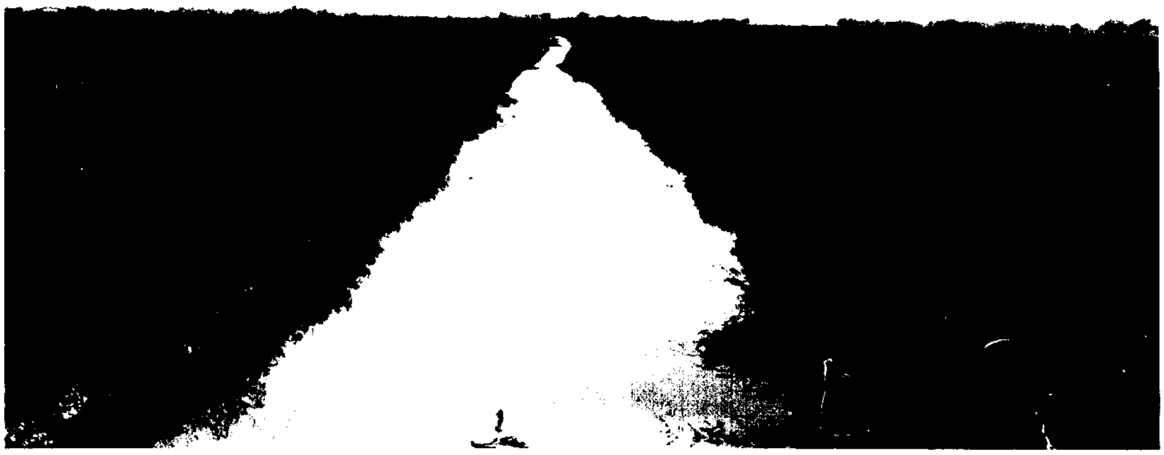
- Anticipate minimal, if any, environmental impact to the Aquifer other than increased volumes of water.

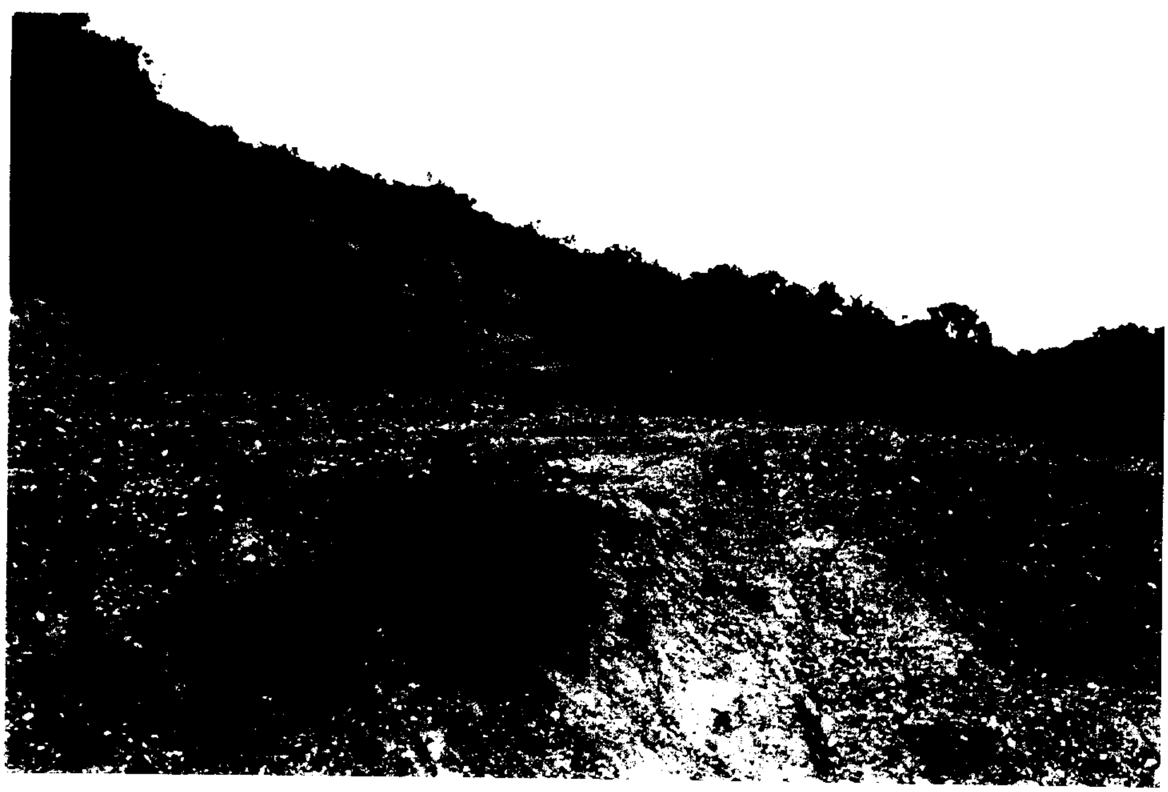
- Eliminates any evaporative losses from canals, reservoirs or streams used to transport water.

- Makes water "available" for sale to any pumper in the system.

- Aquifer will receive water not otherwise available by "natural" processes.







TEXAS WATER COMMISSION

PROTECTING TEXANS' HEALTH AND SAFETY BY PREVENTING AND REDUCING POLLUTION

April 12, 1993

Mr. John W. Ward, President
Bexar-Medina-Atascosa Counties WCID No. 1
Post Office Box 170
Natalia, Texas 78059

Re: Medina Lake Dam, Inventory No. TX 1787
Medina Diversion Dam, Inventory No. TX 1788

Dear Mr. Ward:

We have completed our review of the "Structural Stability Analysis for Medina Lake's Main and Diversion Dams" dated March 29, 1993, by Blackwell Environmental, Inc., for the BMA. This report and the monitoring program established for the structures have addressed the concerns outlined in our letter of April 4, 1990, (copy attached). Accordingly, by letter dated April 6, 1993, we have notified Mr. Doug Hearn, P.E., R.P.L.S., of Blackwell Environmental, Inc., that we agree that both dams should be considered structurally and hydraulically adequate, as designed for the current conditions at the site.

As you are aware, site conditions can change over time. Due to the sensitivity of these two projects to certain parameters, our acceptance of the future safety of the dams is conditional upon the continued monitoring program that has been established for the projects. Therefore, we would request that BMA periodically provide us with copies of the monitoring reports in order that we might continue our acceptance of the future safety of the dams.

If you have any questions concerning our position on the status of the dams, or if we can be of additional assistance, please feel free to call my office (512/463-7884).

Sincerely,

Warren D. Samuelson

Warren D. Samuelson, P.E.
Manager, Flood Management &
Groundwater Programs Section

DCS/am

cc: Edmond R. McCarthy, Jr., McGinnis, Lochridge & Kilgore, Austin
Jim Blackwell, President, Blackwell Environmental, Austin

TEXAS WATER COMMISSION

B. J. Wynne, III, Chairman
John E. Birdwell, Commissioner
Cliff Johnson, Commissioner

John J. Vay, General Counsel
Michael E. Field, Chief Hearings Examiner
Brenda W. Foster, Chief Clerk

Allen Beinke, Executive Director

April 4, 1990

Mr. C. A. Muellar, President
Bexar-Medina-Atascosa Counties WCID No. 1
P.O. Box 170
Natalia, Texas 78059

Re: Medina Dam
Inventory No. TX 1787

Medina Diversion Dam
Inventory No. TX 1788

Adjudication Certificate No. 2130(B)

Dear Mr. Muellar:

Thank you for your letter of March 27, 1990, concerning recommendations offered as a result of our inspections at your dams. We are in agreement with repairs undertaken or planned.

We have completed our review of the engineering reports on referenced dams prepared for the Edwards Underground Water District. We offer the following comments and recommendations:

1.) As indicated in the enclosed copy of our hydraulic study, the reservoir and tailwater elevations used in the stability analysis of Medina Dam are appropriate. We are also in agreement that the structure is hydraulically inadequate. Modification of the dam to withstand overtopping or to pass the probable maximum flood needs to be pursued. Hensley-Schmidt, Inc. indicated in their report of September 28, 1989, that the structure would not be threatened by erosion along the downstream toe if overtopped. It is recommended that this question be further addressed in conjunction with other studies recommended below.

2.) Our review of the stability analyses prepared by Prodek, Inc. and by Hensley-Schmidt, Inc. indicates that the analysis is sensitive to the values used in the assumptions. It also appears that both dams may be unstable during flood events. Due to the lack of reliable base line data and to the issues listed below, the detailed design report recommended by Hensley-Schmidt, Inc. should be undertaken as soon as possible to determine what modifications, if any, are needed for both dams.

3.) It is indicated in the geological assessment that: a) "faults occur beneath Medina Dam" and "in the vicinity of Diversion Dam"; b) the artesian well water originates from the lake and is possibly coming through a fault; and c) solutioning and large cavities may exist beneath the dam. We too have concerns about the faults, solutioning, and cavities and about the large seepage flows in the left (east) abutment and the apparent fluctuation of their discharge points. It appears that further study and monitoring are warranted and should be pursued as soon as possible. It would also appear that additional investigations may be necessary to determine if other solutioning channels or cavities exist.

4.) The effectiveness of the current relief well system is also a concern and should be addressed as part of the design report.

5.) The other recommendations given in the reports should also be implemented as soon as possible.

6.) If post tension anchors are to be used, will corrosion of the anchors be a problem?

We appreciate the opportunity to review the reports. All reports have been returned to the Edwards Underground Water District as requested. Final copies of the reports should be provided for Commission files as soon as they are available.

It is requested that the items listed in this letter be addressed as soon as possible. A time frame for completion of these items and for modification of the dams should be provided at an early date. In addition, the emergency action plan should be reviewed and updated. The revised plan should then be provided to all appropriate parties.

If there are any questions, feel free to call (512/371-6301).

Sincerely,

Warren D. Samuelson

Warren D. Samuelson, P.E.
Chief, Dam Safety and
Flood Management Section

WDS:ph
Enclosure

TEXAS WATER COMMISSION

PROTECTING TEXANS' HEALTH AND SAFETY BY PREVENTING AND REDUCING POLLUTION

April 6, 1993

Douglas Hearn, P.E., R.P.L.S.
Blackwell Environmental, Inc.
9020 Capital of Texas Highway North
Bldg II, Suite 550
Austin, Texas 78759

Re: Medina Lake Dam, Inventory No. TX 1787
Medina Diversion Dam, Inventory No. TX 1788

Dear Mr. Hearn:

We have completed our review of "Structural Stability Analysis for Medina Lake Main and Diversion Dams", dated March 29, 1993. Based on your investigations and study we agree that both dams should be considered as structurally and hydraulically adequate, as designed, for the current conditions at the site. Because of the sensitivity of these sites to certain parameters such as uplift pressures, our acceptance of the future safety of the dams is conditional upon the the continued monitoring program that has been established for the projects.

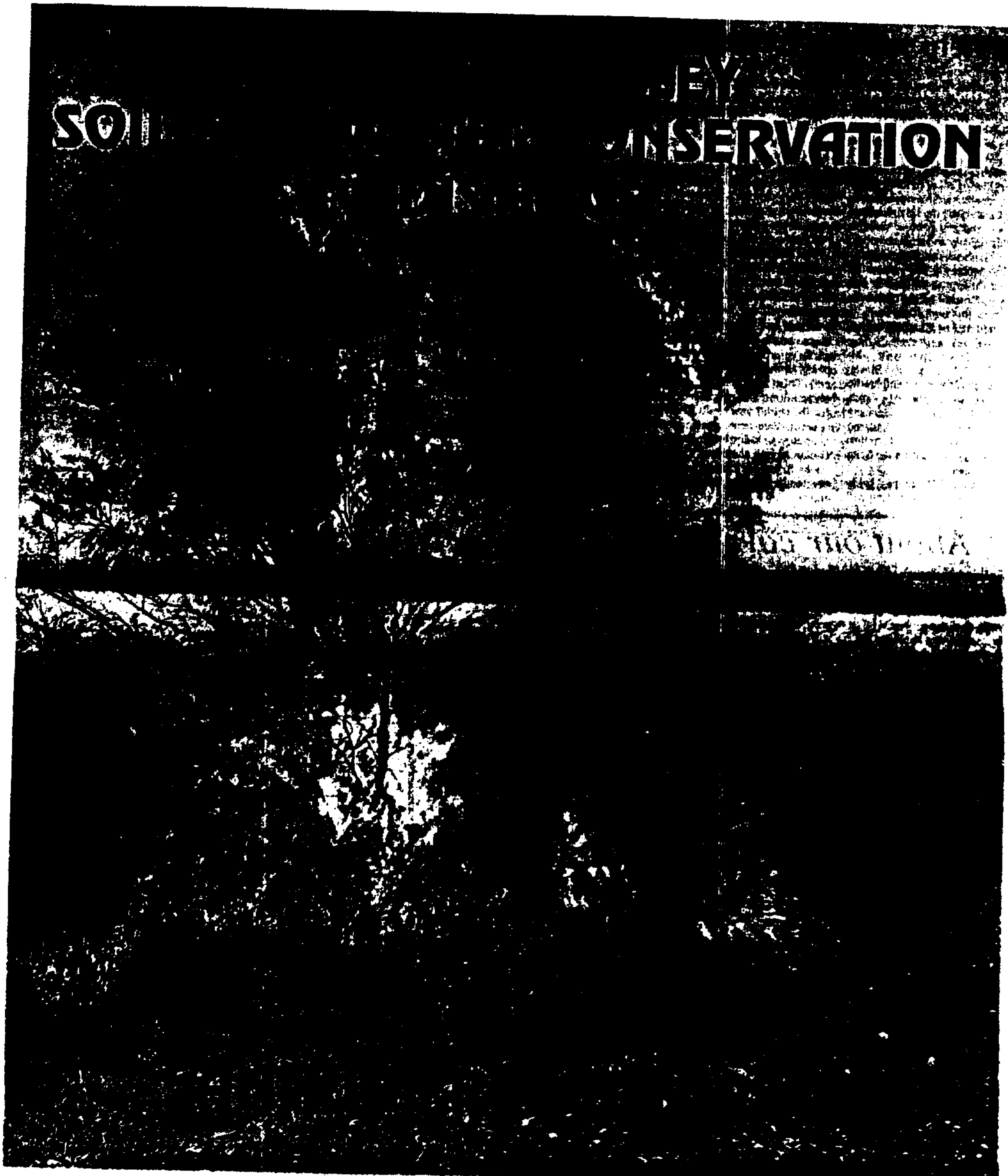
If you have any questions concerning our position on the status of the dams, or if we can be of additional assistance, please feel free to call my office (512/463-8575).

Sincerely,

Warren D. Samuelson

Warren D. Samuelson, P.E.
Manager, Flood Management & Groundwater
Programs Section

DCS



Medina Lake: Rediscovered resource

BMA begins upgrade, looks to the future

Long ignored by all but the farmers in Medina and western Bexar counties and the individuals who came to know the relaxation of recreation on its calm waters, Medina Lake and its owner, the Bexar-Medina -Atascosa Counties Water Control & Improvement District (BMA), have been thrust recently into the public's eye. Although more than 80 years old, Medina Lake and the BMA irrigation system has only recently attracted the attention of municipal water users in the central Texas region.

Spurred on by the growing water crisis created by the overdrafting of the region's sole source of drinking water– the Edwards Aquifer– and the ruling by a Federal Judge earlier this year that the overdrafting would have to come to an end, municipal water users, particularly in Bexar County, have begun eyeing Medina Lake. The only existing surface water resource in the region, it is coveted as a potential source of supplemental municipal water supplies.

The concept was no surprise to the folks at BMA. They had long ago conceived of using Medina Lake as a municipal water source, and begun work to bring the idea to fruition. In fact, the only surprise to BMA was why it took so long for everyone else to figure out the potential value of Medina Lake.

Medina Dam was constructed during a 53-week period between November 11, 1911 and November 28, 1912. total cost of the Dam was $1,550,750. These are remarkable figures when compared to the costs and time frame associated with even smaller reservoirs today.

The lake, which holds some 254,000 acre-feet of water, provides up to 66,000 acre-feet of irrigation water annually.

Continued urbanization within the BMA system has resulted in a reduced demand for irrigation water during the past decade. Annual demands for irrigation water within the system have dropped to approximately 39,000 acre-feet per year. The excess deliverable water from the Medina Lake can be made available for other beneficial uses, including municipal use.

As early as 1986, BMA began actively investigating ways to convert its excess irrigation water to municipal water for use by BMA's neighbors in Medina, Bexar and Bandera counties. These efforts climaxed in August 1991 when BMA signed a long-term water supply agreement for the sale of these excess waters to the Bexar Metropolitan Water District (BexarMet).

BexarMet, the second largest retail municipal water system in Bexar County had contracted with BMA to obtain a surface water supply to supplement its groundwater supply – the Edwards Aquifer. The agreement between BMA and BexarMet contemplated use of the water by BexarMet as well as other municipal users in Bexar and Bandera counties.

Due to the age of the BMA system and the limited maintenance that had been performed during this 80-plus year history, BMA undertook an intensive refurbishing effort to improve the transportation and efficiency of the canal delivery system.

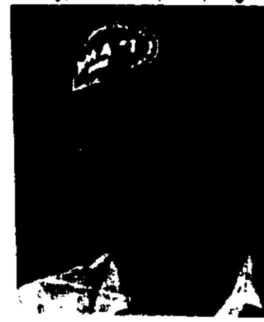
In part, this effort was spurred on by BMA's initiation of water conservation programs within the system beginning in 1990, which led to the formal adoption of a Water Conservation Plan in October 1992. BMA realized that through conservation it could meet its existing and future demands for irrigation water and increase the amount of excess water that could be made available for municipal use.

BMA's refurbishing efforts began in earnest in 1992 with a five-year program to spend $300,000 per year within the system on conservation-oriented projects. In 1992 and early 1993, a portion of these monies were used in a matching grant program sponsored by the Soil Conservation Service involving the repair of slides on canal banks along approximately five miles of the canal. A portion of the first year's money was also used to purchased specialized machinery capable of more efficiently and effectively maintaining and repairing the canal system. To date, BMA has upgraded more than 60 miles of the system's Main Canal through repairs, relining and refurbishing efforts.

In a related conservation effort, BMA identified the need to locate and correct losses from the canal system caused by seepage and evaporation aggravated by poor transportation efficiencies and, in some instances, unauthorized "borrowing" of water. To accomplish this goal BMA obtained matching grant funds from the Texas Water Development Board (TWDB) to install five flow meters along the Main Canal from Diversion Lake to the Pearson Junction in Medina County. BMA has plans to install additional meters to monitor the losses along all of its primary canals within the system. To further those plans, BMA has an application pending before the TWDB for additional matching grant funds. If approved, that grant would allow BMA to install meters along the Main Canal into Bexar County.

In addition to completing its refurbishing efforts along the canal system, BMA plans to conduct soil surveys and analysis throughout the system. This information will then be used in a pilot project in which BMA plans to monitor irrigation techniques and demands within the various soil types in the system to develop improved irrigation efficiencies. This information will then be distributed to the individual farmers for implementation.

All of BMA's water loss and efficiency information will also be used to assist BMA in the development of new water rates that will more accurately reflect the cost of the water. Presently, BMA charges customers for water on the basis of the number of acres of land to be watered, not the actual volume of water used. BMA expects to see a remarkable increase in water conservation in the system once volume based rates are adopted and users realize the value of the resource. BMA's long range plans include monitoring each individual water customer's irrigation turnout(s) either with a permanently installed or portable meter. Again, any savings in Medina Lake water attributed to reduced irrigation demand can be converted to municipal use.



Kirk Decker, BMA Manager

To complete the steps necessary for BMA to realize its goal of making water available for municipal use, BMA has pending before the Texas Natural Resources Conservation Commission (formerly the Texas Water Commission) an application to amend its present authorization to divert water from Medina Lake for irrigation use to the additional use of "municipal purposes." That application is scheduled for action by the Commission on Dec. 1, 1993.

Though unrelated to BMA's direct conservation efforts, between March 1990 and April 1993, BMA undertook a significant effort to protect and promote the value of Medina Lake as a surface water resource. Relying upon assumptions that were unsupported by actual field tests or data, the Edwards Undergound Water District (EUWD) had previously raised questions about the stability of Medina Dam. EUWD representatives went so far as to describe this engineering marvel as being a mere "blob of concrete."

As a result of this mischaracterization, BMA spent in excess of $135,000 over a three-year period to conduct an in-the-field engineering analysis of both the Medina and the Diversion dams [illegible] stability of the structures during an occurrence of a 100-year flood event and even the theoretical "Probable Maximum Flood (PMF)" event. In April 1993, the Texas Water Commission accepted the conclusions of BMA's engineering analysis.

John Ward
Chairman of the Board of BMA

BMA also has pending a request to the Soil Conservation Service, USDA, to develop a work plan leading into a "Small Watershed Project" pursuant to Public Law 566. This project, if authorized, would result in SCS providing technical and, possibly, financial assistance to BMA to further develop its conservation and resource enhancement efforts in the BMA system below the Medina and Diversion dams.

These efforts comtemplate enhanced canal refurbishing and repair efforts to facilitate greater conservation of water resources; identification of other environmental resources, including wetlands area which may require protection or replacement through mitigation; development of educational and recreational facilities within the system which emphasize BMA's environmental resources including fish and wildlife and their respective habitat; and, last but certainly not least, improved irrigation capabilities both for the system proper and the individual irrigation operations in the BMA system.

Each of these projects is an integral element of BMA's MasterPlan and its 25-year planning horizon. BMA has enjoyed and benefitted from its close working relationship with SCS and Medina Valley SWCD during the past several years. As BMA looks forward to carrying out the MasterPlan, which will take it into its second hundred years, BMA is eager to continue to strengthen its partnership with SCS and MVSWCD.

Bexar-Medina-Atascosa (BMA) Irrigation District Board during a recent business meeting. BMA, headquartered at Natalia, has recently started upgrading and developing long-range plans for the future operation of the District.