DRAFT

YCFCWCD-YZWD
Conjunctive Water Use Feasibility Study

Indian Valley Dam and Spillway

Cache Creek Dam

Capay Diversion Dam

Yolo County Flood Control & Water Conservation District

Woodland, California

July 2003

WOOD RODGERS
ENGINEERING ▪ PLANNING ▪ MAPPING ▪ SURVEYING
3301 C Street, Bldg 100-B
Sacramento, CA 95816
Tel: 916.341.7760
Fax: 916.341.7767

WOOD RODGERS

July 31, 2003

Mr. Tim O'Halloran, General Manager
Yolo County Flood Control &
Water Conservation District
34274 State Highway 16
Woodland, California 95695

Dear Tim:

Subject: YCFCWCD-YZWD, Conjunctive Water Use Feasibility Study (8108.030) – Draft Report

Wood Rodgers, Inc. is pleased to submit its draft report on the feasibility of the District implementing a conjunctive water use project within the Yolo-Zamora Water District.

Although implementing a conjunctive water use project within the study area is not considered feasible at this time, information obtained in preparing the feasibility study should be beneficial in the future for both the District and Yolo County generally. This information includes:

1. The reservoir operations model developed for the District's Cache Creek System (i.e., Cache Creek, Clear Lake, and Indian Valley Reservoir) provides a tool to evaluate other scenarios to manage water within the Cache Creek watershed for water supply, flood control, and environmental restoration.
2. The groundwater model, with the data input and calibration performed for this study, provides a tool that can be expanded for application to the District's Cache Creek Recharge/Recovery Project and for a county or regional groundwater model as well.
3. The evaluation of canal design criteria provides a basis for the District to formalize design criteria to use in a system rehabilitation and improvement program.
4. The surveys and inventory performed provides information to facilitate evaluating and designing a rehabilitation/improvement program for the West Adams, East Adams, and Acacia canals.

Wood Rodgers appreciates having the opportunity to work on this study with the District and landowners within the Yolo-Zamora Water District, and looks forward to addressing comments or questions the District or others may have.

Sincerely,

Francis E. Borcalli P.E.

Enclosure (5)
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Corporate Office: 3301 C Street, Bldg. 100-B · Sacramento, CA 95816 · 916.341.7760 · Fax 916.341.7767
San Francisco Office: 94 29th Street · San Francisco, CA 94110 · 415.206.1098 · Fax 415.206.1658
www.woodrodgers.com

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INTRODUCTION

The Yolo County Flood Control & Water Conservation District (District), working with landowners within the Yolo-Zamora Water District (YZWD), has investigated the feasibility of implementing a conjunctive water use project within the YZWD. This investigation was made possible with grant funding from the State of California, Department of Water Resources (DWR) "Groundwater Storage Feasibility Study/Pilot Project," Grant Contract No. F90002. The location of the District in relation to the YZWD is shown on Map 1.

The YZWD was planned to be the recipient of supplemental surface water supplies from the Tehama-Colusa Canal Project when it was extended into Yolo County in the late 1960's. However, this never materialized. The Tehama-Colusa Canal was terminated at Bird Creek, just northwest of the YZWD with the Dunnigan Water District being the southern-most district served. The YZWD was the only entity, of the seven planned, to not receive water for irrigation from the project. As a consequence, water needs within the YZWD are met entirely from groundwater supplies. This reliance on groundwater has resulted in subsidence, in excess of five feet, being documented in the area over the last 50 years.

Recognizing the situation within the area of the YZWD as well as areas north of Woodland where water needs are met entirely from groundwater supplies, the District has long supported the concept of a conjunctive water use project within the area and has pursued such a project informally on a couple of occasions in the past. The funding made available by DWR for this feasibility study has facilitated a more complete assessment of the opportunity and potential for the District to assist the YZWD in this regard.

To perform this feasibility study, the District contracted the engineering services of Wood Rodgers, Inc. The services of the Water Resources Association of Yolo County (WRA) were utilized to assist with the public involvement component of the work.

BACKGROUND

The District, upon completing construction of Indian Valley Dam and Reservoir in 1975, determined the opportunity existed to expand the conjunctive use of surface water and groundwater. This opportunity and interest on the part of the District was reaffirmed when the Board of Directors adopted its Water Management Plan (Plan) in October 2000. The District's Plan identified two areas where opportunity appeared to expand the conjunctive water use to enhance groundwater storage. Two action items were outlined in the District's Plan to address these areas. These two areas involve lands fully developed for agriculture and rely almost entirely on groundwater for irrigation. One area is west and north of the City of Woodland and the other area is the YZWD.

For the reasons stated above, the District applied for grant funding to investigate the feasibility of more efficiently utilizing water supplies available from the District's Cache Creek System, i.e., Cache Creek, Clear Lake, and Indian Valley Reservoir, while providing environmental benefits consistent with goals of the County and resource agencies. It was anticipated the efficient use of these water supplies would increase groundwater storage to enhance the groundwater supply for the YZWD to avoid or minimize additional land subsidence in the area as a result of groundwater extraction. Land subsidence reportedly has adversely affected wells in the area, as well as increasing the extent of flooding from drainage along the Colusa Basin Drain. The project envisioned for this conjunctive use project involves improved management of available water supplies and opportunities for environmental benefits, and improvements to the District's existing West Adams Canal system and China Slough, a natural but substantially modified storm drainage channel.

The District has easements and rights-of-way along its canal system; however, easements along China Slough would need to be obtained from landowners to facilitate performing operations and maintenance activities in that area.

PUBLIC INVOLVEMENT

The public involvement part of this feasibility study was an important part of the overall work. Accordingly, at the onset of the work, the District developed an approach to deal with: (1) the prospective water users, and (2) the general public including the water users.

The involvement of the prospective water users was dealt with in creating a Project Advisory Group (PAG). The PAG was comprised of water users/landowners within the District and within the YZWD. From May 2002 to March 2003, nine meetings of the PAG were held throughout the course of the study with landowners and water users to obtain input and guidance on alternative projects, the analyses, and ultimately the feasibility of the concept. The analyses and results of the input and guidance received from the PAG are embodied in this report.

With respect to the involvement of the general public, one public workshop was held in Woodland on January 30, 2003. This workshop was conducted by the WRA.

Additionally, WRA staff held extensive communications with local and regional agricultural and urban water agencies; environmental and public interest groups; and local environmental leaders to gain an understanding of their issues, viewpoints, and concerns related to the proposed conjunctive water use project. The results of the public involvement effort by the WRA are summarized in Appendix A.

STUDY AREA

This section of the report provides background resource information on the study area that is generally the YZWD as delineated on Map 1.

Land Use

DWR compiled land use information for Yolo County in 1961, 1973, 1976, 1981, 1989, and 1997. The land use data compiled for 1989 and 1997 is available in electronic form and is used herein to describe the study area. Presented on Map 2 and Map 3 are the land uses in Yolo County in 1989 and 1997. The respective land uses for the YZWD in relation to Yolo County are summarized on Table 1 for 1997. As noted, the YZWD represents only three percent of the County. The gross area within the YZWD is 22,332 acres including “islands” or parcels excluded from within “legal” boundaries of the YZWD. As indicated on Table 2, the area is fully developed with field and truck crops comprising about 82 percent of the land. Land in urban-type uses represents just less than 3 percent of the area.

Water Use

Water used for agricultural, urban, and domestic uses within the study area is entirely from groundwater supplies. An estimate of the magnitude of water use was made for agricultural production for “normal” and “critical dry” years utilizing unit water use figures developed by DWR (Table 3). Using the unit water use figures an estimate of the total agricultural water use for irrigation was made for "normal" hydrologic conditions. These results are presented on Table 4. As shown on Table 4, the average applied water for the 1997 crop mix is 2.36 acre-feet/acre.

Groundwater

Groundwater, general levels and historic behavior over time, is best represented by well hydrographs and groundwater contour maps. Groundwater levels are monitored by the District, the U. S. Bureau of Reclamation, and DWR, and compiled in an overall groundwater database maintained by DWR. However, at this time groundwater data gathered by other districts, cities, and the County are not forwarded to DWR to compile in the database. Information compiled for selected wells in the study area is presented on groundwater level hydrographs on Figure 1and Figure 2. In general, the groundwater levels in the area, after having gone through the 1976/77 drought and the 1987/1992 drought, have held up very well. The water levels declined during the drought years, however, recovered reasonably well following the drought. Presented on Map 4 is a representation of the spring to fall changes in groundwater levels in Yolo County for 2002. As indicated, the seasonal drawdown in the study area is somewhat greater than the balance in the County.

Subsidence

The east side of Yolo County, generally from Davis to Woodland and to the Yolo Zamora area, is susceptible to subsidence. This is well documented from early surveys conducted by DWR in cooperation with the U. S. Geological Survey as shown on Figure 3, which shows information up to 1981. More recent subsidence surveys are being performed as part of a subsidence monitoring program implemented as a cooperative effort on the part of districts, cities and the County, and DWR. The original Global Positioning System survey to establish a subsidence monitoring network in Yolo County was accomplished in 1999. A network survey was conducted in 2002, with the next survey is scheduled for 2005. The results of the surveys conducted in 2002 are presented on Figure 4. The surveys were performed in July-August, when groundwater pumping is at or near the seasonal maximum, thus the readings may be affected by the elastic behavior of the ground when groundwater pumping is occurring. Generally it would be best to obtain the data in the spring after the land would have had an opportunity to “rebound” and pumping for irrigation is generally minimal. Assuming the behavior of the ground in relation to pumping was similar from 1999 to 2002, the data compiled does represent relative ground movements in response to groundwater pumping. Referring to Figure 4, it can be seen that the greatest ground lowering occurred in the study area. Referring back to Figure 2 and

Figure 3, it would appear, although no groundwater level readings were reported in 1999, that groundwater levels during this 1999-2002 period remained relatively constant. If, in fact, the decrease in land elevation of up to seven centimeters occurred during this period, it may be the result of groundwater lowering that occurred during previous drought periods.

WATER SUPPLY ALTERNATIVES

The concept of the conjunctive water use project and the grant application was based upon utilizing the District's existing water supply to provide supplemental water for irrigation within the YZWD. During the course of the study and from input received during the PAG meetings, it became desirable to examine other water supplies. Accordingly, the study was expanded to consider utilizing "winter" water from Cache Creek and the Colusa Basin Drain. Although the Colusa Basin Drain is an element of the Sacramento River System, the Sacramento River was not considered in the water supply alternatives. As a result of work completed previously by the District, working with other water purveyors in both Yolo and Solano counties, the District filed applications for appropriating water from the Sacramento River. The City of Woodland and the City of Davis, jointly with the University of California, Davis, are investigating the feasibility of utilizing water under this application.

Each of the alternative water supplies considered for this feasibility study are discussed below.

District's Cache Creek System

The District's surface water supply consists of the Cache Creek System, which includes Cache Creek upstream of the Capay Diversion

Dam, Clear Lake, and Indian Valley Reservoir. The respective facilities are shown on Map 5. The water supplies available from the District's Cache Creek System are the result of water rights acquired or appropriated on its own behalf. These water rights are summarized below.

Surface Water

Riparian Rights – The District owns land on Cache Creek and the North Fork Cache Creek that have riparian rights. These rights are used for purposes of irrigation and hydroelectric power generation.

Pre-1914 Water Rights – The District has an 1855 priority right to the natural flow of Cache Creek, and 1912 priority right to store water in Clear Lake to El. 7.54 on the Rumsey Gage for later release and beneficial use, including irrigation, municipal use, and hydroelectric power generation. These rights allow for the storage of 313,000 acre-feet in Clear Lake.

Post-1914 Water Rights – The District has permits for Indian Valley Reservoir, which allow for the storage of 300,000 acre-feet during the winter for later release for irrigation and to generate hydroelectric power.

The District has also filed an application to appropriate up to 90,000 acre-feet from Cache Creek. This water is intended for groundwater storage.

Groundwater

To the extent the District delivers water into an area that becomes part of the underlying groundwater, the District may claim a right to that water.

The various components of the District's water supply system are described below.

Clear Lake **–** Clear Lake is a large shallow natural body of water with a surface area of approximately 44,000 acres when full, and has a maximum depth of approximately 50 feet. The lake is operated under the terms of the "Solano Decree" (February 1978). This decree stipulates the amount and rate by which the District can withdraw water between the limits of zero and 7.54 feet on the Rumsey Gage, which is located on Clear Lake at Lakeport. Zero on the Rumsey Gage is regarded as the natural rim of the lake. At zero, water ceases to flow into Cache Creek. Runsey Gage 7.54 feet is considered a "full" lake with 313,000 acre-feet of storage. The District's allowable withdrawal from Clear Lake is determined by the stage of Clear Lake on May 1. The maximum withdrawal is 150,000 acre-feet. If the stage of Clear Lake is 3.22 feet or less on the Rumsey Gage on May 1, the District may not withdraw any water to deliver downstream of Cache Creek Dam that season. Clear Lake provides no carryover storage. Therefore, the District attempts to use its full allowable withdrawal each year.

The District owns and operates Cache Creek Dam, a conservation structure constructed on Cache Creek approximately five miles downstream of Clear Lake. The structure, constructed in 1914, is approximately 49 miles upstream from the District's Capay Diversion Dam.

The District, in cooperation with the U.S. Geological Survey (USGS), operates and maintains a stream gage approximately 400 feet downstream of the Cache Creek Dam.

Indian Valley Dam and Reservoir – In 1975, the District completed construction of the Indian Valley Dam and Reservoir. The Indian Valley Dam and Reservoir are owned and operated by the District. The dam and reservoir are located on North Fork Cache Creek approximately 54 miles upstream from the District's Capay Diversion Dam.

When full, Indian Valley Reservoir has a surface area of 4,000 acres and a total storage capacity of 300,600 acre-feet. Forty thousand acre-feet of the reservoir storage is dedicated to flood control. Unlike Clear Lake, Indian Valley Reservoir provides carryover storage.

The District, in cooperation with the USGS, operates and maintains a stream gage on the North Fork Cache Creek near Highway 20.

Cache Creek – Downstream of Clear Lake and Indian Valley Dam and Reservoir, the most significant streams are Long Valley Creek, a tributary to North Fork Cache Creek, and Bear Creek. All precipitation in the Cache Creek watershed occurs as rainfall. Thus, runoff drops off sharply following winter and spring rainfall.

DWR operates and maintains a stream gage on Cache Creek near Rumsey. The District, in cooperation with the USGS, operates and maintains a stream gage on Cache Creek near the town of Yolo.

System Operation/Water Supply

As noted above, the operation of Clear Lake is governed by court decrees with very specific provisions affecting the amount and timing of water releases from Clear Lake. Indian Valley, on the other hand, has a great deal of flexibility from an operational standpoint.

The District's basic management objective of its water supply system is to utilize runoff in Cache Creek first. If runoff in Cache Creek is not sufficient to meet the irrigation demand, the District will withdraw from Clear Lake in accordance with the Solano Decree. Once the District compiles its "water orders" and estimates its seasonal demand, the District will then determine the amount of water required from Indian Valley Reservoir. Releases from Indian Valley Reservoir are made to augment releases from Clear Lake on as uniform a basis as possible. In years when inadequate water supplies are available from Clear Lake, the District will withdraw water from Indian Valley Reservoir. Water supplies from Indian Valley Reservoir are used to meet current year demand. The facility is not operated to maximize carryover storage. Although Indian Valley Reservoir was designed to provide a firm yield of approximately 55,000 acre-feet, the District determined it was most efficient, from a water management standpoint, to operate to meet demand in a given year even though there may be no water available in subsequent years. This was the case in 1990, when the District had little or no water to deliver from Clear Lake or Indian Valley. This operational strategy maximizes storage in the groundwater basin, which is the most efficient reservoir available to land within the District. If Indian Valley were operated on a firm yield basis, the frequency and magnitude of flood spills would be greater than under current operations. Water "dumped" as a flood spill is essentially lost from the standpoint of Yolo County.

A reservoir operations model was developed to characterize the water supply and reliability of the supply available from the Cache Creek System. The model was developed to simulate operations for the hydrologic period 1921-2002. The model was constructed using MIKE-BASIN software developed by the Danish Hydraulic Institute, and is run inside Microsoft Excel. MIKE BASIN processed quantitative data and Excel managed the operating rules stipulated in the Solano Decree through macros in Visual Basic Computer Code. The model provides flexibility to some of the input variables such as irrigation diversions, winter diversions, and simulation time periods, decision criteria for Indian Valley operations was used to develop the operations model. The results of the operation in terms of annual water delivery and reliability of meeting that demand are presented on Figure 5. The existing system demand (diversion at Capay) over the past years ranged from approximately 130,000 to 209,000 acre-feet.

The highest system demand of 209,000 acre-feet was used to represent the District's demand at Capay in all years. This is conservative from the standpoint of the water users within the District; however, for the purposes for which it being used, it was deemed appropriate. Based upon the operations model, the reliability of providing 209,000 acre-feet/year is approximately 67 percent as shown on Figure 5.

Water delivered to the study area will be subordinate to water delivered to water users within the District. Accordingly, the reliability of providing various amounts of supplemental water supplies to the study area was determined. The results of this analysis are presented on Figure 6. As illustrated on Figure 6, the reliability of supplemental water supplies of 5,000 to 10,000 acre-feet is about 67 percent, and the reliability of greater amounts decreases rather sharply. Accordingly, for purposes of this study it appears a conjunctive use project using the District's existing water supplies should be sized on a water supply of 10,000 acre-feet.

Cache Creek "Winter" Water

As noted previously, the District has filed an application to appropriate water from Cache Creek as part of a groundwater recharge/recovery project. To utilize "winter" water from Cache Creek for a conjunctive use project in the study area, will require storage. The concept envisioned would be to provide seasonal storage whereby water, when available, would be diverted in the non-irrigation season to storage, and withdrawn to meet irrigation demands in the summer. To characterize the availability of "winter" water from Cache Creek, the reservoir operations models were used. A winter diversion capacity of 100 cfs was assumed for purposes here. Presented on Figure 7 is the reliability of a "winter" water supply from Cache Creek.

Colusa Basin Drain "Winter" Water

The water in the Colusa Basin Drain is fully appropriated in the summer, however, during the period of September through April, based upon research performed by the District in filing an application in 1994 for appropriating water from the Sacramento River, water would be available for appropriation virtually every year, thus constituting a "firm" water supply.

The quality of water from the Colusa Basin Drain is of concern to the City of Sacramento and other downstream users of the Sacramento River for municipal water supplies. Data recently compiled on water quality of the Colusa Basin Drain was examined from the standpoint of its suitability for irrigation. The information compiled and evaluated is presented in Appendix B. From this examination of the water in the Colusa Basin Drain, it appears the high sodium absorption ratio of the water combined with the fine-grained soil in the study area have the potential to put a significant amount of sodium into the soil thereby resulting in reducing infiltration rates. A careful assessment of the soil-water management will be required for the use of this water.

PROJECT ALTERNATIVES

In working with the PAG, four alternatives were identified for delivering various sources of supplemental water to the study area for irrigation. The respective alternatives are as follows:

- § Alternative No. 1. – District Water with West Adams Canal Conveyance
- § Alternative No. 2 – District Water with Cache Creek Conveyance
- § Alternative No. 3 – Cache Creek “Winter” Water with Seasonal Storage
- § Alternative No. 4 – Colusa Basin Drain “Winter” Water with Seasonal Storage

A description of each alternative follows.

Alternative No. 1

Alternative No. 1 is based upon using surface water from the District’s Cache Creek System when available. The availability of the water supply is predicated on meeting the demands of the District’s water users first. The water would be diverted at the Capay Diversion Dam into the West Adams Canal. The water would flow through the District’s West Adams Canal, East Adams Canal, and Acacia Canal, from which the water would be delivered to China Slough. The layout of the respective facilities is presented on Map 6.

Water Supply

Referring to Figure 6, it appears the maximum reasonable water supply would be approximately 10,000 acre-feet. This supply is available approximately 67 percent of the time or 6.7 years out of 10. The system was operated such that a full water supply or no water was available. The system was not operated to deliver a partial supply.

Service Area

Using a water supply of 10,000 acre-feet and an average water use of 2.36 acre-feet/acre indicates that approximately 4,200 acres could be irrigated. Assuming approximately 10 percent of the land is utilized as farm buildings, roads, etc., a gross service area of approximately 4,700 acres or approximately 22 percent of the YZWD.

Facilities Improvements

As described earlier for Alternative No. 1, the District’s existing system would be modified to accommodate water delivery to the study area. Delivering water to the study area during the summer will necessitate enlargement of the existing facilities. Currently, the District has no design criteria by which to evaluate the capacity of existing facilities or for designing new facilities. Accordingly, design criteria was developed for purposes of determining the capacity required to serve the study area and for evaluating the existing system. A discussion of the considerations given to formulating a design criteria is summarized below.

<u>Formulating Design Criteria</u> – The basis for sizing irrigation facilities must consider the level of service provided to the water users. From the standpoint of farm and water management, providing as much flexibility as possible would be desirable. Accordingly, from the standpoint of formulating design criteria for the District with the long-term prospects of system modernization and providing the water users flexibility in management and irrigation technology, a “demand” system would be desirable. A “demand” system will allow the water users to irrigate with no constraints or “congestion” imposed on the water users. A “demand” system can be advantageous to the water users; however, unless the District’s system is designed appropriately it can result in increased spills or reduced efficiencies on the part of the District unless the spills are recoverable. On the other hand, features such as re-regulating reservoirs, similar to Chapman Reservoir on the District’s Winters Canal, can be incorporated into the system at strategic locations to minimize or eliminate nonrecoverable spills. For purposes of this feasibility study, no attempt was made to evaluate the West Adams Canal system for such facilities. This analysis is limited to the canal capacity analysis.

References for canal sizing that recognize the needs of the water users include work completed by:

1. Clement, R., Le Calcul des Debits dans les Canalisations d’Irrigations. Journees d’etudes sur l’Irrigations, 27-30 June, 1955, Association amicable des Ingenieurs du Genie rural, Paris 19, Avenue du Maine, pp. 29-40, 1956.

2. Clemmens, Albert J., canal Capacities for Demand Under Surtace Irrigation, Journal of Irrigation and Drainage Engineering, ASCE, Vol. 112 No. 4. Nov. 1986.

The relationships developed by Clement take into account particular aspects of the service area including turnout capacity, time the system is in service, and the probability or degree of reliability that water will be available when required by the water user.

The relationships developed by Clemmens represents a "demand" and "arranged" service system. Under the "demand" system the water user can open and close the turnout without coordination with the District. Under the "arranged" system, the water user coordinates the opening and closing of the turnout with the District.

Using both references, calculations were performed to develop comparative design criteria for canal sizing. A memorandum addressing the analysis is presented in Appendix C. The results of the analysis are presented on Figure 8.

Evaluation of Existing System

The upper reach of the West Adams Canal from the Capay Diversion Dam to the Hungry Hollow Canal turnout is in need of repair. Physical data on the West Adams Canal are not available to evaluate the existing capacity in relation to the capacity required to serve the study area or a desired "target" level of service. Accordingly, the West Adams Canal, East Adams Canal, Acacia Canal, as well as China Slough, were surveyed during the irrigation season of 2002, to complete the work within the time frame of the grant. In view of the time frame, the survey could not be as complete as it would have been if the work had been performed when the system was out of service. However, the information provides an inventory of the system and was suitable for evaluating the existing capacity and assessing modifications required to accommodate the capacity to modernize the system and serve the study area.

The capacity of the existing system was estimated throughout the entire reach of the canal system presented on Map 6. The existing capacity is presented on Plan and Profile Drawings in Appendix D. Also presented is the design flow for the system with and without service to the study area under the "demand" design criteria. The same information is presented on drawings in Appendix E for the system with and without service to the study area under the "arranged" design criteria.

Alternative No. 2

Alternative No. 2 is based upon using surface water from the District's Cache Creek System similar to Alternative No. 1. Rather than water being diverted into the West Adams Canal, water would be allowed to pass the Capay Diversion Dam and conveyed in Cache Creek down to Interstate 5 where the water would be diverted and delivered to China Slough. It is recognized that water would be lost to the District's delivery system due to percolation along the reach of Cache Creek from County Road 85 to Interstate 505; however, recoverable by groundwater extraction. On the other hand, water that currently spills from the end of the West Adams Canal through the Salsbury Spill, just upstream from County Road 94B, would be recoverable. In addition, conveying water throughout the entire reach of Cache Creek from the Capay Diversion Dam to Interstate 5, may be advantageous in relation to assisting Yolo County to fulfill some of its goals for environmental restoration as presented in the Cache Creek Resources Management Plan.

A modification of this alternative, which has been considered by the District, previously, although not examined in this study, would be to recover the water in the vicinity of the District's existing Moore Canal crossing of Cache Creek and diverting the water to the lower reach of the West Adams Canal.

Water Supply

The water supply available for Alternative No. 2 is considered the same as for Alternative No. 1, i.e., 10,000 acre-feet with a reliability of 67 percent. For purposes of this study it is assumed the losses along Cache Creek would be made up through the recovery of water flowing through the Salsbury Spill.

Service Area

The gross service area for Alternative No. 2 would be 4,700 acres, the same as for Alternative No. 1.

Facilities Required

The facilities required for Alternative 2 are presented on Map 7. The primary facilities include a diversion structure in Cache Creek to create a forebay for a new pump station. The pump station required for Alternative No. 2 includes a diversion structure that would discharge into a buried pipeline and convey the diverted water to the head of China Slough. The improvements to China Slough consists largely of clearing and establishing a road for operations and maintenance and construction of check structures at various locations to create a forebay from which water users could pump water for irrigation. It is anticipated the water users would install portable units similar to current diversions along the Acacia Canal.

Diversion Dam – It is anticipated that a diversion dam consisting of an inflatable rubber dam similar to the one installed at the Capay Diversion Dam would be constructed immediately upstream of the Interstate 5 bridge. The dam would be 10 feet high and approximately 100 feet long. The dam would be inflated to create the forebay for the pump station. When not required for diverting water, the dam would be deflated.

Pump Station – The pump station would be designed to deliver 115 cfs to the head of China Slough. The pump station would be equipped with three 450 hp units and one 250 hp unit. One of the 450 hp units would be a standby unit and used in the event one of the other units was down for repair or servicing. The intake to the pump station would be cylindrical stainless steel wedge-wire screens with an air-scouring cleaning system.

Conveyance Pipeline – Approximately 12,300 lineal feet of 60-inch diameter pipe will be required to deliver water from the pump station to the head of China Slough.

China Slough Improvements – As noted in Alternative No. 1, China Slough currently has adequate capacity for irrigation. The channel will be cleaned and an operating road will be constructed along the entire length to facilitate operations and maintenance of the channel, as well as to facilitate locating portable pumping unit by individual water users. An estimated eight check structures will be required to control the water level in China Slough to facilitate pumping by adjacent water users.

Alternative No. 3

Alternative No. 3 is based upon using surface water made available by diverting water from Cache Creek during winter months to a storage facility in the Dunnigan Hills in the winter months, and withdrawing the water for irrigation the following season. Water will be diverted at the Capay Diversion Dam into the West Adams Canal and conveyed through the West Adams Canal, Hungry Hollow Canal, Goodnow Lateral, Drake Ditch, and Clover Canal to the CR19 reservoir, a water storage facility in the Dunnigan Hills. The layout of the respective facilities for Alternative No. 3 is presented on Map 8.

Water Supply

Referring to Figure 7, it appears that approximately 35,000 acre-feet could be diverted with a reliability, similar to the District's water supply of 67 percent. The gross storage capacity of CR19 reservoir however, is only 16,000 acre-feet. In this alternative, the reservoir capacity is limiting. Again referring to Figure 7, the reservoir capacity of 16,000 acre-feet can be provided approximately 75 percent of the time. Diverting water in the winter at the rate of approximately 100 cfs would require approximately 80 days to fill the reservoir. Water could be diverted at a greater rate; however, the improvements to the District's existing canals would be more extensive. The concept in this alternative is, therefore, to divert water at a rate of approximately 110 cfs including conveyance losses estimated at approximately 10 percent.

Service Area

The water supply available under Alternative No. 3 is greater than Alternative No. 1 and Alternative No. 2. As noted above, the gross reservoir storage is 16,000 acre-feet. Assuming evaporation and seepage losses amount to approximately 10 percent, the net water supply available is 14,400 acre-feet. This amount of water would serve a gross area of 6,800 acres, or about 31 percent of the YZWD.

Facilities Required

The facilities required for Alternative No. 3 include improvements to portions of the District's existing canal system, the construction of a reservoir including outlet works to release water to the Acacia Canal, and improvements to China Slough. A discussion of the facilities is provided below.

Existing Canals Improvements – From a field reconnaissance of the canals required for use in delivering water under this alternative, improvements will be required in the Goodnow

Lateral, Clover Canal, and the Acacia Canal. The canal capacity will need to be increased to include all structures crossing existing county or private roads. With water being diverted in the non-irrigation period there is no conflict in using the existing capacity of the West Adams Canal or the Hungry Hollow Canal. The upper reach of the West Adams Canal will require improvements to handle cross-drainage, which tends to deposit considerable amounts of sediment in the canal during high rainfall events. This sediment will have to be kept out of the canal if the canal is to remain serviceable during the winter months. Similarly, portions of the Hungry Hollow Canal and Goodnow Lateral are subject to accumulating sediment during periods of high rainfall and will require provisions to mitigate this occurrence.

CR19 Reservoir – The location of the storage reservoir is shown on Map 8. Construction of the dam and reservoir will require relocating approximately one mile of CR19. No existing structures will require removal. The existing land use within the reservoir is largely open space or pasture with some pasture and vineyard. The reservoir will require construction of two earth embankment dams. Water will flow into the south reservoir from the Clover Canal until it fills and spills into the north reservoir. A spillway will be constructed with a capacity of 2,930 cfs. The watershed of the two drainages is about 3.7 square miles. The bottom of the dam is El.100 and the top of the dam is El. 160. The maximum pool is El. 150. Outlet works will be required at both dams to release water to the Acacia Canal.

Acacia Canal **–** The Acacia Canal will require some enlargement to accommodate an increase in capacity similar to Alternative No. 1.

China Slough **–** The improvements required in China Slough are the same as required for each of the previous alternatives.

Alternative No. 4

Alternative No. 4 is based upon using surface water made available by diverting water from the Colusa Basin Drain to a storage facility in the Dunnigan Hills, in the winter months, and withdrawing the water for irrigation the following season. Water will be diverted by pumping from the Colusa Basin Drain and conveyed by a buried pipeline to the CR19 reservoir described for Alternative No. 3. Water would be released from the reservoir to the Acacia Canal to China Slough. The layout of the respective facilities for Alternative No. 4 is presented on Map 9.

Water Supply

The water supply from the Colusa Basin Drain is considered to be a firm water supply. The amount of water will be dictated by the amount of storage available. Accordingly, using the CR19 reservoir with a gross capacity of 16,000 acre-feet, the net water supply will be 14,400 acre-feet as noted for Alternative 3. However, instead of being available 75 percent of the time, the supply will be available each year.

Service Area

The service area for Alternative No. 4 is gross area of 6,800 acres, the same as for Alternative No. 3.

Facilities Improvements

The facilities required for Alternative No. 4 include a diversion or water control structure on the Colusa Basin Drain to ensure a forebay for the pump station, the pump station, conveyance pipeline, storage reservoir with outlet facilities to release water to the Acacia Canal, and improvements to the Acacia Canal and China Slough. Each facility is described below.

Diversion/Water Control Structure - The diversion or water control structure will be constructed in the Colusa Basin Drain to ensure that a forebay sufficient for operation of the pump station will exist under all flow conditions to divert water to storage. The structure is similar to that envisioned for the diversion structure located near Interstate 5 under Alternative No. 2, which incorporates an inflatable rubber dam 10 feet high and 100 feet in length.

Pump Station

The pump station will have a discharge capacity of 100 cfs and the range in total head to which the pumps will operate is from 160 to 220 feet. The pump/motor selection will be based upon two head ranges - one for heads of 160 feet to 190 feet, and one for heads of 190 feet to 220 feet.

Conveyance Pipeline

The conveyance pipeline is a 54-inch reinforced concrete pipe approximately 54,800 feet in length. The pipe will be bore and jacked under Interstate 5.

PROJECT BENEFITS

The primary benefits anticipated for the proposed conjunctive water use project were to incrementally improve the management of water resources available from the Cache Creek System to increase groundwater storage in the study area. To the extent groundwater storage was increased and groundwater levels raised, the potential for land subsidence would be reduced as well. Some incidental benefits would be derived by reduced heads for pumping groundwater in the area.

To evaluate the impact to the groundwater basin from providing supplemental surface water supplies to the study area, Wood Rodgers retained the services of WRIME to perform groundwater modeling for the respective alternatives. This report is included as Appendix F.

WRIME utilized the Lower Colusa Basin Integrated Groundwater and Surface Water Model (LCBIGSM) developed by DWR to evaluate potential conjunctive use projects in the Colusa Basin area in Yolo and Colusa counties. The model input data was updated and the model was calibrated in cooperation with the District and DWR for application in this feasibility study. The LCBIGSM was initially developed using the historic data for the hydrologic period 1980 to

1995. For purposes of this study, the hydrologic period of October 1921 through September 1994 was used.

Referring to the well hydrographs presented earlier on Figure 1 and Figure 2 in relation to information determined from the groundwater analysis, it appears the subsurface recharge into the study area balances the extraction such that there is no apparent overdraft. The groundwater analysis puts some dimension on the amounts and directions from which the recharge is occurring. For the model cells utilized to identify the study area, the following are the amounts of recharge occurring on an average annual basis throughout the 72-year simulation period.

Location	Recharge	
	Acre-Feet	Percent
From Cache Creek	2,970	13
From Dunnigan Hills	8,320	36
From East of Colusa Basin Drain	12,110	51
TOTAL	23,400	100

To the extent supplemental water is supplied to the study area, the recharge noted above will be reduced with greatest reduction occurring in the recharge from east of the Colusa Basin Drain, or essentially Reclamation District No. 108. By virtue of recharge being reduced, the opportunity to increase storage or “bank” water is reduced as well.

With respect to the impact on groundwater levels in the study area, the average increase was estimated to be five feet with Alternative No 1 and No. 2; nine feet with Alternative No. 3; and 13 feet with Alternative No. 4.

Of significant interest from the results of the groundwater simulation is that irrespective of the number of years supplemental water is provided in advance of curtailing water delivery, the groundwater levels drop sharply to the base condition due to the fact that the opportunity to "bank" water is very limited. In essence, with supplemental water delivered to the study area, it appears the basin does not accumulate or store significant amounts of groundwater to draw upon when supplemental water is not available.

To the extent supplemental water is available, it is expected that land subsidence would be reduced although this was not evaluated in the scope of WRIME's work. As noted earlier and shown in Appendix G, subsidence may be continuing in the Yolo-Zamora area even though it appears groundwater extraction/recharge is somewhat balanced. The time of year for the subsidence measurement, however, may not be reflecting the actual situation since groundwater pumping is extensive during the selected survey period.

COMPARATIVE COSTS

For purposes of determining the preferred alternative and relative feasibility of the respective alternatives, comparative construction costs were prepared for review by the PAG. The comparative costs for each alternative are presented on Table 5 through Table 8. Presented on Table 9 is a summary of the comparative costs in relation to the service area and water delivery for each alternative. As shown on Table 9, the annual cost for water delivered, not including costs for operations and maintenance, ranges from $111 per acre-foot to $209 per acre-foot. The annual costs are based upon amortizing the construction cost under the terms for loans through DWR to construct groundwater storage projects.

ENVIRONMENTAL CONSIDERATIONS

From an environmental standpoint, Alternative No. 2, which involves the use of Cache Creek for conveyance of water throughout the summer months in years when water was available, provides an opportunity to support efforts for environmental restoration consistent with Yolo County's goals for the Cache Creek Resources Management Plan. Recognizing a potential opportunity for environmental benefits associated with this alternative, the District retained the services of the Natural Heritage Institute (NHI) to perform an evaluation of the resources and to identify opportunities and constraints associated with this reach of Cache Creek. It appears from this preliminary work performed by NHI, there may be some opportunity for environmental restoration; however, considerably more analysis and evaluation will be required to formalize such a program. An important aspect of the Creek and opportunity highlighted by NHI relates to potential benefits for environmental restoration from a water control structure located in the vicinity of the District's Moore Canal crossing of Cache Creek. As noted earlier in this report, constructing a facility at that location could be a viable alternative to constructing the water control structure near Interstate 5 as discussed in Alternative 2. In either case, there may be opportunities for collaboration with Yolo County to accomplish its goals for environmental restoration as identified in the Supplemental EIR for the Cache Creek Resources Management Plan, June 2002.

Although not documented, staff of the WRA, under the public involvement part of this study, communicated with various interest groups as noted previously. From information reported, concern was expressed in relation to environmental impacts from proposals to modify the flow regime in Cache Creek.

Certainly, if any of the alternatives are to considered further, a baseline environmental assessment would be required to evaluate potential environmental impacts for compliance with the California Environmental Quality Act (CEQA) and permitting requirements of regulatory agencies consistent with the scope of the particular proposal. Depending upon the environmental resources identified, compliance with the National Environmental Protection Act (NEPA) could be required as well.

PROJECT FEASIBILITY

The comparative costs and relative benefits of the alternatives were the subject of discussion at a PAG meeting on March 12, 2003, with the objective of identifying a preferred alternative. Following the discussion however, it was the consensus of the PAG that none of the alternatives were feasible at this time. The costs of the respective projects in relation to the option of continuing to pump groundwater were too high.

Subsidence, although reportedly has adversely affected wells in the past, was not deemed a significant issue in relation to the costs and reliability associated with the delivery of supplemental water supplies to the area.

Presented in Appendix H is a copy of the letter from the YZWD Board of Directors to the District confirming the alternatives evaluated were not financially feasible at this time to deliver supplemental surface water for a conjunctive water use project.

FINDINGS

Findings from the work performed, and meetings and discussions conducted with the PAG during the course of this feasibility study are as follows:

1. It is not feasible, at this time, to implement a conjunctive water use project within the study area utilizing water from Cache Creek or the Colusa Basin Drain.

2. Land within the Yolo-Zamora area is fully developed and the groundwater extraction/recharge appears reasonably balanced due largely to subsurface flow from the area east of the Colusa Basin Drain and the Dunnigan Hills on the west.

3. The opportunity to increase groundwater storage or to "bank" water within the study area is limited.

4. From a water management standpoint, there is an increment of water (5,000-10,000 acre-feet in seven of 10 years) from the District's Cache Creek System that could be managed more effectively.

5. There is unmanaged "winter" water in the order of 20,000 to 30,000 acre-feet within the Cache Creek System that is potentially available in seven of 10 years.

6. There appears to be unmanaged "winter" water in the order of 20,000 to 40,000 acre-feet within the Colusa Basin Drainage System that is potentially available as a "firm" water supply.

RECOMMENDATIONS

Although the concept of a conjunctive water use project in the study area portion of the YZWD was not feasible, information has been developed from this study to assist the District in improving the management of water resources to benefit water users and Yolo County generally. As a result of the work performed and the reported findings, Wood Rodgers recommends the District consider the following:

1. Formalize design criteria for its water delivery and distribution system to facilitate consistencies in a targeted level of service in the rehabilitation and modernization of the water system over time.

2. Refine the reservoir operations model developed as part of this study and define an operating protocol for the Cache Creek System to facilitate improved management of the available water resources over time.

3. Collaborate with Yolo County and other entities in formulating a water management/environmental restoration plan for Cache Creek from the Capay Diversion Dam to the Moore Canal Crossing to improve water management and assist in fulfilling goals of the

County consistent with its Cache Creek Resources Management Plan.

4. Collaborate with other agencies such as the cities of Woodland Davis and the University of California, Davis, to examine opportunities to utilize “winter” water from Cache Creek and the Colusa Basin Drain to enhance the overall water supply for Yolo County.

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Tables

Tables

TABLE 1

YCFCWCD/YZWD
CONJUNCTIVE WATER USE FEASIBILITY STUDY

YOLO COUNTY AND YOLO-ZAMORA WATER DISTRICT LAND USE: 1997

Land Use	Area, ac		District as Percent of County
	County	District	
Water	9,261	11	0
Urban	30,437	608	2
Orchards	26,059	555	2
Pasture, Farmsteads, Dairies, and Livestock	45,197	2,293	5
Field and Truck Crops	253,637	18,214	7
Rice	30,409	12	0
Vineyards	9,437	24	0
Subtotal	404,437	21,718	5
Native and Riparian Vegetation	244,919	615	0
Barren and Wasteland[1]	1,319	0	0
Land Not Surveyed	2,696	0	0
TOTAL	653,371	22,333	3

[1] Includes dry stream channels and barren land.

Source: California Department of Water Resources.

TABLE 2

YCFCWCD-YZWD
CONJUNCTIVE WATER USE FEASIBILITY STUDY

YOLO-ZAMORA WATER DISTRICT LAND USE: 1997

Land Use	Gross Area, ac	
	With Excluded Parcels	Without Excluded Parcels
Orchards		
Almonds	123.2	123.2
Eucalyptus	5.1	5.1
Pistachios	32.7	32.7
Walnuts	394.4	393.3
Subtotal	555.4	554.3
Pasture, Farmsteads, Dairies, and Livestock		
Alfalfa and Alfalfa Mixtures	1,993.0	1,986.3
Farmsteads	241.0	217.2
Livestock Feed Lots	7.1	7.1
Mixed Pasture	46.1	46.1
Native Pasture	5.3	5.3
Subtotal	2,292.5	2,262.0
Field and Truck Crops		
Beans (dry)	24.0	24.0
Bushberries	27.0	27.0
Carrots	23.1	0.0
Corn (field and sweet)	2,372.1	2,331.9
Cotton	627.2	627.2
Grain Sorghum	90.5	90.5
Land cropped in past years but not tilled at time of survey	184.6	179.0
Melons, Squash, and Cucumbers	271.4	177.6
Misc. and Mixed Grain and Hay	85.6	85.6
Misc. Truck	13.3	0.0
Mixed (four or more)	5.7	5.6
Onions and Garlic	7.7	7.7
Peppers (chili, bell, etc.)	111.0	111.0
Safflower	865.2	853.4
Sudan	52.6	52.6
Sugar Beets	50.0	49.7
Sunflowers	403.1	379.4
Tomatoes	6,687.6	6,141.4
Unknown Field	370.3	370.3
Unknown Grain	5,897.6	5,229.3
Unknown Truck	44.5	44.5
Subtotal	18,214.1	16,787.7
Rice		
Rice	11.8	11.8
Subtotal	11.8	11.8
Vineyards		
Vineyards	24.3	24.3
Subtotal	24.3	24.3
Native and Riparian Vegetation		
Native and Riparian Vegetation	614.9	614.9
Subtotal	614.9	614.9
Water		
Water	11.3	11.3
Subtotal	11.3	11.3
Urban		
Urban	608.1	597.4
Subtotal	608.1	597.4
TOTAL	22,332.4	20,863.7

Source: California Department of Water Resources.

TABLE 3

YCFCWCD/YZWD
CONJUNCTIVE WATER USE FEASIBILITY STUDY

AGRICULTURAL UNIT WATER USE VALUES (NORMAL)

Crop	1997			
	ETAW, afpa	Irrigation Efficiency, %	AW, afpa	EAW, afpa
Alfalfa	3.0	68	4.4	1.4
Almonds	1.8	69	2.6	0.8
Deciduous	2.5	70	3.6	1.1
Field Corn	1.8	69	2.6	0.8
Grain	0.6	67	0.9	0.3
Misc. Field	1.5	68	2.2	0.7
Misc. Truck	1.2	67	1.8	0.6
Olive/Citrus	1.3	68	1.9	0.6
Pasture	3.3	64	5.2	1.9
Rice	3.4	56	6.1	2.7
Safflower	0.7	78	0.9	0.2
Sugar Beets	2.3	68	3.4	1.1
Tomatoes	2.1	69	3.0	0.9
Vineyards	1.9	68	2.8	0.9

AGRICULTURAL UNIT WATER USE VALUES (CRITICAL DRY)

Crop	1997			
	ETAW, afpa	Irrigation Efficiency, %	AW, afpa	EAW, afpa
Alfalfa	3.7	68	5.4	1.7
Almonds	2.0	69	2.9	0.9
Deciduous	2.8	70	4.0	1.2
Field Corn	1.9	69	2.8	0.9
Grain	1.1	67	1.6	0.5
Misc. Field	1.6	68	2.4	0.8
Misc. Truck	1.3	67	1.9	0.6
Olive/Citrus	0.0	68	0.0	
Pasture	4.1	64	6.4	2.3
Rice	3.5	56	6.3	1.8
Safflower	0.8	78	1.0	0.2
Sugar Beets	2.7	68	4.0	1.3
Tomatoes	2.3	69	3.3	1.0
Vineyards	2.1	68	3.1	1.0

AW = Applied Water
EAW = Excess Applied Water
ETAW = Evapotranspiration of Applied Water

Source: California Department of Water Resources

TABLE 4

YCFCWCD/YZWD
CONJUNCTIVE WATER USE FEASIBILITY STUDY

YOLO-ZAMORA WATER DISTRICT WATER USE: 1997

Land Use	Irrigated Area, ac	Estimated AW, af	Estimated ETAW, af	Excess EAW, af
Alfalfa	1,993	8,769	5,979	2,790
Almonds	123	320	222	99
Deciduous	432	1,556	1,081	475
Field Corn	2,425	6,304	4,364	1,940
Grain	5,473	4,926	3,284	1,642
Misc. Field	1,054	2,319	1,581	738
Misc. Truck	459	827	551	276
Olive/Citrus	0	0	0	0
Pasture	51	267	170	98
Rice	8	48	27	21
Safflower	865	779	606	173
Sugar Beets	50	170	115	55
Tomatoes	6,688	20,063	14,044	6,019
Vineyards	24	68	46	22
TOTAL	19,646	46,416	32,069	14,347
Per Acre		2.36	1.63	0.73

AW = Applied Water
EAW = Excess Applied Water
ETAW = Evapotranspiration of Applied Water

Note: Water demand is based upon agricultural water use under "normal" hydrologic conditions.

Water usage counts irrigation water only. Water applied for the following uses have been neglected: water, urban, native and riparian vegetation, barren wasteland, land not surveyed, farmsteads, feed lots, poultry farms, idle land, and fallow land.

Source: California Department of Water Resources

TABLE 5

YCFCWCD/YZWD
CONJUNCTIVE WATER USE FEASIBILITY STUDY
ALTERNATIVE 1 - DISTRICT WATER WITH WEST ADAMS CONVEYANCE

COMPARATIVE COST

Item	Amount, $
West Adams Canal Head Gate Modification	31,000
Flow Measurement Station	25,000
Canal Improvements (West Adams, East Adams, Acacia)	7,285,000
China Slough Improvements	792,000
Subtotal	8,133,000
Construction Contingency @ 20%	1,626,600
Engineering, Environmental, Surveys, and Contract Administration @ 25%	2,033,250
TOTAL	11,792,850

TABLE 6

YCFCWCD/YZWD
CONJUNCTIVE WATER USE FEASIBILITY STUDY
ALTERNATIVE 2 - DISTRICT WATER WITH CACHE CREEK CONVEYANCE

COMPARATIVE COST

Item	Amount, $
I-5 Diversion Structure and Creek Bank Protection	1,600,000
I-5 Pump Station	2,920,000
Water Delivery Pipeline	2,424,000
China Slough Improvements	792,000
Subtotal	7,736,000
Construction Contingency @ 20%	1,547,200
Engineering, Environmental, Surveys, and Contract Administration @ 25%	1,934,000
TOTAL	11,217,200

TABLE 7

YCFCWCD/YZWD
CONJUNCTIVE WATER USE FEASIBILITY STUDY
ALTERNATIVE 3 - CACHE CREEK "WINTER" WATER WITH SEASONAL STORAGE

COMPARATIVE COST

Item	Amount, $
Canal Improvements	
West Adams Canal	2,368,000
Flow Measurement Station	25,000
Goodnow Lateral and Clover Canal	945,000
Acacia Canal	519,000
China Slough	792,000
CR 19 Reservoir and Water Delivery Pipelines	19,341,000
Subtotal	23,990,000
Construction Contingency @ 20%	4,798,000
Engineering, Environmental, Surveys, and Contract Administration @ 25%	5,997,500
TOTAL	**34,785,500**

TABLE 8

YCFCWCD/YZWD
CONJUNCTIVE WATER USE FEASIBILITY STUDY

ALTERNATIVE 4 - COLUSA BASIN DRAIN "WINTER" WATER WITH SEASONAL STORAGE

COMPARATIVE COST

Item	Amount, $
Colusa Basin Drain Pump Station	2,000,000
Water Delivery Pipeline	10,232,000
CR 19 Reservoir and Water Delivery Pipelines	19,341,000
Canal Improvements	
Acacia Canal	519,000
China Slough	792,000
Subtotal	32,884,000
Construction Contingency @ 20%	6,576,800
Engineering, Environmental, Surveys, and Contract Administration @ 25%	8,221,000
TOTAL	**47,681,800**

TABLE 9

YCFCWCD/YZWD
CONJUNCTIVE WATER USE FEASIBILITY STUDY

SUMMARY OF COMPARATIVE COSTS

Alternative	Service Area, ac	Cost $	Water Delivery af/py	Construction Cost		Annual Cost[1]	
				$/ac	$/af	$/ac	$/af
1	4,200	11,793,000	6,700	2,808	1,760	177	111
2	4,200	11,217,000	6,700	2,671	1,674	168	106
3	6,100	34,785,000	10,800	5,702	3,220	360	203
4	6,100	47,682,000	14,400	7,817	3,311	494	209

[1] Annual cost is based upon 100 percent of the construction cost ammortized at 2.4 percent per annum for 20 years.

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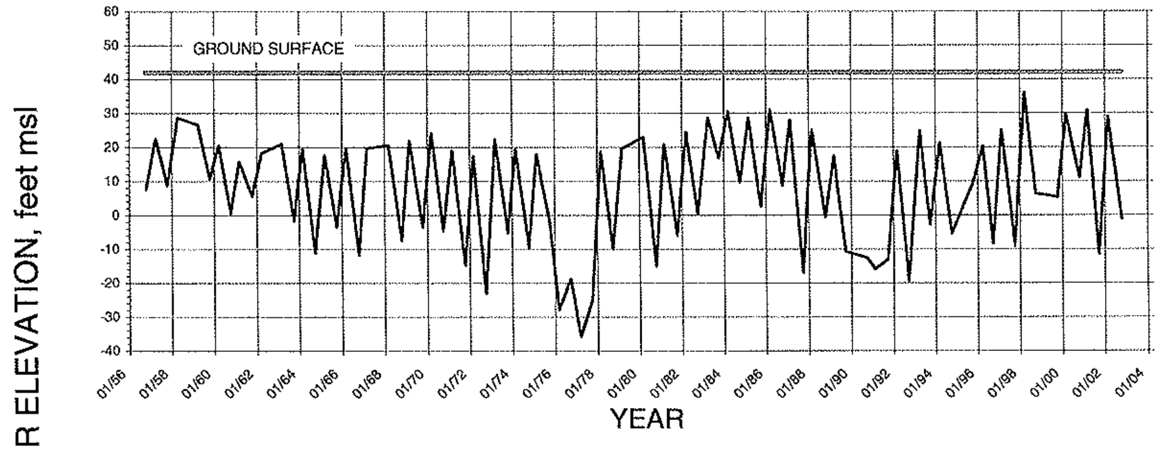
Figures

Figures

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

WATER LEVEL HYDROGRAPHS

WELL NO. 11N/01E-15C01



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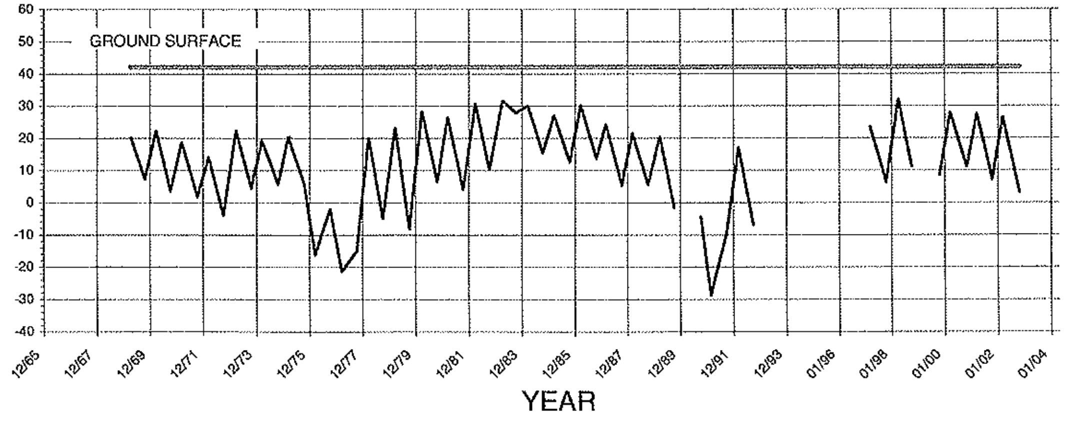

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

WATER LEVEL HYDROGRAPHS

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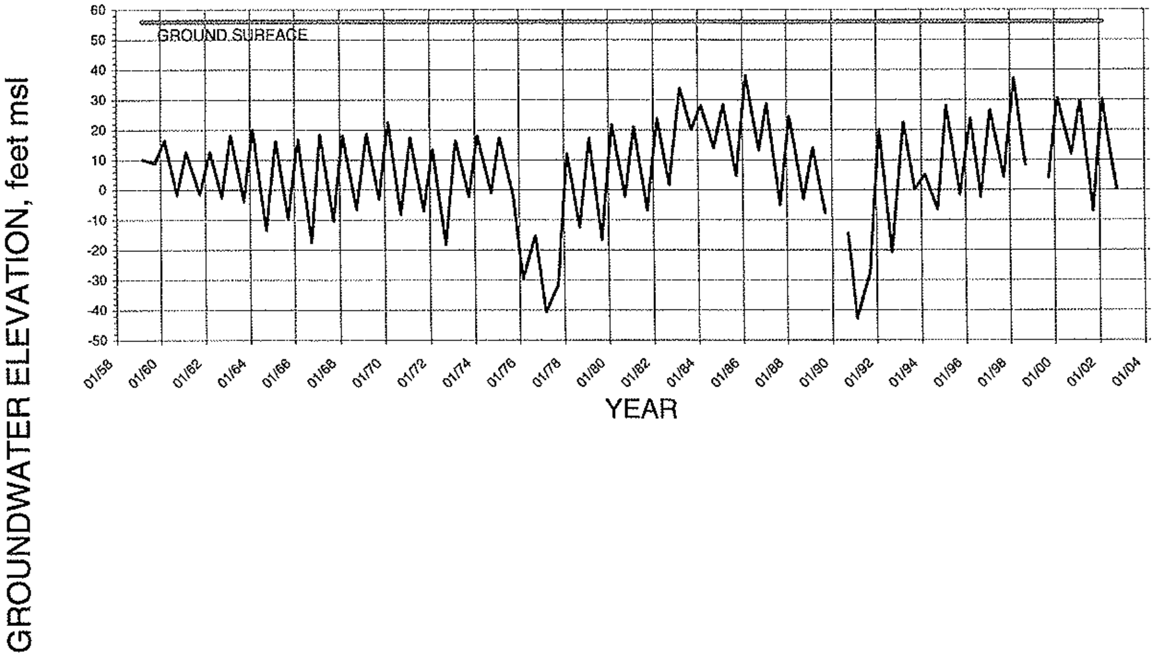
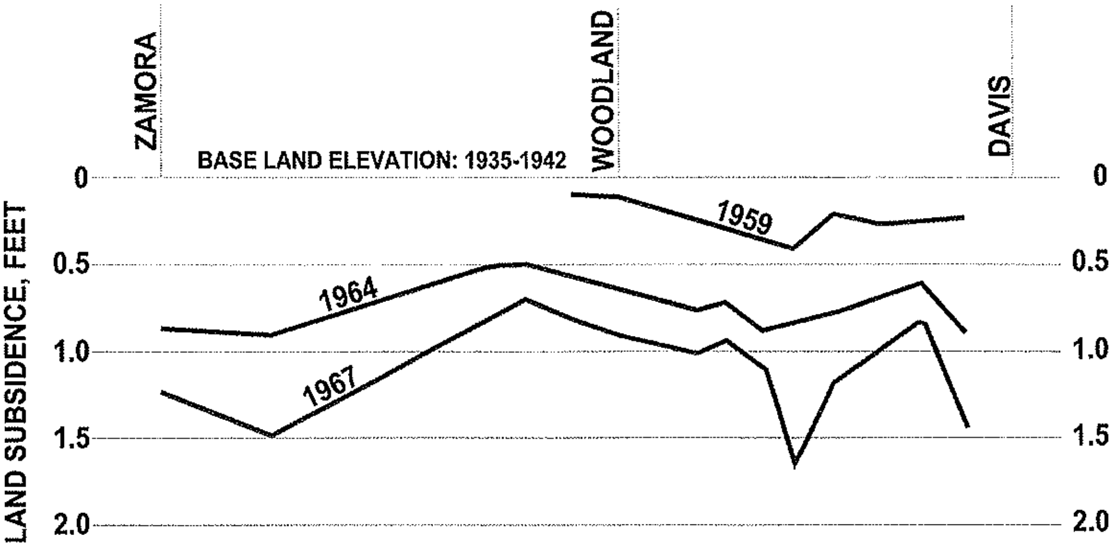
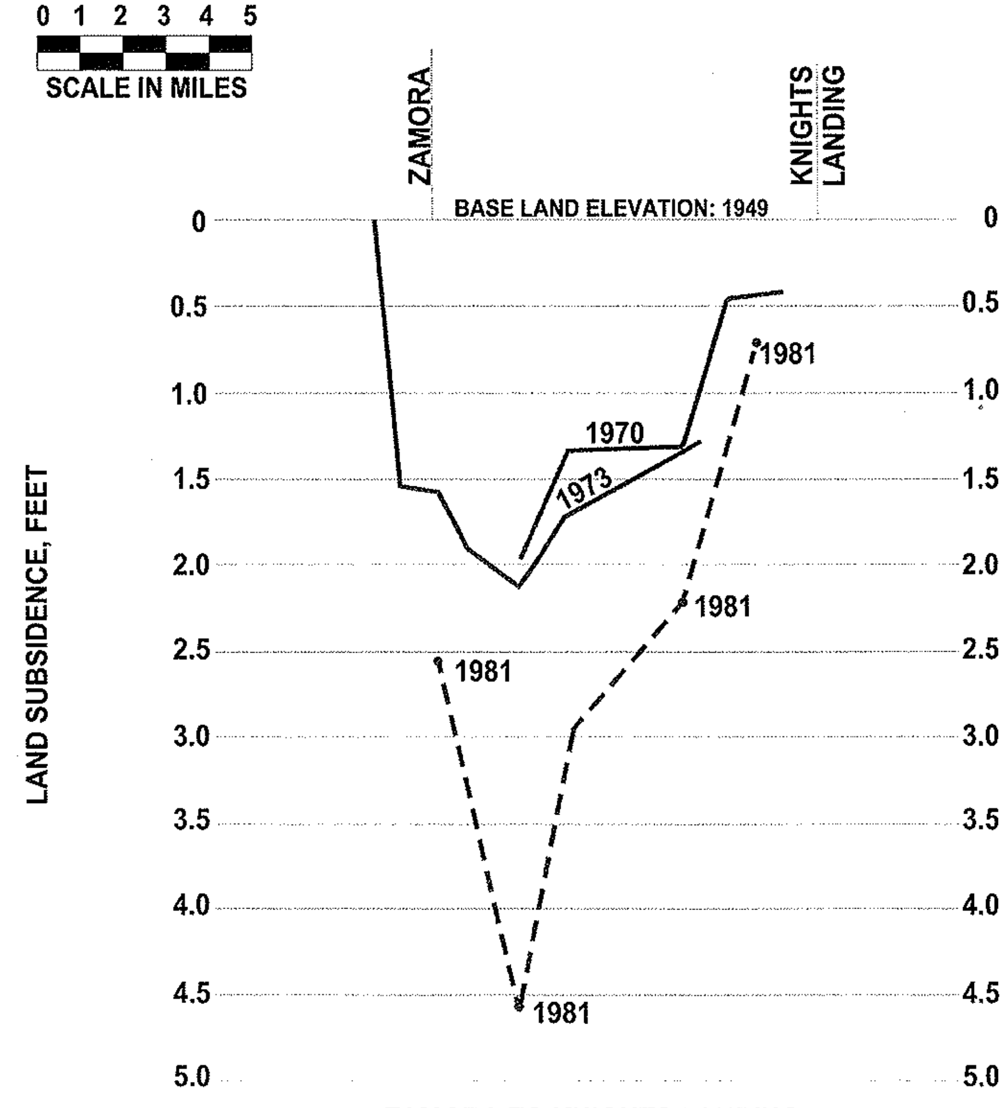


1/24/03

FIGURE 2



ZAMORA TO DAVIS



ZAMORA TO KNIGHTS LANDING

YCFCWCD/YZWD CONJUNCTIVE
WATER USE FEASIBILITY STUDY

**YOLO COUNTY
LAND SUBSIDENCE**

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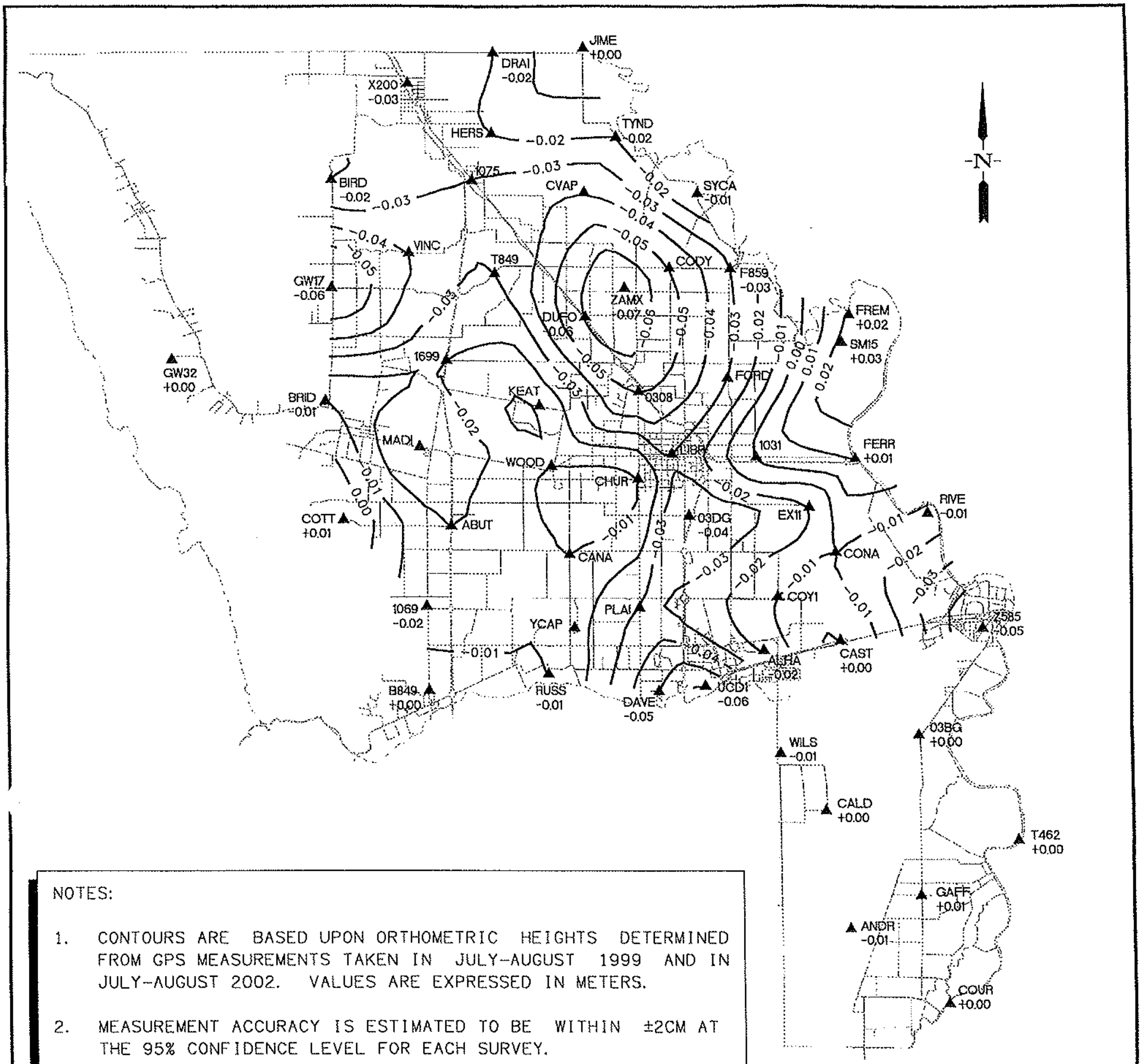
SOURCE: "YOLO COUNTY WATER PLAN", 1984

FIGURE 3



NOTES:

1. CONTOURS ARE BASED UPON ORTHOMETRIC HEIGHTS DETERMINED FROM GPS MEASUREMENTS TAKEN IN JULY-AUGUST 1999 AND IN JULY-AUGUST 2002. VALUES ARE EXPRESSED IN METERS.

2. MEASUREMENT ACCURACY IS ESTIMATED TO BE WITHIN ±2CM AT THE 95% CONFIDENCE LEVEL FOR EACH SURVEY.

3. THE COMBINATION OF MEASUREMENT ERROR AND THE AVAILABILITY OF ONLY TWO DATA POINTS AT EACH STATION MAY RESULT IN UNRELIABLE SUBSIDENCE RATE CALCULATIONS.

4. CONTOUR LOCATIONS ARE APPROXIMATE DUE TO THE SPARSE DISTRIBUTION OF THE DATA POINTS.

5. STATIONS IN THE SOUTHEASTERN PORTION OF THE COUNTY WERE NOT OBSERVED IN 1999. SUBSIDENCE INFORMATION FOR THESE STATIONS IS BASED UPON 1997 OBSERVATIONS.

JAMES H. FRAME III
No. 5435

LICENSE EXPIRES
SEPTEMBER 30, 2004

KILOMETERS
MILES

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Davis, CA 95616
(530) 756-8201 (FAX)
1280-039C

YOLO SUBSIDENCE NETWORK
1999 - 2002 SUBSIDENCE CONTOURS
YOLO COUNTY, CALIFORNIA
FEBRUARY, 2003 SCALE: 1"= 10KM

FIGURE 4

YCFCWCD/YZWD
CONJUNCTIVE WATER USE FEASIBILITY STUDY
CACHE CREEK SYSTEM - WATER SUPPLY RELIABILITY[1]
(% of years total demand met)

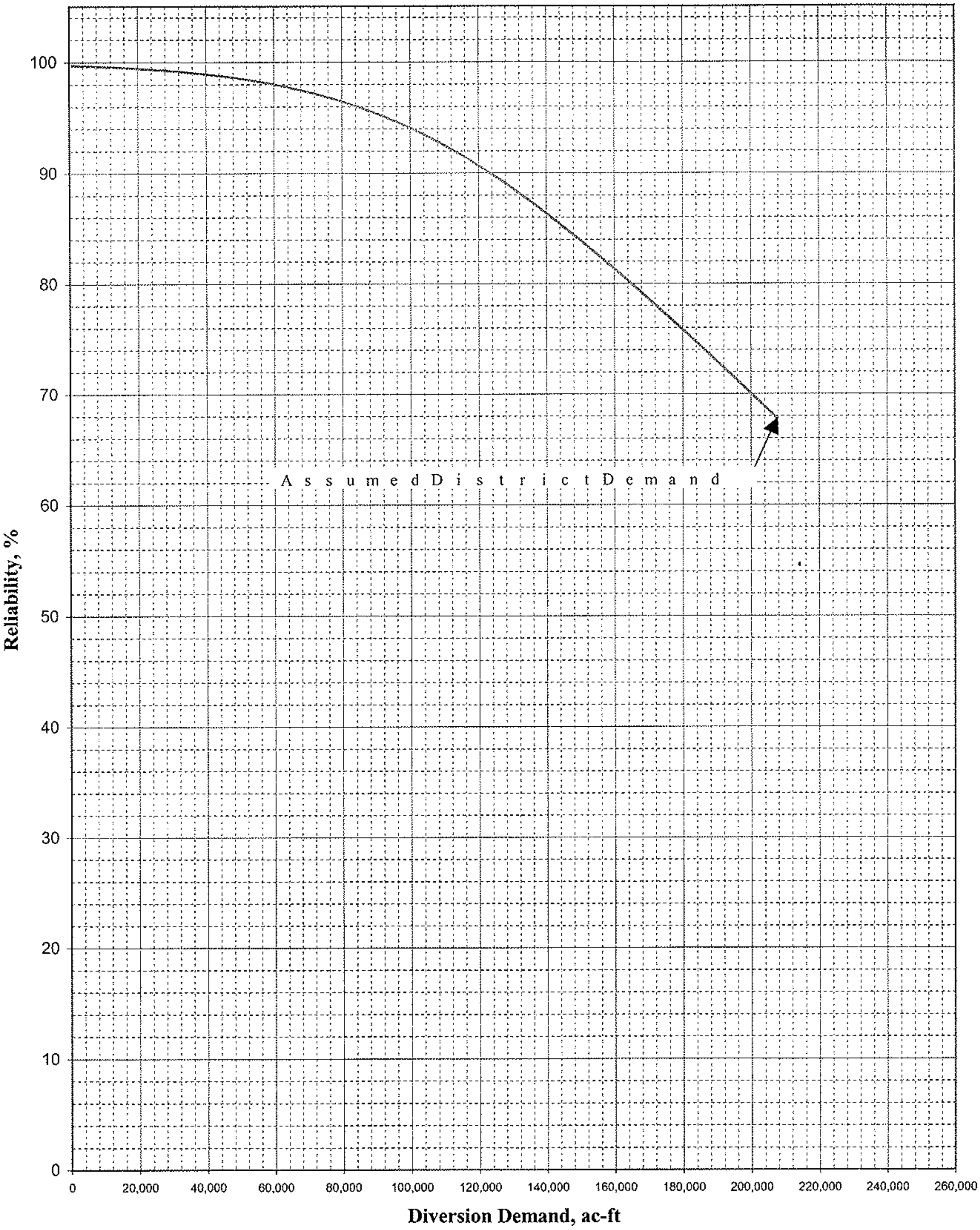

FIGURE 5

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[1] Based upon operations model for hydrologic period 1921-2001.

YCFCWCD/YZWD
CONJUNCTIVE WATER USE FEASIBILITY STUDY
CACHE CREEK SYSTEM - WATER SUPPLY RELIABILITY[1]
(% of years demand met)

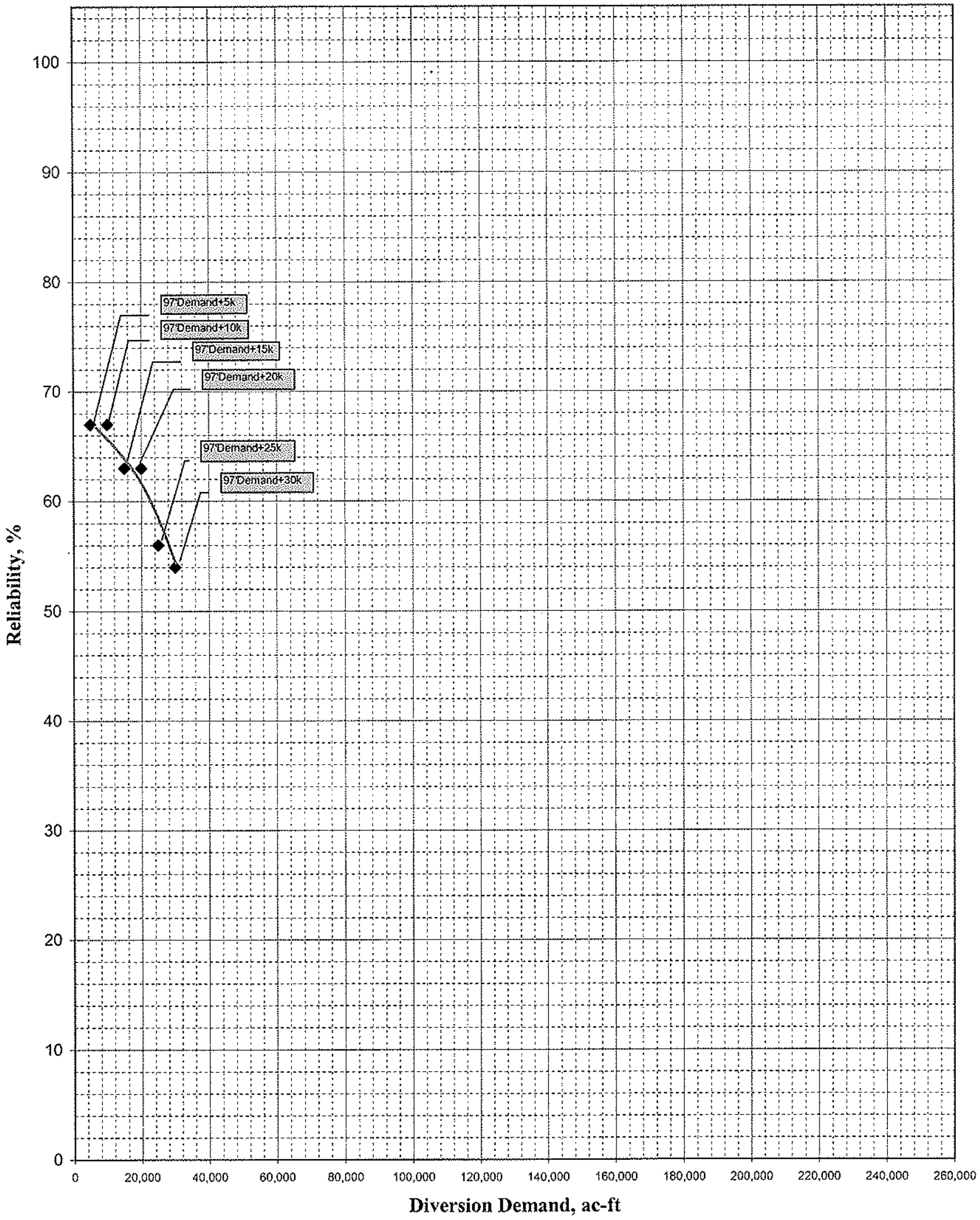

FIGURE 6

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[1] Based upon operations model for hydrologic period 1921-2002.

YOLO COUNTY FLOOD CONTROL &
WATER CONSERVATION DISTRICT

YCFCWCD/YZWD CONJUNCTIVE WATER USE FEASIBILITY STUDY

RELIABILITY OF WINTER DIVERSIONS AT CAPAY DAM

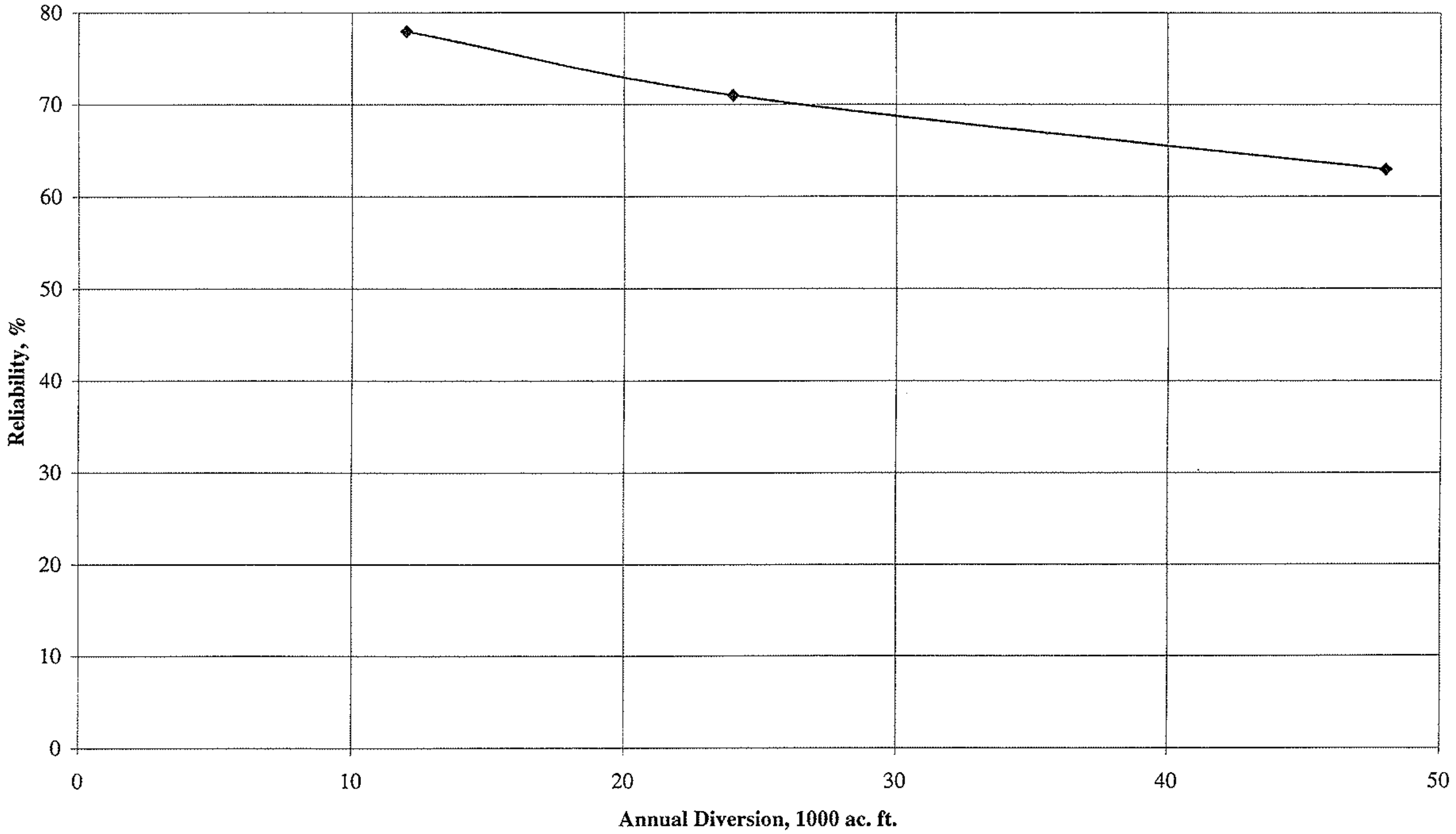


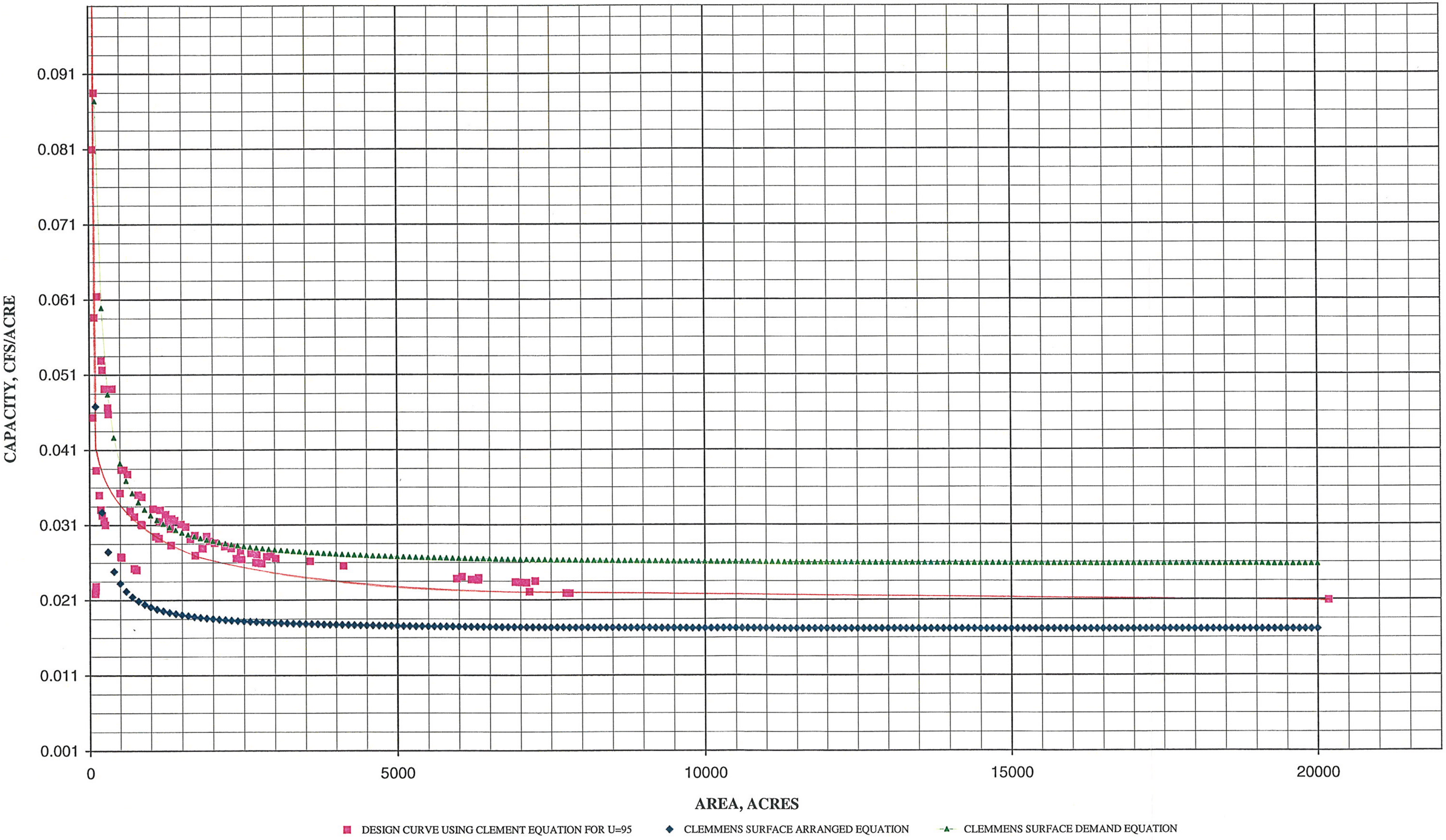
FIGURE 7

10/14/2002

Wood Rodgers, Inc.

YCFCWCD/YZWD
CONJUNCTIVE WATER USE FEASIBILITY STUDY

WEST ADAMS CANAL – DESIGN CAPACITY
COMPARISON OF CLEMENT AND CLEMMENS EQUATIONS



NOTE: CURVES DO NOT ACCOUNT FOR SEEPAGE LOSSES

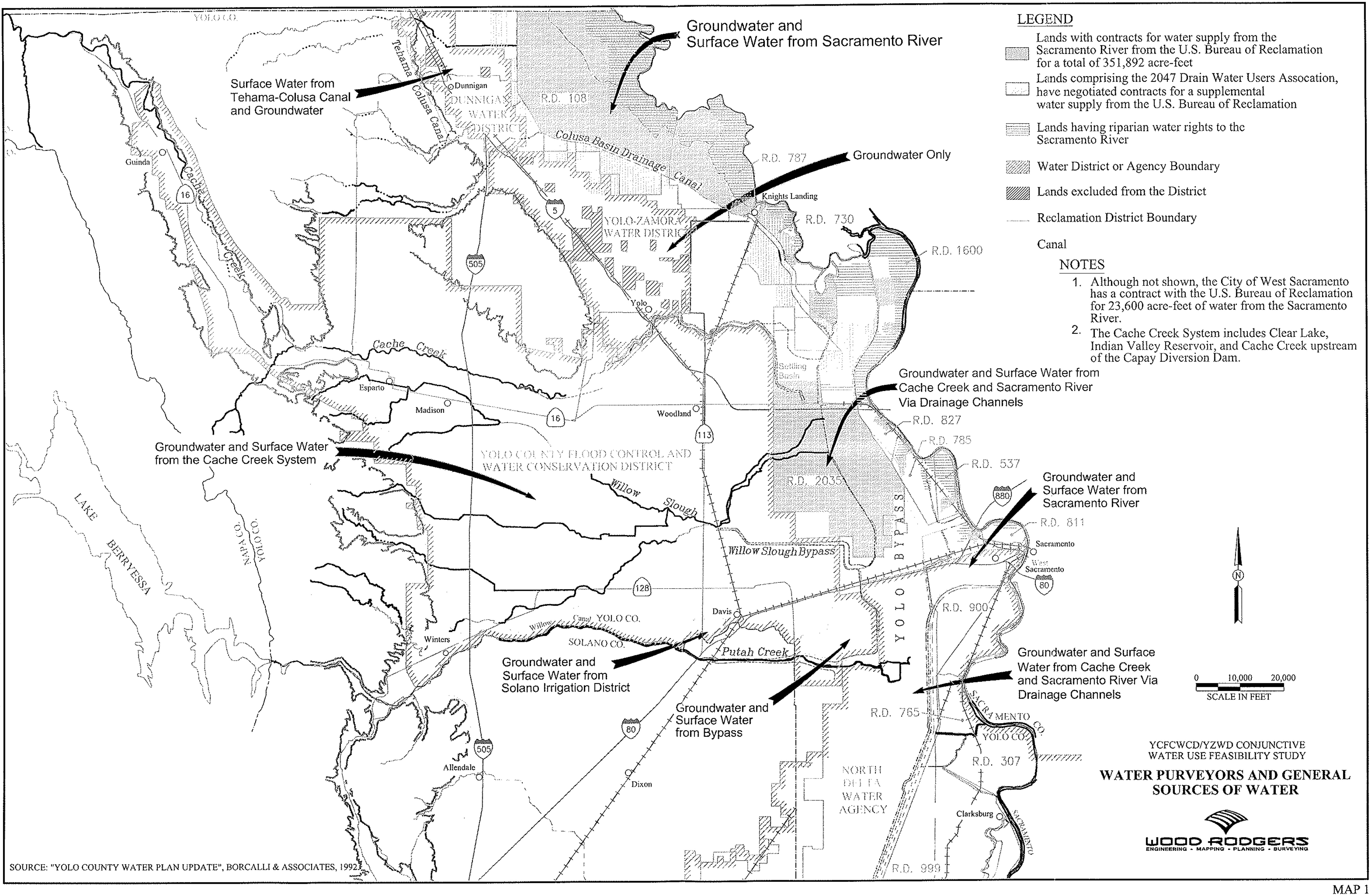
FIGURE 8

WOOD RODGERS

ENGINEERING ▪ PLANNING ▪ MAPPING ▪ SURVEYING

Maps

Maps



LEGEND

▩	Lands with contracts for water supply from the Sacramento River from the U.S. Bureau of Reclamation for a total of 351,892 acre-feet
☐	Lands comprising the 2047 Drain Water Users Assocation, have negotiated contracts for a supplemental water supply from the U.S. Bureau of Reclamation
▤	Lands having riparian water rights to the Sacramento River
▨	Water District or Agency Boundary
▨	Lands excluded from the District
----	Reclamation District Boundary
	Canal

NOTES

1. Although not shown, the City of West Sacramento has a contract with the U.S. Bureau of Reclamation for 23,600 acre-feet of water from the Sacramento River.
2. The Cache Creek System includes Clear Lake, Indian Valley Reservoir, and Cache Creek upstream of the Capay Diversion Dam.

SOURCE: "YOLO COUNTY WATER PLAN UPDATE", BORCALLI & ASSOCIATES, 1992.

YCFCWCD/YZWD CONJUNCTIVE
WATER USE FEASIBILITY STUDY

WATER PURVEYORS AND GENERAL SOURCES OF WATER

WOOD RODGERS
ENGINEERING • MAPPING • PLANNING • SURVEYING

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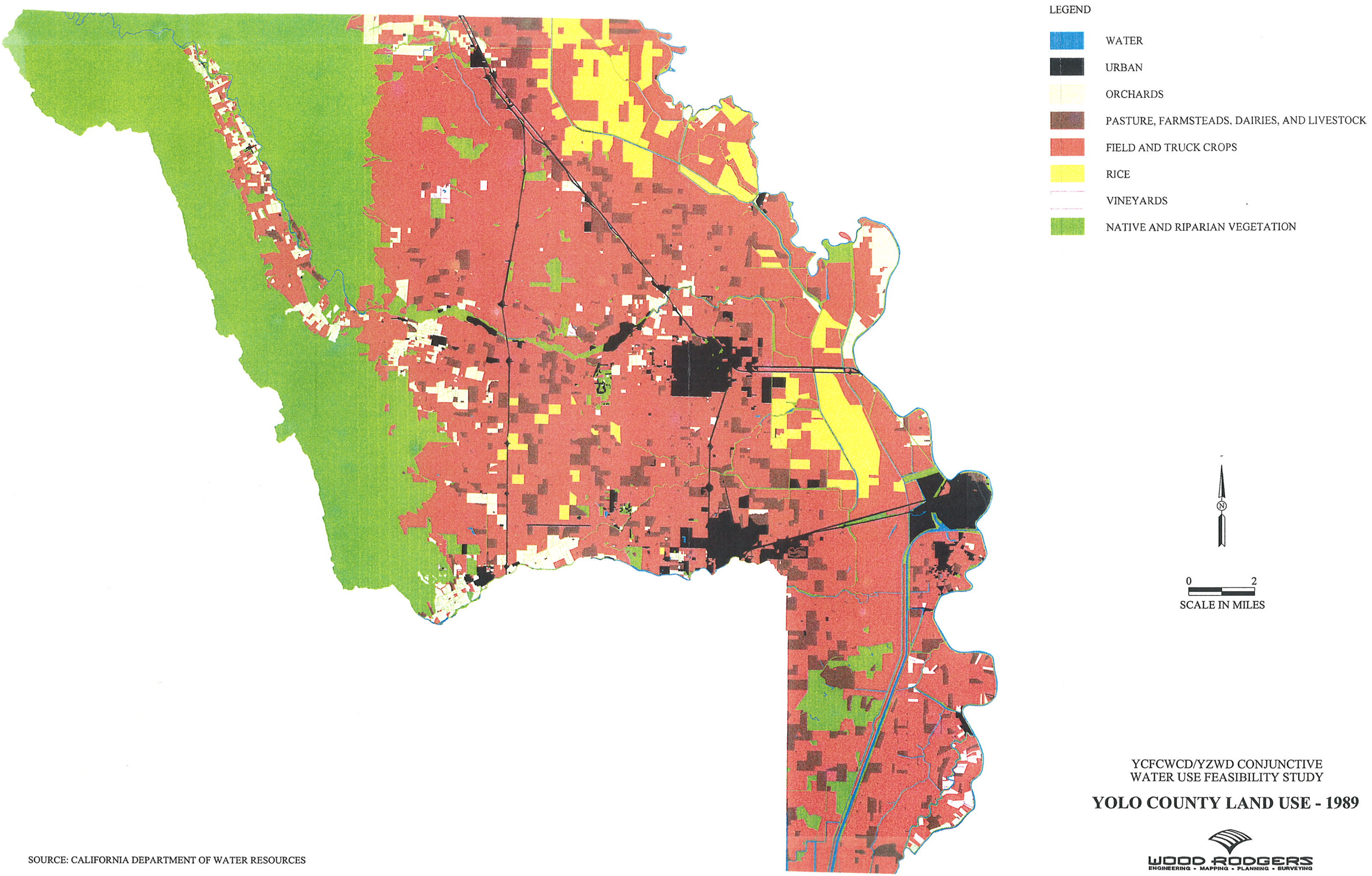
MAP 1



YCFCWCD/YZWD CONJUNCTIVE
WATER USE FEASIBILITY STUDY

YOLO COUNTY LAND USE - 1989

WOOD RODGERS
ENGINEERING • MAPPING • PLANNING • SURVEYING

SOURCE: CALIFORNIA DEPARTMENT OF WATER RESOURCES

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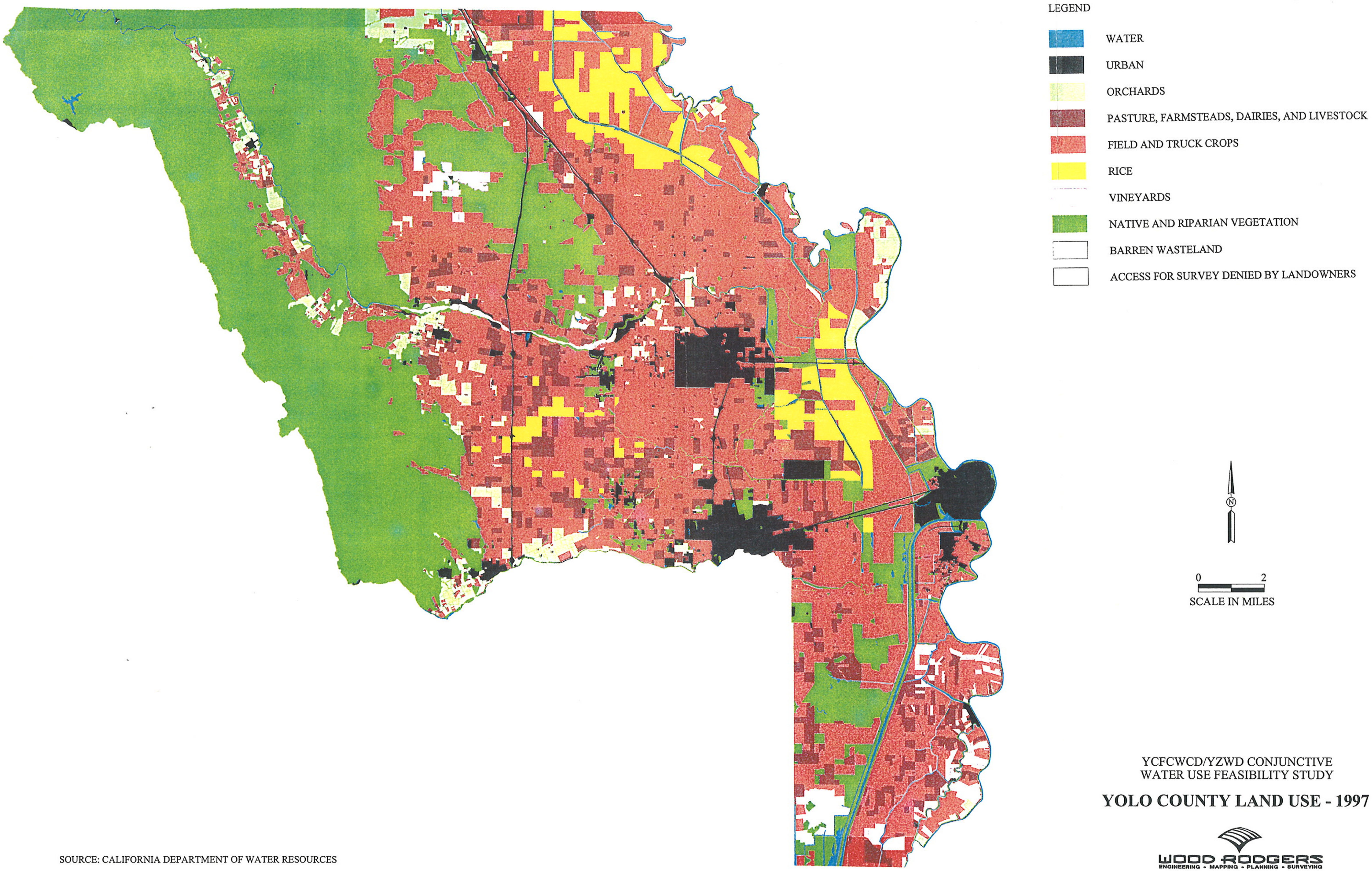
MAP 2



SOURCE: CALIFORNIA DEPARTMENT OF WATER RESOURCES

YCFCWCD/YZWD CONJUNCTIVE
WATER USE FEASIBILITY STUDY

YOLO COUNTY LAND USE - 1997

WOOD RODGERS
ENGINEERING • MAPPING • PLANNING • SURVEYING

MAP 3

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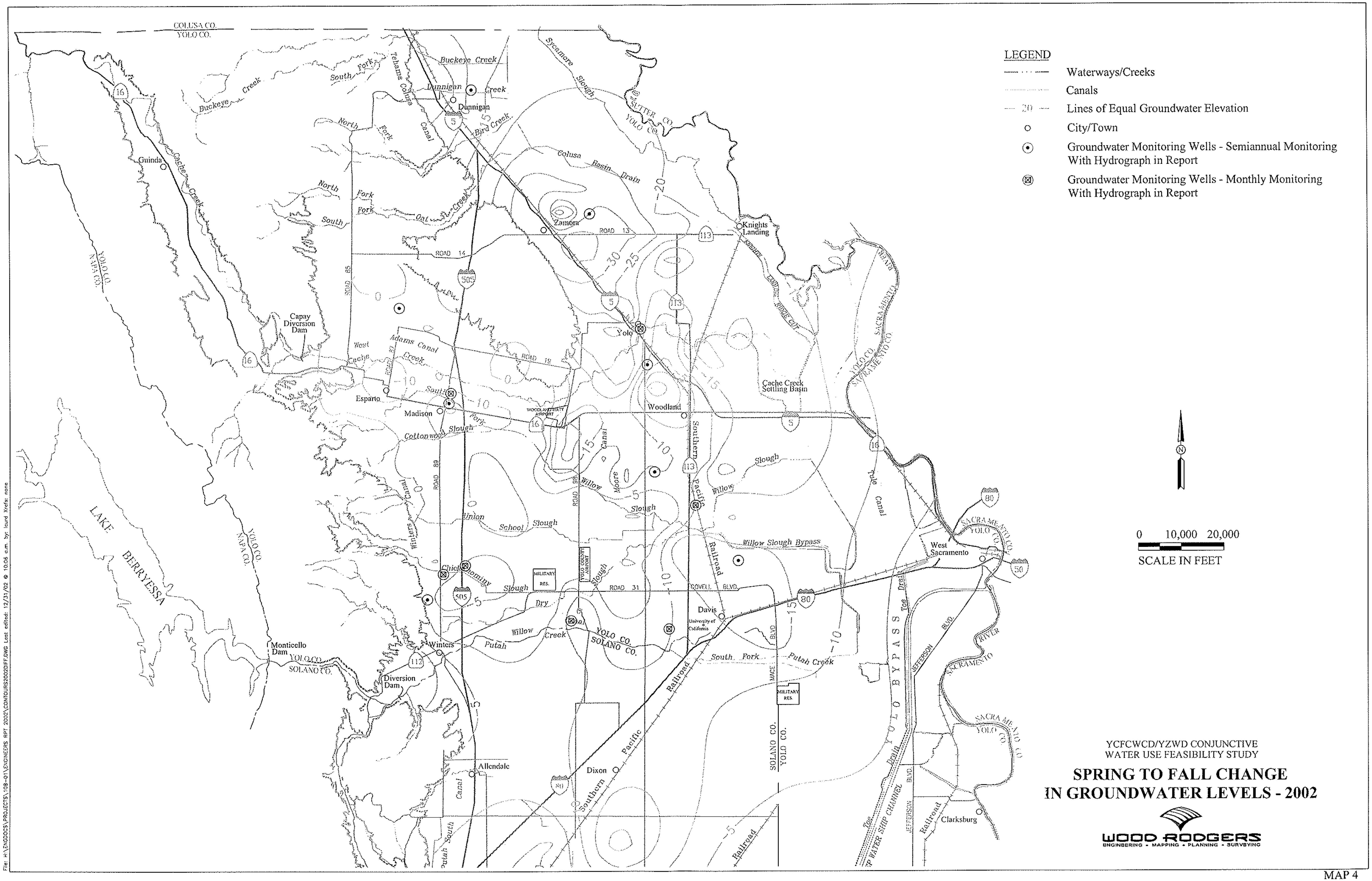

YCFCWCD/YZWD CONJUNCTIVE
WATER USE FEASIBILITY STUDY

SPRING TO FALL CHANGE IN GROUNDWATER LEVELS - 2002

WOOD RODGERS
ENGINEERING • MAPPING • PLANNING • SURVEYING

MAP 4

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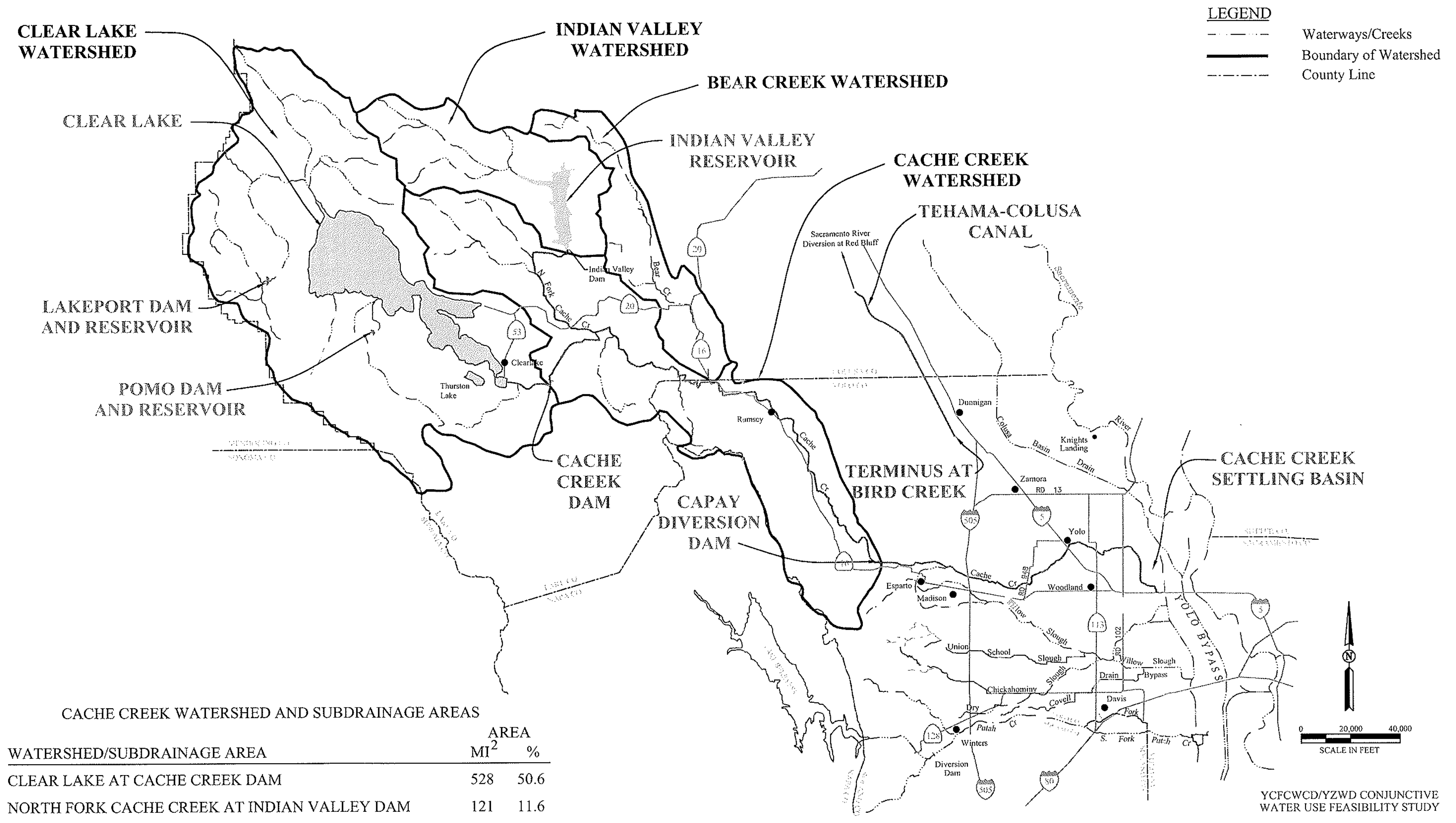

CACHE CREEK WATERSHED AND SUBDRAINAGE AREAS

WATERSHED/SUBDRAINAGE AREA	AREA MI^2	 %
CLEAR LAKE AT CACHE CREEK DAM	528	50.6
NORTH FORK CACHE CREEK AT INDIAN VALLEY DAM	121	11.6
BEAR CREEK AT CACHE CREEK	100	9.6
CACHE CREEK DOWNSTREAM OF CACHE CREEK DAM AND NORTH FORK CACHE CREEK DOWNSTREAM OF INDIAN VALLEY DAM	295	28.2
TOTAL	1,044	100.0

SOURCE: "YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT WATER MANAGMENT PLAN", BORCALLI & ASSOCIATES, INC., OCTOBER 2000.

YCFCWCD/YZWD CONJUNCTIVE
WATER USE FEASIBILITY STUDY

CACHE CREEK WATERSHED ABOVE CAPAY DIVERSION DAM

WOOD RODGERS
ENGINEERING • MAPPING • PLANNING • SURVEYING

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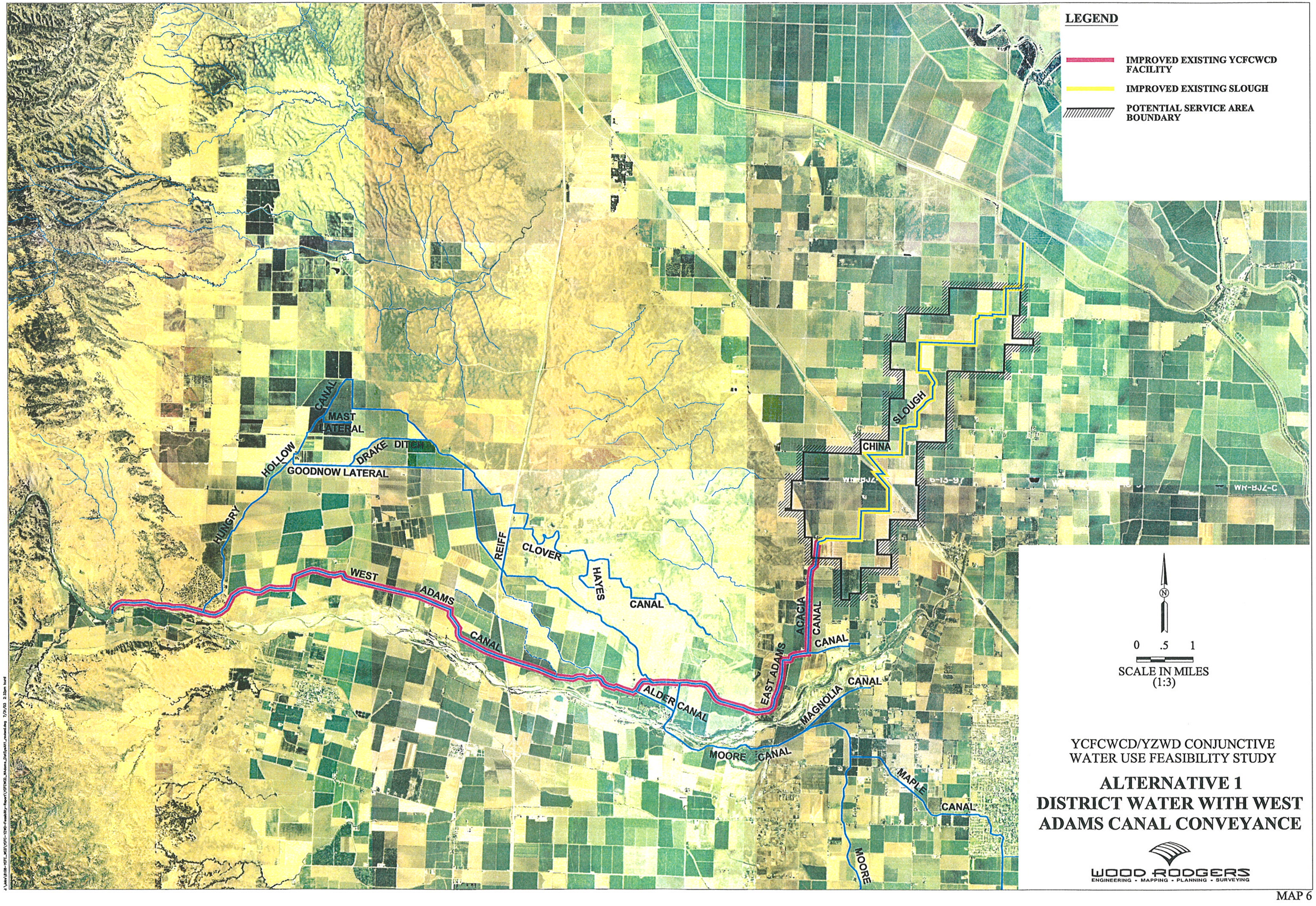
4/02



LEGEND

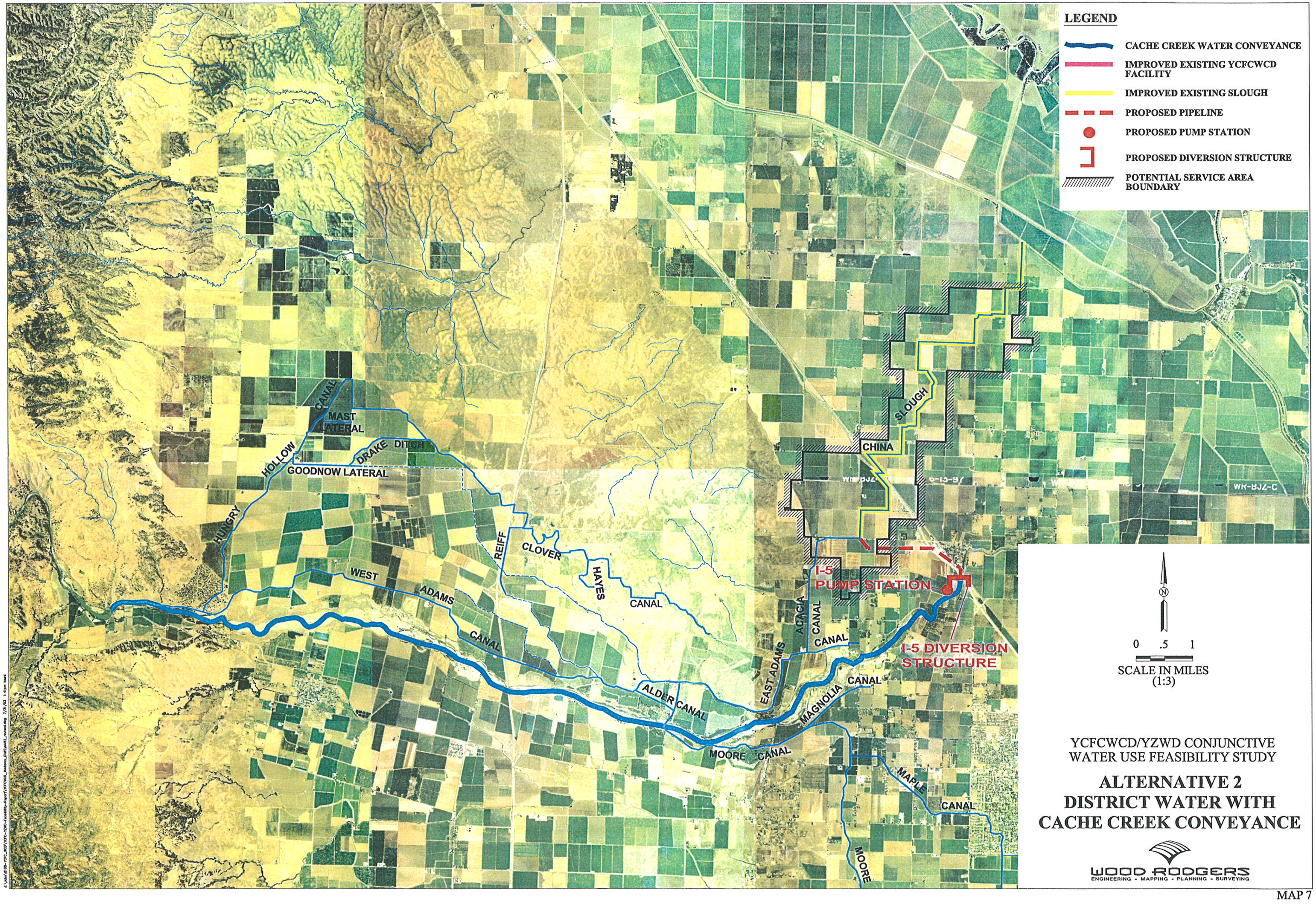
🟥	IMPROVED EXISTING YCFCWCD FACILITY
🟨	IMPROVED EXISTING SLOUGH
▨	POTENTIAL SERVICE AREA BOUNDARY

YCFCWCD/YZWD CONJUNCTIVE
WATER USE FEASIBILITY STUDY

ALTERNATIVE 1
DISTRICT WATER WITH WEST ADAMS CANAL CONVEYANCE

WOOD RODGERS
ENGINEERING • MAPPING • PLANNING • SURVEYING

MAP 6

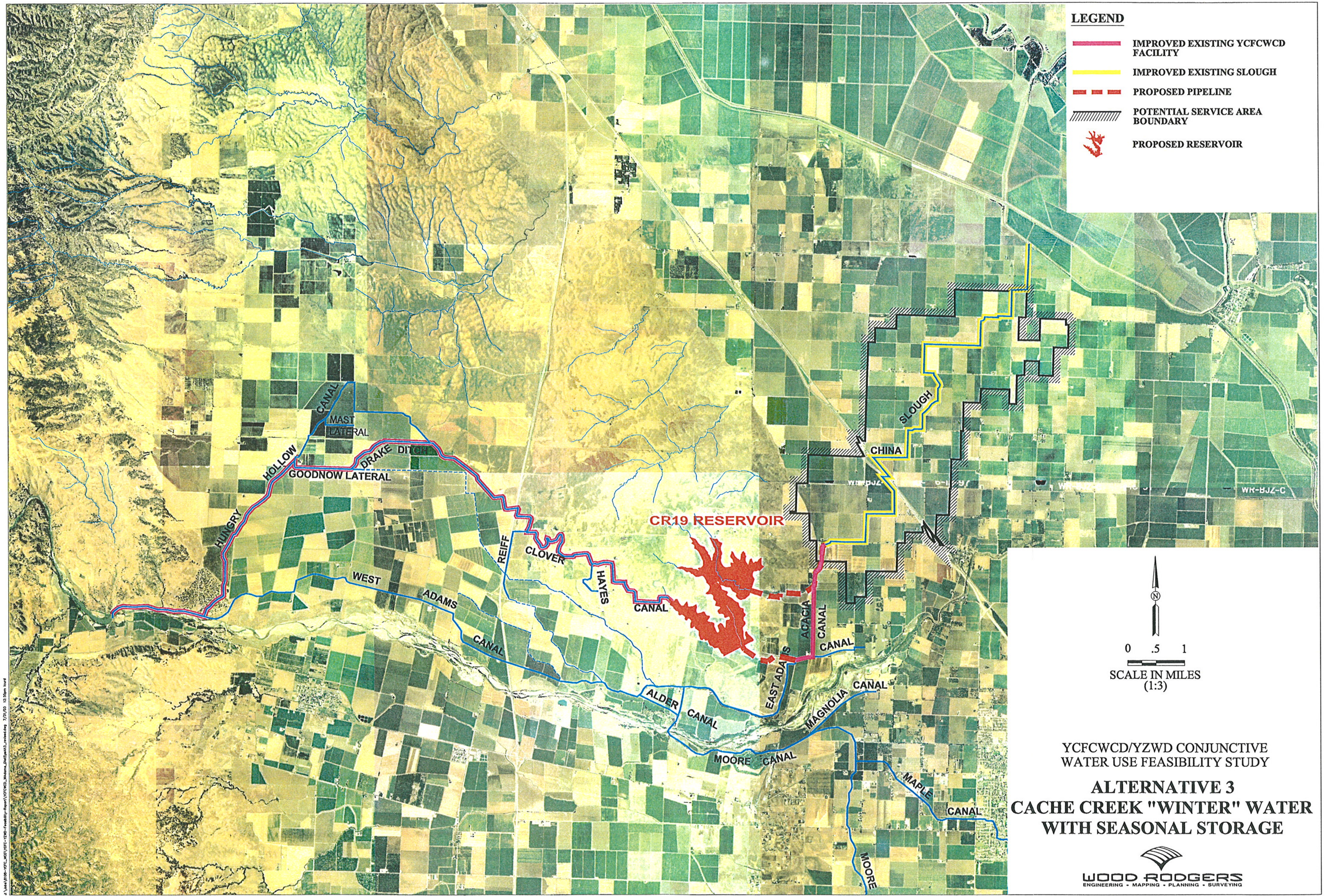


YCFCWCD/YZWD CONJUNCTIVE
WATER USE FEASIBILITY STUDY

ALTERNATIVE 2
DISTRICT WATER WITH
CACHE CREEK CONVEYANCE

WOOD RODGERS
ENGINEERING • MAPPING • PLANNING • SURVEYING

MAP 7

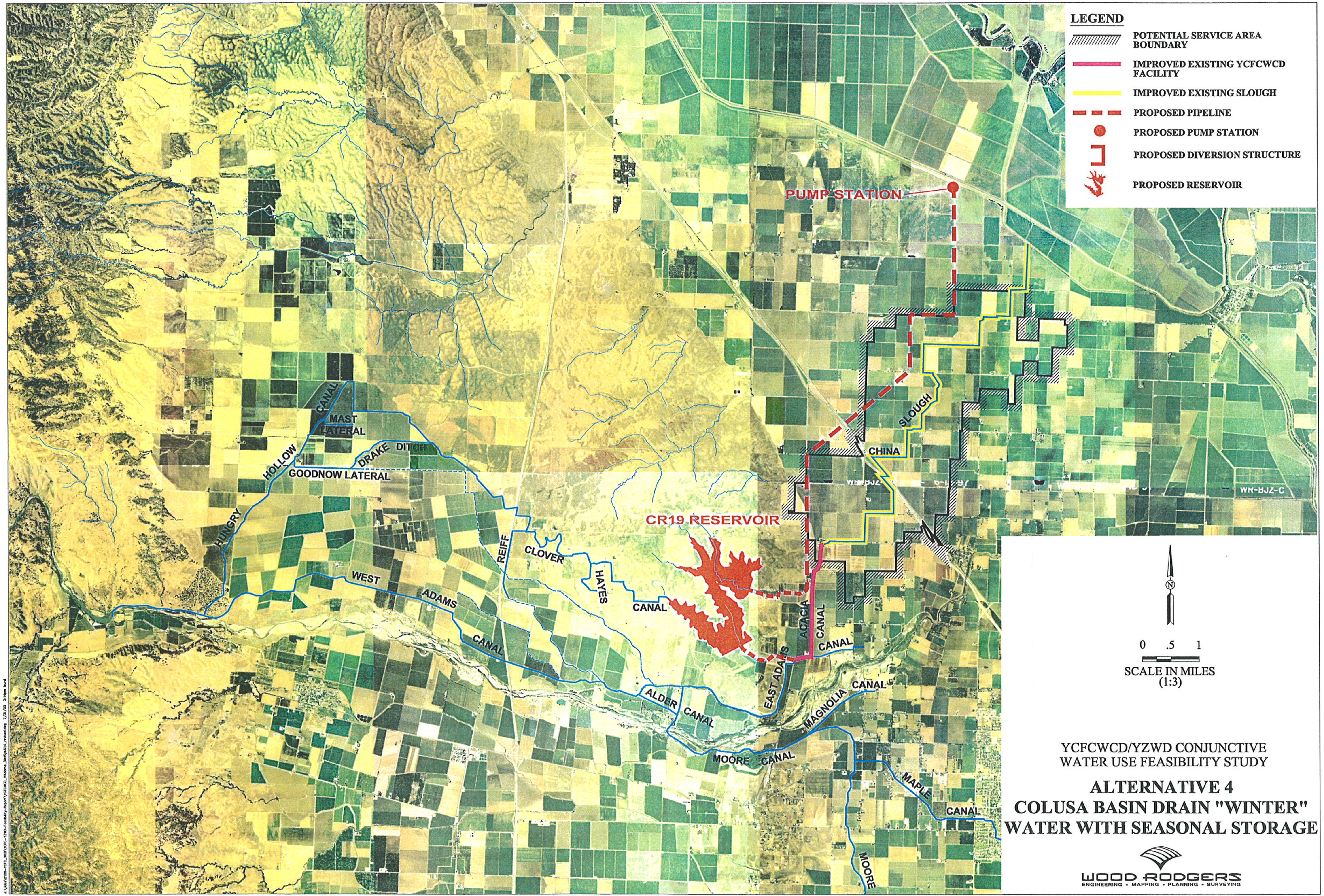


YCFCWCD/YZWD CONJUNCTIVE
WATER USE FEASIBILITY STUDY

ALTERNATIVE 3
CACHE CREEK "WINTER" WATER WITH SEASONAL STORAGE

WOOD RODGERS
ENGINEERING • MAPPING • PLANNING • SURVEYING

MAP 8



YCFCWCD/YZWD CONJUNCTIVE
WATER USE FEASIBILITY STUDY

ALTERNATIVE 4
COLUSA BASIN DRAIN "WINTER" WATER WITH SEASONAL STORAGE

WOOD RODGERS

ENGINEERING ▪ PLANNING ▪ MAPPING ▪ SURVEYING

Appendices

Appendices

WOOD RODGERS

ENGINEERING ▪ PLANNING ▪ MAPPING ▪ SURVEYING

Public Outreach

Appendix A

YOLO-ZAMORA CONJUNCTIVE USE FEASIBILITY STUDY
PUBLIC OUTREACH COMPONENT
2002-2003

Background:

The Water Resources Association of Yolo County (WRA) received funding to conduct a public outreach and community assessment effort regarding the Yolo-Zamora Conjunctive Use Feasibility Study (Y-Z Study). Public involvement is an essential component to exploring feasible conjunctive use opportunities in the Yolo-Zamora area. The Y-Z Study and the public outreach/community assessment effort were supported by a grant from the California Department of Water Resources (under Proposition 13) to the Yolo County Flood Control & Water Conservation District.

Public Outreach / Community Assessment Goal:

To conduct a public workshop in Yolo County for the purpose of exploring conjunctive use opportunities in the Yolo-Zamora area through public review and comment.

Public Outreach / Community Assessment Objectives:

- Increase awareness of land subsidence and conjunctive use options to decrease subsidence in Yolo-Zamora area, and solicit input to develop feasible alternatives.
- Solicit input regarding local water management options and feasibility to support conjunctive use utilizing surface water from Cache Creek.
- Develop an operating framework to continue on-going discussions for long-term solutions.

Public Outreach / Community Assessment Actions:

Staff held extensive conversations with local and regional agricultural and urban water agencies, environmental and public interest groups (California Sport Fishing Alliance, Audubon Society, Cache Creek Wild, Ducks Unlimited, Inc., Friends of the River), local environmental leaders, and farmers to gain an understanding of their issues, viewpoints, and concerns in order to introduce the issues (conjunctive use, water supply reliability, subsidence) and facilitate a successful public meeting with open discussions.

Staff coordinated and facilitated a Public Workshop and Tour on January 30, 2003. Nearly thirty individuals participated (including current and former county supervisors, water managers, board members, staff, and consultants, and at least eight members of the general public (see attached sign-in sheet). In order to increase comfort, participants were invited to write down their comments, opinions, and questions - all comments were kept anonymous. A transcription of all comments received is attached.

Summary of Issues and Concerns

Will the agricultural economy support the cost of future water options?
(Recommendation: Seek funding to conduct cost-benefit analysis.)

Have environmental impacts been thoroughly investigated utilizing the best available science? (Recommendation: In coordination with various resource experts (UC Davis, CA Dept of Fish and Game, etc), develop a strategy to prioritize needed scientific investigations on Cache Creek ecosystem.)

Are there environmental impacts associated with current water management options? (i.e., water rights application for Cache Creek witner flows, off-stream storage, water transfers, etc.) (Recommendation: Seek funding to conduct scientific investigations to understand priority issues and identify best options.)

Persons and Organizations Contacted:

In addition to numerous personal conversations, WRA staff met with representatives of various environmental groups, including California Sportfishing Alliance, Yolo Audubon Society, Cache Creek Wild, Ducks Unlimited, Inc., Friends of the River, and with other recognized environmental leaders in Yolo County. WRA staff also met staff representing CALFED (Dennis Bowker, Watershed Program), California Department of Water Resources (DWR) (Rich Juricich, Marsha Prillwitz, Susan Oldland, and others), GIS mapping experts and technical staff (including Ray McDowell, California Resources Agency, and Bill Brewster, DWR Central District).

In addition, WRA staff met with various public affairs consultants, including Tod Bedrosian, Meri Miles (CH2MHill) and Melinda Posner (Lucy & Company) and researched public involvement and facilitation methodologies at U.C. Davis Library.

Recommendations for Future Discussions

The Public Outreach Component increased public level of awareness of water management issues in Yolo County, and will be a cornerstone of future public involvement and educational activities.

Support for a conjunctive use project in Yolo County increased as potential environmental and agricultural benefits were identified. For example, environmental groups became educated about protecting groundwater and slowing subsidence rates, and the potential for additional water for both irrigation and environmental flows in Cache Creek during the summer and fall. Operational improvements to the YCFC&WCD distribution system gained support. It is recommended that the YCFC&WCD and others continue to convene leadership in the farming community, environmental community, resource agencies and out-of-county interests to further identify environmental and agricultural benefits. It is also recommended that a system-wide strategy to prioritize further scientific, economic and feasibility studies be established. Stakeholder development and acceptance of a scientifically defensible strategy will increase the opportunity to acquire state and federal funding.

There did not seem to be wide support for any specific option included in the Study, although grant funds should be sought to conduct further economic, environmental, and technical investigations. At the February 2003 Project Advisory Group (PAG) meeting, YCFC&WCD made an informal offer to water users adjacent to China Slough to deliver a limited amount of "surplus" Cache Creek water this year. Unfortunately, the offer was viewed as too expensive to utilize this irrigation season (2003).

WRA

WATER RESOURCES ASSOCIATION OF YOLO COUNTY

January 16, 2003

PUBLIC NOTICE

Public Workshop on Yolo-Zamora Surface Water Options

Landowners and tenants in the Yolo-Zamora and Yolo County Flood Control & Water Conservation District areas, as well as representatives of the business community, local community organizations, and the public are invited to a free workshop on the **Yolo-Zamora Conjunctive Use Feasibility Project** on January 30, 2003. The workshop will present information and options to provide surface water to farmers in the southern portion of the Yolo-Zamora area. The public is encouraged to comment on potential benefits and potential disadvantages of the project, and identify topics for further study.

The workshop will be facilitated by the Water Resources Association of Yolo County on behalf of the Yolo County Flood Control & Water Conservation District and the Yolo-Zamora Water District. The project is funded by a grant from the CA Department of Water Resources.

The Public Workshop will be held:
Thursday, January 30, 2003, from 9:30 am to noon
Leake Community Room, Woodland Public Library
250 First Street, Woodland.

An optional, free bus tour of the project area will be held from 12:30 to 3 p.m. **Since space is limited** and lunch will be included on the tour, please call Donna Gentile, Water Resources Association of Yolo County, at (530) 666-2733 by **noon on Friday, January 24, 2003** to reserve a seat for the tour.

(2015.5 C.C.P.)

Filing Stamp

STATE OF CALIFORNIA
County of Yolo

I am a citizen of the United States and a resident of the county aforesaid. I am over the age of eighteen years and not a party to or interested in the above-entitled matter. I am the principal clerk of the printer of

THE DAVIS ENTERPRISE
315 G STREET

a newspaper of general circulation printed and published Sunday through Friday in the city of Davis, county of Yolo, and which newspaper has been adjudged a newspaper of general circulation by the Superior Court of the County of Yolo, State of California, under the date of July 14, 1952, Case Number 12680. That the notice, of which the annexed is a printed copy (set in type not smaller than non-pareil), has been issue of said newspaper and not in any supplement thereof on the following dates to-wit:

January 17,19,20
All in the year(s) 2003

I certify (or declare) under penalty of perjury that the foregoing is true and correct.

Dated at Davis, California,
This 24th day of January, 2003

Legal Publications Clerk

Proof of Publication
2002168
NPH

PUBLIC NOTICE | PUBLIC NOTICE

NOTICE OF PUBLIC HEARING

The Yolo County Flood Control and Water Conservation District has contracted with the Water Resources Association of Yolo County to conduct public involvement for the **Yolo- Zamora Conjunctive Use Feasibility Project**. This project is funded by a grant from the CA Department of Water Resources. The purpose of the project is to assess the feasibility of providing surface water to farmers in the southern portion of the Yolo-Zamora area.

Landowners and tenants in the Yolo- Zamora and YCFC & WCD areas, as well as representatives of the business community, local community organizations, and the public are invited to participate in a Public Workshop. The Workshop will provide project information and options. The public will be invited to comment on potential benefits and potential disadvantages of the project and identify topics for further study.

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from 9:30 a.m. to Noon

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DE2002168 January 17,19,20, 2003

PROOF OF PUBLICATION

(2015.5 C.C.P.)

STATE OF CALIFORNIA
County of Yolo

THE DAILY DEMOCRAT

a newspaper of general circulation, printed and published daily in the City of Woodland, County of Yolo, and which newspaper has been adjudged a newspaper of general circulation by the Superior Court of the County of Yolo, State of California, under the date of June 30, 1952, and in accordance with the provisions of Title 1, Division 7, of the Government Code of the State of California; that the notice, of which the annexed is a printed copy (set in type not smaller than nonpareil) has been published in each regular and entire issue of said newspaper and not in any supplement thereof on the following dates to-wit:

January 17, 18, 19

all in the year 2003

I certify (or declare) under penalty of perjury that the foregoing is true and correct.

Date at Woodland

California, this 19th day of January 2003

Signature

This space is for the County Clerk's Filing Stamp

Proof of Publication of

Notice of Public Workshop

Water Resources Association

NOTICE OF PUBLIC WORKSHOP

The Yolo County Flood Control and Water Conservation District has contracted with the Water Resources Association of Yolo County to conduct public involvement for the Yolo-Zamora Conjunctive Use Feasibility Project. The Project is funded by a Grant from the CA Department of Water Resources. The purpose of the project is to assess the feasibility of providing surface water to farmers in the southern portion of the Yolo-Zamora area. Landowners and tenants in the Yolo-Zamora and YCFC&WCD areas, as well as representatives of the business community, local community organizations, and the public are invited to participate in a public Workshop. The Workshop will provide project information and options. The public will be invited to comment on potential benefits and potential disadvantages of the project, and identify topics for further study. The Public Workshop will be held: Thursday, January 30, 2003, from 9:30 am to noon. Leake Room, Woodland Public Library 250 First Street, Woodland. An optional bus tour for the project area will be held from 12:30 to 3:00 pm Since space is limited and lunch will be included on the tour, please call Donna Gentile at (530)666-2733 by noon on Friday, January 24, 2003 to reserve a seat for the tour.

33-January 17,18,19,2003

PROOF OF PUBLICATION

YOLO-ZAMORA CONJUNCTIVE USE FEASIBILITY PROJECT

To Assess Feasibility of Providing Sur. e Water to Portions of Yolo-Zamora

AGENDA Public Workshop

January 30, 2003 - 9:30 a.m. to Noon

10 min	WELCOME/INTRODUCTION	Mary-Ann/Dave Scheuring	Intros, mention 2 hour parking limit, restrooms
10 min	PROJECT BACKGROUND	Deborah/Twyla	Yolo County Water Plans DWR - planning assistance, grant monies Conjunctive Use Opportunities Y-Z area, YCFC&WCD applied on behalf Twyla- Brief History of Y-Z Deb - why hold a Public Workshop? (community courtesy, Public Funds, Brown Act, good decision making process) Crucial Conversations: opinions vary, emotions run strong, stales are high… public (vs. private) - make safe, respectful
5 min	SUBSIDENCE	Fran Borcalli	History, Y-Z area in particular Deb- Define Terms Subsidence: Collapse of Aquifer, g/w extraction that results in surface of the land sinking 7 cm in three years Show Ruler with 7 cm indicated Conjunctive Use - formalized way to utilize surface water when avail, groundwater other times Water Supply Reliability [can you depend on getting what you need? Every year? During Necessary Times? Drought? In-Lieu Recharge - allowing g/w to recover due to use of other (surface) water sources
15 min	PROJECT APPROACH	Fran	5 min on general approach 3-5 minutes on each of 4 Options
20 min	Discuss Upsides (Identify Interests)	Deb facilitate group	Appreciate your sharing your biews, jot down on placemats felt pens available Help Us Find/Verify the Upsides I Like This Option Because: I Need This Option Because: I Would Probably Gain From This Option Because:

YOLO-ZAMORA CONJUNCTIVE USE FEASIBILITY PROJECT

To Assess Feasibility of Providing Surface Water to Portions of Yolo-Zamora

AGENDA Public Workshop

January 30, 2003 - 9:30 a.m. to Noon

20 min	Discuss Downsides	Deb facilitate group	I Don't Like This Option Because: I Need Something This Option Does Not Provide Something I Really Value May Be At Risk I May Lose Something With This Option Someone Else May Lose With This Option
15 min	Discuss Info Gaps	Deb facilitate group	Continue jotting down on placemats
15 min	Discuss Recommendations	Deb facilitate group	Best We Know Right Now Reiterate Purpose of Feasibility Study Look for Solution That Makes Sense Include Comments About What Is Really Important to You
10 min	Schedule/Next Steps	Mary-Ann, Fran	
	LUNCH BREAK		
	BUS TOUR	Deb	Tour Information

WRA

WATER RESOURCES ASSOCIATION OF YOLO COUNTY

Thursday, January 30, 2003

PUBLIC WORKSHOP – Yolo-Zamora Conjunctive Use Feasibility Project

We would like to have a record of your attendance. Your signature is not a prerequisite for attending this meeting.

	Name	Address	Representing	Phone / EMAIL
1	ALEX LONG	P.O. BOX 225 ZAmora Ca.	SELF	(530) 662-5551
2	Frank Sieferman Jr.	905 Lopes St Woodland	3rd district Yolo County	(530) 666-8621
3	Mike Horgan		YCFCWCD	662-0265
4	Bruce Rominger		YCFCWCD	
5	Harry Walker	Woodland	Self	
6	Chris LEININGER	PO BOX 160 VINA CA 96092	RANCHER	cleininger@jps.net (530) 839-2720
7	CHRIS BARTON		YCFC&WCD	
8	BOB EOFF		✓	
9	Steve Gold	Sacramento	California DWR	916-653-9495
10	CHUCK OWENS	1416 9th ST Sac, 95814	DWR	916/654-6274 owens@water.ca.gov
11	Cynthia C. Peterson		Dunnigan WD	530-724-3271 dwd@afes.com
12	George Wooo Jr	P.O. Bx 373 Yolo, CA 95697	Self	662-6088
13	TOM HERMLE	P.O. BOX 176 ZAMORA 95698	Yolo ZAMORA WD	662-2342
14	Taylor Thompson	95697 P.O. Box 249 - Yolo	Yolo-Zamora W.D.	666-2893
15	Lynnel Pollock	625 Court St Woodland 95695	Yolo County BOS WRA-Yolo Co.	666-8627 lynnel.pollock@yolocounty.org
16	Lester MESSINA	PO BOX 351 Willows CA 95988	Glenn Cty Ag Dept	934-6501 wateradv@countyofglenn.net
17	Frank Siefermen	P.O Box 135 Zamora 95698	Self.	662-2561
18	John Stone	33710 C.O Rd 17	Self	662-6574

WRA

WATER RESOURCES ASSOCIATION OF YOLO COUNTY

Thursday, January 30, 2003

PUBLIC WORKSHOP – Yolo-Zamora Conjunctive Use Feasibility Project

We would like to have a record of your attendance. Your signature is not a prerequisite for attending this meeting.

	Name	Address	Representing	Phone / EMAIL
19	Mary-Ann Warmerdam	34274 SH 16 Woodland 95695	YCFCWRD	530.662.0265 mwarmerdam@ycfcwcd.o
20	Fran Borcalli	3301 C St., Bldg 100B Sacramento, CA 95816	Wood Rodgers	916-326-5224 fborcalli@woodrodgers.com
21	John Fielden	901 P Street Sacramento 95814	DWR	916-651-7053 jfielden@water.ca.gov
22	Rich Juricich		DWR	916-651-9225 juricich@water.ca.gov
23	Mark Souverville	3251 S Street Sacramento CA 95816	DWR	916-227-7601 msouv@water.ca.gov
24	Kyle Lang	21548 Old River Rd ; W sac 95691	Lang farms	916 716 3703
2	David Scheuring		YCFCWCD	
26	Donna [illegible]		WRA	
27	Deborah Brauer		WRA	
28	Jacques Debra		DAVIS	

Yolo-Zamora Conjunctive Use Feasibility Project
Public Workshop Comments 1/30/03

TOPICS OF COMMENTS	OPTION I		OPTION II	
	Pros	Cons	Pros	Cons
SUBSIDENCE	Reduces likelihood of subsidence and subsidence impacts			
COSTS	All gravity feed, no pumping cost, less expense. Least Cost. Low Cost.	Is this cost-effective?		Pumping costs are going to rise
	Reduces pumping costs			
	Reduce Drainage into Cache Creek	Reduce Total Water in Cache Creek	Would be water in Cache Creek where usually dry. Rewatering of Creek.	
			City of Woodland to receive largest recharge benefit and should be financially involved with transportation loss	
	Improves g/w recharge in Y-Z area		Add'l recharge along Cache Creek	
TIMING	Quickly on-line			
ENVIRONMENTAL IMPACTS	Minor envtl impact. Less envtl hassles.		Habitat Improvement. Potential for habitat benefits in Cache Creek.	
	Maximize utilization of already developed supply		Keeping flows in Creek may prevent brush from growing in channel	
RELIABILITY		60-70% reliability		
WATER QUALITY	Water quality			Picking up natural flow in lower Cache Creek is high boron
MISC COMMENTS	Could be used in combination with other alternatives		More water may keep ATVs out of Creek!	
	Should be implemented regardless			

Yolo-Zamora Conjunctive Use Feasibility Project
Public Workshop Comments 1/30/03

TOPICS OF COMMENTS	OPTION III		OPTION IV	
	Pros	Cons	Pros	Cons
SUBSIDENCE			Reduces likelihood of subsidence and subsidence impacts	
COSTS	Gravity feed a plus.	Will cross/flood public road reservoir)		Too expensive, cost to pump will increase. On-going power costs
			Reduces pumping costs	Is this cost-effective?
	Improved flexibility with reservoir	In wet years, possibility of needing to spill water from reservoir may exacerbate flooding along China Slough	Would use flood water	Would be too costly
	Is excellent and holds collateral opportunity		Taking winter flows out of Colusa Drain lessens flows into Bypass	Not best - pump to Bird Creek Res and Oat Creek more feasibility from Colusa Basin Drain as source
			Relieve Flooding Pressure. Improves g/w recharge in Y-Z area.	
TIMING			Possible water quality improvement to Delta	
ENVIRONMENTAL IMPACTS			May be least environmentally challenged	
RELIABILITY	Better reliability		100% reliability. 100% reliability. 75% yield. Improved reliability of supply.	
WATER QUALITY	Gravity flow of higher quality water		Benefit water quality for downstreamof 2040	
MISC COMMENTS	Expanded Hungry Hollow Canal could be used to convey summer water the same as West/East Adams in Option I	Will property acquisition be necessary?		Will property acquisition be necessary?
	Rd 19 res could store winter water for cities possibility! Need urban partners to build reserve		Need urban partners	Water rights issue

Yolo-Zamora Conjunctive Use Feasibility Project
Public Workshop Comments 1/30/03

TOPICS OF COMMENTS	OTHER OPTIONS	
	Pros	Cons
SUBSIDENCE		
COSTS	Need to look at storage on Bird Creek (from 2047 water). It would be gravity coming out, 75% reliability Zamora Reservoir and pumping plant Cache Creek Upstream Storage: 1) Stops mercury movement; 2) Lowers stream temperature for fish - increasing fisheries; 3) Provides down-stream water supply opportunity: Ag and City; 4) Provide regional flood protection; 5) Recreation opportunity.	
TIMING		
ENVIRONMENTAL IMPACTS		
RELIABILITY		
WATER QUALITY		
MISC COMMENTS		

Yolo-Zamora Conjunctive Use Feasibility Project
Additional Public Comments
January 30, 2003 Workshop and Personal Communications

In addition to the transcribed comments included on the previous pages, the following requests/comments/data gaps were also communicated:

OPTIONS

What is affordable? What are farmers willing to pay for surface water?

Each option should be summarized in a consistent format, addressing the following: benefits of each option, cost estimates for each option, barriers to each option (including technical, economic, and political challenges).

Need economic analyses of options (including ability to pay and financing options)

Need information on water "losses" (evaporative losses from reservoirs and seepage and evaporative losses from ditches). Would some water recharge the groundwater?

We should attempt a phased implementation, with the ambition to supply water to all of Northern Yolo and to maintain control locally and then perhaps to sell some water out-of-County.

CACHE CREEK AND ECOSYSTEM

Need information on environmental benefits to Cache Creek.

There are many unanswered technical and scientific questions yet to be asked about Cache Creek. Let's try to find grant money to study, monitor, and (hopefully) answer Cache Creek ecosystem and fisheries questions.

LEGAL AUTHORITY/WATER RIGHTS

Does the Yolo-Zamora Water District have the legal and financial ability to levy assessments to help meet local cost-share responsibilities if an option is choosen for construction?

Describe and explain the legal water rights to various water sources (groundwater, Cache Creek, Sacramento River) in Yolo County.

Do these options (including reservoirs) have any possibility of seizure of land from unwilling right-of-way land owners?
Please emphasize legal review and statutory limitations and integration with State and Federal laws, including water rights, flooding, water quality, general planning, transportation issues, and

environment vs. development issues.

We need to "tie up" water supply or it WILL go South.

WATER QUALITY

What is the status of mercury concentrations in Cache Creek and groundwater basins? Would mercury accumulate in any proposed reservoirs and thereby become a future concern/liability?

GROUNDWATER MANAGEMENT

Will I be able to drill a well next to the water delivery system on my own ground (land rights)?

Need to establish groundwater management objectives.

Need more information on groundwater benefits – and it doesn't seem "fair" that others might benefit without participating (that is, paying). For instance, groundwater levels could improve in Yolo-Zamora area due to some farmers' paying for surface water and everyone's groundwater levels would improve.

Additional modeling of the Yolo County aquifers is needed in order to better analyze options and potential impacts.

IN-COUNTY AND OUT-OF-COUNTY WATER TRANSFERS

Policy discussions should be held in Yolo County to discuss inter-district water transfers within the County and water transfers among members of shared watersheds and groundwater basins (for example, within the Colusa Basin Drain and the Tehama-Colusa Canal).

INTERSTATE 5 AND RAILROAD IMPACTS

What (if any) is the relationship between Interstate 5 and the zones of subsidence and flood zones in Yolo County?

What are CALTRANS and Railroad slant on pipeline under I-5? (permits, enviro, etc)

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WOOD RODGERS

ENGINEERING ▪ PLANNING ▪ MAPPING ▪ SURVEYING

Memorandum-Suitability of Colusa Basin Drain Water for Irrigation in the Yolo-Zamora Area

Appendix B

WOOD RODGERS

Memorandum

TO: Fran Borcalli

FROM: Rowland L. Hall

C:

DATE: 10/15/02

SUBJECT: YCFCWCD/YZWD – Suitability of Colusa Basin Drain Water for Irrigation in the Yolo-Zamora Area

INTRODUCTION

The suitability of the Colusa Basin Drain (CBD) water for direct re-use as irrigation water or for other conjunctive use applications is not a simple matter. There are many factors that must be examined before a determination of suitability can be made. These factors include the chemical composition of the water, the physical properties of the soils, and the types of crops or vegetation that will be using the water. The soil properties, water quality, and plant interactions must all be compatible before the water can be deemed "suitable for irrigation.. If they are not compatible, the applied irrigation water could have an adverse effect on the chemical and physical properties of the soil on which they are applied, and to the plants that use the water.

The main factors that determine the suitability of water for irrigation, water storage, and other types of conjunctive use projects are briefly discussed in the following sections.

SOIL PROPERTIES

The soil properties of texture, structure, depth, permeability, and chemistry play an important part in irrigation management. These properties will control the amount of water that can be stored in the soil, the rate of infiltration, the amount of water available to plants, and the degree of salinity/sodicity.

Soil Texture

Typical soils consist of varying percentages of sand, silt, and clay. The percentage of sands, silts, and clays is determined by passing the soils through sieves of varying sizes to separate the sand, silt, and clay into their component factions. The percentages are calculated and used to classify the soils into one of twelve basic soil textures as described by the USDA Natural Resources Conservation Service (NRCS) (Soil Survey of Yolo County, California, NRCS). The two primary soil textures that apply to irrigated lands in Yolo County are listed with their soil classifications as follows:

Yolo-Brentwood association - Well-drained, nearly level silt loams to silty clay loams; on alluvial fans. These soils are well drained to poorly drained sandy loams to clays that formed in alluvium on fans and in basins. The soils of this association are used chiefly for irrigated orchards, row crops, truck crops, and field crops. Apricots, almonds, English walnuts, sugar beets, tomatoes, alfalfa, and milo are the main crops.

Rincon-Marvin-Tehama association - This association consists of well-drained and somewhat poorly drained loams to silty clay loams on alluvial fans and basin rims. The soils of this association are used chiefly for irrigated orchards, row crops, and field crops. Apricots, almonds, sugar beets, tomatoes, grain sorghum, alfalfa, and rice are the main crops.

Within most of the potential re-use areas, especially the areas west of CBD, soil textures are generally fine-grained. These fine-grained soils are classified as sandy loams to clay, and loams to silty clay loams.

Soil Structure

Soil structure refers to the grouping of sands, silts, and clays into larger aggregates of various sizes and shapes. Soil structure is produced by a combination of root penetration, wetting and drying cycles, and animal activity that combines with inorganic and organic elements that provide various degrees of cementing or binding of the soil materials. Structural aggregates that are resistant to physical stress are important to a soils tillability and productivity. The movement of water, air, and plant roots through a soil is affected by the soil structure. Stable aggregates result in a system of interconnected soil pores that allow for rapid exchange of air and water with plant roots, a desirable characteristic for healthy plants.

Good soil structure is maintained through good soil management practices. These management practices are critical in the potential re-use areas because of the abundant fine-grained nature of the soils and a relatively high proportion of sodium to calcium and magnesium. Fine-grained soils generally have a greater number of exchange sites where sodium can be readily exchanged for calcium and magnesium ions (or vise-versa). If a significant amount of sodium is exchanged for calcium (or magnesium) in the soils, sodium may become dominant resulting in lower infiltration rates, decreased water holding potential, and may inhibit the plants ability to uptake water and nutrients.

Soil Depth

Soil depth refers to the thickness of the soil materials that provide the necessary structural support, nutrients and water for plants. The depth of soil can affect irrigation management. If the depth of soil is less than three feet, the rooting depth and available soil water for plants is decreased because soils with less available water for planting requires more frequent irrigations. The depth of soils within the CBD potential re-use area is generally greater than three feet.

Soil Permeability and Infiltration

Permeability of soil is a measure of the ability of water and air to move through it. It is influenced by the size, shape, and continuity of pore spaces, which in turn is dependent on soil bulk density, structure, and texture. Most of the time, soil permeability is classified based on the most restrictive layer within the upper 5 feet of the soil profile. Soils with a slow, very slow, or rapid to very rapid permeability classification are not suitable for irrigation.

Soil Permeability Classes

Classification	Infiltration Rate (inches/hr)
Very Slow	Less than 0.06
Slow	0.06 – 0.2
Moderately Slow	0.2 – 0.6
Moderate	0.6 – 2.0
Moderately Rapid	2.0 – 6.0
Rapid	6.0 – 20.0
Very Rapid	Greater than 20

Infiltration is the downward flow of water from the surface through a soil. The infiltration rate is a measure of a soils ability to adsorb an amount of rain or irrigation water over a period of time (commonly inches per hour). Coarse textured soils such as sands and gravels have very high infiltration rates. Infiltration rates for medium and fine textured soils such as loams, silts, and clays are lower than those of coarse textured soils and are more dependent on the stability of the soil aggregate. Water and plant nutrient losses are greater in soils with the highest infiltration rates. The soils within the potential re-use areas are relatively fine-grained with Slow to Moderately Rapid infiltration rates.

Water Holding Capacity

There are four levels of soil moisture that reflect the availability of water in soil; saturation, field capacity, wilting point, and oven dry. Saturation occurs when the soil pores are filled with water. Field capacity is the level of moisture left in the soil after field drainage. The wilting point is the soil moisture content whereby most plants cannot exert enough force to pull the water away from the soil particles.

Water between field capacity and the wilting point is available for plant use. Crops that reach the wilting point will be permanently damaged. When a soil is dried in an oven, all the water is removed. Oven dry is used in this manner to provide reference when talking about the other soil moisture levels. Holding capacity generally discusses the water available for plant use. The water holding capacities for the various soil textures within the Colusa Basin area are given in the following table:

Holding Capacity for Various Soil Textures

Soil Texture	Available Soil Moisture	
	(Inches/inch)	(Inches/ft)
Fine Sandy Loams	0.14 – 0.18	1.7 – 2.2
Loams and Silt Loams	0.17 – 0.23	2.0 – 2.8
Clay Loams and Silty Clay Loams	0.14 – 0.21	1.7 – 2.5

Interactions Between Soil, Water, and Plants

The Colusa Basin supports a diverse agricultural economy with much of the land currently being irrigated. Rice, fruits nuts, tomatoes, sugar beets, corn, alfalfa, and wheat are the major crops.

Understanding the interactions between soil and water and how these interactions affect crops is critical to irrigation management. Knowledge of water use patterns and how they affect plants throughout the growth cycle has a major influence on the water quality within the irrigation district. Poorly managed water applications lead to crop water stress, leaching of fertilizers and pesticides, and salinity problems.

WATER QUALITY OF THE COLUSA BASIN DRAIN

The evaluation and assessment of water quality and suitability for irrigation was conducted using readily available (to the public) analytical chemistry data published by the US Geological Survey (USGS) and the Sacramento River Watershed Program (SRWP). Both programs monitor water quality within the CBD. The USGS and the Central Valley Regional Water Quality Control Board monitor specific sites within the Sacramento River Watershed on a regular basis as part of the National Water-Quality Assessment Program (NAWQA). The results of the NAWQA monitoring are published in a report entitled "1998 California Hydrologic Data Report", US Geological Survey, 1998.

The Sacramento River Watershed Program has conducted additional monitoring over the last 10 years. The monitoring data collected during 2000 to 2001was used in the evaluation of the water quality. This data is published in the "Annual Monitoring Report: 2000 – 2001", (SRWP, 2002).

Both monitoring and sampling programs included a fixed sampling point at the CBD at Road 99E near Knights Landing, California. The USGS selected this point because it is one of the best points in California for evaluation of water draining agricultural lands. A continuous record at this site over the last several years and the fact that much of the water that is drained by the Colusa Drain comes from the area planned for re-use makes this site especially suited for the irrigation suitability evaluation.

The U.S. Geological Survey NWQAP program monitored the peak flow events and collected samples from the CBD analysis on a monthly basis. The SRWP monitoring was primarily event based , with monitoring scheduled and coordinated after a significant rainfall event had occurred, or during the summers peak irrigation drainage. This method is useful in determining the "worst case" chemical releases to the environment. A data base summary of the analytical chemistry results for 30 sampling events conducted in 1996 through 1998 is attached to this document as Appendix A. Additional sampling information from the Sacramento River Watershed Program monitoring events is also included in Appendix A.

In most irrigation operations, salinity is the primary water concern because of its effect on both soil structure and crop yield. But to determine suitability of water for irrigation, there are additional concerns such as sodicity and the relative amounts of carbonate vs. bicarbonate that must be considered.

Drainage waters from irrigated lands may also contain other chemical compounds such as excess nutrients or toxic substances such as metals, pesticides, and herbicides. These compounds have the potential to contaminate irrigation drain waters above levels that are safe for human consumption. Even very small quantities of some chemicals are toxic to aquatic organisms and higher trophic levels.

For the purpose of this study, the water quality evaluation was divided into five main parts including Salinity, Anions and Cations, Sodicity, Nutrients, and Toxicity. The following sections discuss each individual component of the CBD water.

SALINITY

The part of the irrigation water that is actually consumed by plants is relatively free of dissolved materials. Plants do selectively retain some nutrients and a part of the dissolved mineral matter, but the amount of major cations and anions is not a large part of the total content in the irrigation water. Plants will readily uptake calcium and magnesium salts; however, the bulk of matter in the water that the plants consume will be left behind. This matter cannot be left behind or allowed to rise too high because excess concentrations of the remaining solutes in the soil moisture will interfere with the osmotic processes by which plant root membranes are able to assimilate water and nutrients.

Generally, irrigation water quality refers to the kind and amount of salts present in the water (total dissolved solids) and their effects on crop growth and development. All naturally occurring waters contain dissolved salts and trace elements in varying concentrations as a result of natural weathering processes.
The salt concentrations influence the osmotic pressures of the soil and water, that is to say the higher the salt concentration, the higher the osmotic pressures. As the osmotic pressure increases with increasing salts, the ability of plants to adsorb the water through their root systems becomes more difficult. Salts also can affect the soil structure by creating unfavorable conditions for plant growth and by reducing the soil infiltration rates.

Total Dissolved Solids (Electrical Conductivity)

Total Dissolved Solids (TDS) is a measure of the concentration of soluble salts in a water sample and is usually expressed in terms of electrical conductivity (EC). Electrical conductivity is a measurement that directly reflects the salt content of the water because chemically pure water doesn't conduct electricity, and water containing dissolved salts do.

Measurements of EC can detect two possible water-soil conditions. 1) Salinity or salt condition caused by the accumulation of salts in the root zone and 2) Potential permeability and soil structure problems or reductions in plant water intake caused by a condition in which the sodium becomes the dominant ion in the soils.

The analytical chemistry data provided by the USGS and the SRWP indicated the total dissolved solids in the CBD water was elevated when compared to other non-agricultural waters in the Sacramento River Watershed; however, the water is a Class 2 irrigation water which is good water for irrigation based on salinity.

The salinity of a given body of water is classified based on the effect of the water on growing crops. Class 1 irrigation water is excellent water for irrigation purposes with a Salinity/TDS reading of less than 250 umhos/cm. Class 2 water is considered good irrigation water with Salinity/TDS readings between 250 and 750 umhos/cm. Class 3 waters range from 750 to 2,000 umhos/cm. Use of class 3 waters for irrigation is possible, but, it will usually require a leaching program before it can be implemented.

Water in the CBD ranges from 0.23 mmhos/cm to 0.765 mmhos/cm. This means from the standpoint of salinity or TDS only, the CBD water is good water. In thirty sampling events, there was only one time when the water moved into the Class 3 category.

ANIONS AND CATIONS

The compounds and substances that are called "salts" are either positively or negatively charged ions. These ions readily combine with other substances in ionic reactions. Water passing through soils can exchange its ions for those in the soil or vise versa. The ionic properties and the types and relative proportions of the ions in solution determine the compatibility of the soil with the water. The wrong combination of these ions can cause salinity or sodicity problems, which can result in the loss of soil structure and a reduced infiltration rate

Carbonate (CO3)

Because calcium and magnesium carbonates are relatively insoluble, high carbonate water is usually associated with high concentrations of sodium (and sometimes potassium). When drying soils saturated with high carbonate waters, the carbonate ion will remove calcium and magnesium ions from the soils and the soils will become alkaline. This is not the case with the CBD water as the Bicarbonate ion is dominant.

Bicarbonate (HCO3)

Bicarbonate is the ion normally responsible for alkalinity, or the capacity of water to neutralize acids. Water with large amounts of bicarbonate ions will precipitate calcium or magnesium as the water dries. This leaves sodium in place of the calcium or magnesium in the soil. Use of high bicarbonate water will usually result in the soil being dominated by the sodium ion.

The water within the CBD is classified as sodium magnesium bicarbonate water. The bicarbonate ion also indicates basic conditions with pH values above 7.0.

Calcium (Ca)

Calcium is an essential plant nutrient that comes from the dissolution of limestone and gypsum and usually occurs in various forms of calcium phosphate. A soil that is dominated by calcium is friable and easily worked, and is conducive to water infiltration. Excess calcium and magnesium can be a hazard due to the effects of soil pH.

Calcium added to irrigation water can lower SAR values and reduce the harmful effects of sodium. The effectiveness of adding calcium depends on its solubility in the irrigation water, which is controlled by the pH, the source of the calcium (e.g. calcium carbonate, gypsum, and calcium chloride), and the concentrations of the other ions in the irrigation water.

Magnesium (Mg)

Magnesium is also an essential plant nutrient that comes from the dissolution of dolomitic limestone. It is similar in reaction to calcium and is generally abundant in soils. A soil that is dominated by magnesium is also friable and easily worked, and is conducive to water infiltration. The water of the CBD has an abundance of magnesium.

Sodium (Na)

Sodium is not generally considered a plant nutrient. All the common salts of sodium are water-soluble which makes sodium the most troublesome of the major constituents in irrigation water. If the sodium is too high, the soil becomes very tight and water will not infiltrate. Sodium concentrations in the range of 0 – 69 ppm is considered ideal with a concentration of 70 – 180 ppm having moderate problems, 181 – 200 ppm having severe problems, and having very severe problems with sodium concentrations greater than 200 mg/L. Concentrations of sodium in the CBD were within the ideal range.

Chloride

Like sodium, chloride is very soluble in water. Chloride is measured in the soil because it often has a direct toxic effect on plants and can contribute to the overall salinity of the water. When calcium chloride is added to a field, the removal of harmful sodium is accelerated because of the chloride ion, which forms a relatively stable alliance with the sodium ion. The concentrations of chloride identified in the CBD waters are relatively low and should not present a problem.

SODICITY

Irrigation waters that contain large amounts of sodium are of concern due to sodium's effect on the soil. Potential sodium hazards are expressed in terms of the sodium adsorption ratio. The sodium adsorption ratio and potential effects are discussed in the following section.

Sodium Adsorption Rate (SAR)

The SAR of a water sample is the proportion of sodium relative to calcium and magnesium. SAR measurements indicate the sodium ion exchange activity as sodium reacts with clay. An adjusted SAR includes the added effects of calcium related to carbonates and bicarbonates. A SAR value of 0 – 2 is considered ideal with SAR values of 3 – 5 having moderate problems, 6 – 8 having severe problems, and having very severe problems with SAR values of greater than 9.

The permissible value of the SAR is a function of salinity. High salinity levels reduce swelling and aggregate breakdown and promote water penetration. With the high proportion of sodium, the opposite effect is produced. High SAR values combined with low Salinity levels produces the greatest reductions in the rate of infiltration.

SAR values for the CBD water ranged from below 3.5 to 12. These values are high and when combined with the lower salinity values for the CBD samples, this indicates that using this water may present a problem if a good irrigation management plan is not implemented prior to use. The effects of the elevated SAR can be minimized or diminished with a proper management plan. The cation exchange process is reversible and can be controlled by adjustments to the composition of the water.

pH

The pH of the water expresses the acidity or alkalinity of the water. Water with a pH reading of less than 7 is considered acidic, and water with a pH above 7 is considered alkaline. The pH readings are important because the pH is a primary factor in determining the amount of nutrients and other substances that will dissolve in the water. Most waters within the district are slightly basic ranging from 7 to 8.5.

NUTRIENTS

The level of nutrients in the CBD waters is relatively high when comparing to streams and rivers that are located in non-agricultural areas. However, the nutrients were not found to be at levels that would require changes in management practices other than adjustments to the fertilization mixture and application. The SRWP study reported some algae in the CBD and recommended checking the algal growth on a regular basis during the summer irrigation drainage.

Excess algal growth is used as an indicator of elevated nutrient concentrations within streams or other bodies of water, especially if the water contains elevated concentrations of nitrogen or phosphorus. Algal growths affect the aquatic receiving waters because they use an abundance of oxygen in the metabolic processes as they digest the nutrients directly from the water. As the algae utilize the oxygen in the water, less oxygen is available for other forms of aquatic life.

When the level of oxygen drops to below the level that sustains life, everything living dies including the aerobic bacteria that have the primary responsibility for cleaning the waters.

The common nutrients are usually classified on the basis of how much is available for plant uptake and use. These classifications are described as low, normal, high, and very high and are listed in the following table.

Plant Nutrient Availability (ppm)

Rating	Ca	Mg	K	P	N	NO3	SO4	S
Low	<20	<10	<5	<0.1	<1	<5	<30	<10
Normal	20-60	10-15	5-20	0.1-0.4	1-10	5-50	30-90	10-30
High	60-80	25-35	20-30	0.5-0.8	10-20	50-100	90-180	30-60
Very High	>80	>35	>30	>0.8	>20	>50	>180	>60

The nutrient values recorded for the CBD waters were High for magnesium, Normal for calcium, phosphorus, nitrogen, and sulfate, and Low for potassium and nitrates.

TOXICITY

Aquatic toxicity monitoring was conducted for CBD waters in the SRWP monitoring program. Laboratory toxicity tests were performed on *Ceriodaphnia dubia* using EPA procedures. There was no significant mortality was observed in the nine samples collected during the 2000 and 2001 SRWP monitoring, however, there was significant reproductivity toxicity in four of the nine CBD water samples. The specific cause of the toxicity was undetermined. The toxicity observed is suspected to be the result of a metabolically activated toxicant such as diazinon or clorpyrifos. The two primary toxicants within the Sacramento River Watershed are Pesticides and Metals. These two categories of toxicants are discussed in the followings sections.

Pesticides

Concentrations of pesticides, as measured in the NAWQA and SRWP monitoring programs, have made significant improvements over the last decade. Water quality samples collected during the NAWQA study were analyzed for over 80 pesticides/herbicides. Of the 80 analytes, 57 pesticides that were analyzed for were not detected, 11 were identified only in trace amounts and 12 were considered as potential toxicants. The primary pesticides identified in the NAWQA study are listed in alphabetical order as follows:

1. Bentazon - Primary concentrations associated with peak storm events during December through March, and from drainage during July through September. Maximum concentration recorded at 0.13 μg/L.

2. Carbofuran - Primary concentrations associated irrigation drainage during May, June, and July. Maximum concentration recorded at 0.4 μg/L.

3. Chlorpyrifos – Relatively minor concentrations identified in April and May, and again in the months of July, August, and September. Maximum concentration recorded at 0.016 μg/L.

4. Cyanazine – Primary concentrations associated with peak storm events during winter, and from drainage during May through September. Highest concentrations occurred during July and August. Maximum concentration recorded at 0.19 μg/L.

5. Diazinon – Consistent minor concentrations associated with stormwater runoff and irrigation drainage during May through September. Maximum concentration recorded at 0.09 μg/L.

6. Diuron – Consistently shows up in relatively minor concentrations February though July. Highest concentrations recorded after stormwater runoff events in January through April. Maximum concentration recorded at 0.69 μg/L.

7. Metolachor - Primary concentrations associated irrigation drainage during May, June, and July. Maximum concentration recorded at 0.2 μg/L.

8. Molinate – Primary concentrations in May, June, and July with lesser amounts in August and September. Maximum concentration recorded at 19 μg/L.

9. Simazine – Primary concentrations associated with peak storm events and drainage during May and June. Maximum concentration recorded at 4.0 μg/L.

10. Thiobencarb - Primary concentrations associated irrigation drainage during May, June, and July. Maximum concentration recorded at 4.4 μg/L.

11. Trichlorpyr - Primary concentrations occur in June and July with lesser amounts in August and September. Maximum concentration recorded at 1.1 μg/L.

12. Carbaryl - Primary Concentrations associated with spring runoff during April and May. Maximum concentration recorded at 0.04 μg/L.

There were no pesticides identified with concentrations that exceed EPA Drinking Water Standards or Health Advisories, however, pesticide concentrations reported in the NAWQA Data reports were occasionally elevated to levels that are toxic to reproductive systems in fish. These levels coincide with storm runoff events and seasonal irrigation drainage. Although there were no pesticides identified with concentrations that exceed EPA Drinking Water Standards or Health Advisories, one must understand that there are only a few pesticides and herbicides that have actually been given standards. As the NAWQA studies continue and the toxic effects of the pesticides and herbicides are evaluated, new standards will be developed.

Metals

The movement of sediments influences water quality within the Sacramento River watershed and affects the loadings of numerous constituents into the Bay-Delta system. Important sediment processes include erosion, sedimentation, re-suspension, and chemical interactions. Sediment transport in the CBD occurs primarily during peak flow events. Total metals transport is strongly associated with these sediment pulses. Colloids represent the dominant form of mercury, lead, and other metals in the water column and are an important factor in the distribution of other metals. Sediment transport is also important in the fate and transport of other organic and inorganic constituents.

Dissolved metals concentrations are gross indicators of metals toxicity. Organic and inorganic complexes reduce the toxicity of some trace metals in ambient waters. Dissolved metals concentrations are also affected by interactions with particulates, algae and other aquatic organisms. There were no metals concentrations identified above the U.S. EPA maximum contaminant levels (MCLs) for drinking water.

Mercury concentrations did not exceed the California Toxics Rule criterion of 50 ng/L in any of the sample data examined for this determination study. Concentrations of methyl mercury did not exceed the human health-based criterion of 0.24 ng/L, however, there were several samples that were above the wildlife-based guidelines of 0.05 ng/L.

There were no metals concentrations that exceed irrigation water quality standards or secondary drinking water standards; however, the highest concentrations may exceed management objectives during specific runoff or drainage events.

SUMMARY

The relationship between water quality and the feasibility of using water for irrigation or other purposes is not a simple matter. There are many factors to be considered before an adequate determination can be made. Soil properties determine the amount of water that is available for plant uptake. The chemical composition of the water has a direct effect on and can even change the soil properties through ionic exchange reactions. The total concentration of dissolved salts and their relative concentrations in the water and the concentrations of potentially toxic chemicals such as pesticides and herbicides are all factors that will determine if the water can be utilized without adverse effects. The evaluation of these factors as they relate to the CBD are summarized as follows:

Soil Properties

- The soils within the CBD are, for the most part, relatively fine-grained loams, silty loams, silty clay loams and clays.
- The fine-grained nature of the CBD soils indicates a relatively high ion exchange capacity throughout most of the land currently being irrigated.
- Soil structure and depth is adequate for most farming activities, however, the drainage of these soils can be slow to moderately rapid.
- The soils within the CBD have a holding capacity that ranges from 0.14 to 2.8 inches per foot.

Water Quality

- The amount of dissolved solids in the CBD water was elevated when compared to other non-agricultural waters in the Sacramento River Watershed; however, the water is still considered "good water" for irrigation(Class 2 irrigation water) based on standard Salinity classification tables.
- Water in the CBD ranges from 0.23 mmhos/cm to 0.765 mmhos/cm. In thirty sampling events, there was only one time when the measured salinity of the CBD water moved into the Class 3 category.
- Waters within the CBD were generally classified as high for magnesium, low normal for calcium, normal for phosphorus, nitrogen, and sulfate, and low for Potassium and nitrates.
- The water is classified as sodium magnesium bicarbonate water with a pH ranging from 7.0 to 8.0.

- SAR values for the CBD water ranged from below 3.5 to 12.
- There were no metals concentrations indicated in the NAWQA data that exceed irrigation water quality standards or secondary drinking water standards, however, the highest concentrations may exceed management objectives, especially during specific runoff or drainage events.
- The analytical chemistry results from samples collected during the NAWQA study indicated pesticide concentrations have been reduced over the last few years due to new management practices. The analytical results were acceptable, however; the occasional runoff events may elevate concentrations in excess of management objectives for agricultural streams.
- There were no compounds identified with concentrations exceeding the US EPA recommended guidelines or secondary drinking water standards.
- Individual storm events that occur December through April result in peak contaminant loads in the CBD. Additional contaminant loads occur as a result of normal irrigation drainage activities during the summer months.

CONCLUSIONS AND RECOMMENDATIONS

The water within the Colusa Basin Drain is relatively good water, however, the soil conditions and the relative proportions of the water constituents indicate that the water and soils are not compatible without some sort of treatment. This is because the soils within the potential re-use area are fine-grained and have a high potential for significant exchange activity.

The high SAR value combined with the fine-grained soil structure indicates an ideal environment for the ionic exchange processes. These processes have a potential to put a significant amount of sodium into the soil. Hi sodium values would cause a breakdown in the soil structure resulting in reduced infiltration rates, reduced plant uptake, and a serious reduction in total yield.

Other conditions include deficiencies of calcium, potassium, and nitrogen.

The CBD water can be used if a treatment is applied to increase these deficiencies. The treatment should reduce the overall pH of the soil and reverse the ionic processes to favor the return of sodium to the water and the addition of calcium into the soil.

It would be ideal if this water was pumped to a storage area, such as a dam or wetland area for the treatments. This would allow time for ultraviolet light and natural forces to act upon the potentially harmful organic substances such as pesticides.

APPENDIX A

COLUSA BASIN DRAIN MONITORING INFORMATION

YCFCWCD/YZWD
CONJUNCTIVE WATER USE FEASIBILITY STUDY

PHYSICAL PARAMETERS - COLUSA BASIN DRAIN[1]

Site Name	Dates	Instantaneous Discharge (cubic meters per second)	Specific Conductance (microsiemens/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen, Percent of Saturation	pH (Standard Units)	Alkalinity (mg/L As CaCO3)	Total Hardness (mg/L as CaCO3)	Suspended Sediment (mg/L)
Colusa Basin Drain Near Knights Landing, CA	2/7/96	125.46	284.00	7.10	68.00	7.70	92.00	82.00	373.00
Colusa Basin Drain Near Knights Landing, CA	3/6/96	E50.98	505.00	9.60	87.00	8.10	160.00	160.00	202.00
Colusa Basin Drain Near Knights Landing, CA	4/23/96	N/A	595.00	8.90	91.00	8.10	210.00	180.00	101.00
Colusa Basin Drain Near Knights Landing, CA	5/22/96	N/A	460.00	N/A	N/A	7.90	130.00	130.00	170.00
Colusa Basin Drain Near Knights Landing, CA	6/14/96	N/A	733.00	5.80	71.00	7.90	170.00	200.00	146.00
Colusa Basin Drain Near Knights Landing, CA	7/23/96	N/A	759.00	12.50	157.00	8.30	200.00	220.00	95.00
Colusa Basin Drain Near Knights Landing, CA	8/27/96	25.69	595.00	6.00	69.00	7.90	210.00	190.00	109.00
Colusa Basin Drain Near Knights Landing, CA	9/9/96	33.42	592.00	5.80	64.00	7.80	170.00	190.00	136.00
Colusa Basin Drain Near Knights Landing, CA	10/18/96	0	664.00	9.80	97.00	8.30	170.00	190.00	75.00
Colusa Basin Drain Near Knights Landing, CA	11/7/96	16.6	576.00	7.60	71.00	7.90	130.00	180.00	60.00
Colusa Basin Drain Near Knights Landing, CA	12/3/96	16.14	613.00	9.20	79.00	8.00	180.00	190.00	84.00
Colusa Basin Drain Near Knights Landing, CA	1/14/97	66.84	600.00	11.60	87.00	8.20	180.00	170.00	137.00
Colusa Basin Drain Near Knights Landing, CA	2/18/97	15.83	713.00	9.00	82.00	8.10	210.00	200.00	167.00
Colusa Basin Drain Near Knights Landing, CA	3/18/97	33.42	626.00	8.20	78.00	8.30	160.00	180.00	278.00
Colusa Basin Drain Near Knights Landing, CA	4/9/97	14.08	629.00	9.20	91.00	8.20	160.00	190.00	121.00

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[1] From USGS/NAWQA Data.

YCFCWCD/YZWD
CONJUNCTIVE WATER USE FEASIBILITY STUDY

PHYSICAL PARAMETERS - COLUSA BASIN DRAIN[1]

Site Name	Dates	Instantaneous Discharge (cubic meters per second)	Specific Conductance (microsiemens/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen, Percent of Saturation	pH (Standard Units)	Alkalinity (mg/L As CaCO3)	Total Hardness (mg/L as CaCO3)	Suspended Sediment (mg/L)
Colusa Basin Drain Near Knights Landing, CA	4/24/97	5.44	517.00	8.40	89.00	8.20	140.00	140.00	142.00
Colusa Basin Drain Near Knights Landing, CA	5/9/97	2.07	583.00	8.00	90.00	8.60	150.00	160.00	N/A
Colusa Basin Drain Near Knights Landing, CA	5/23/97	E14.16	640.00	6.40	74.00	8.00	150.00	170.00	131.00
Colusa Basin Drain Near Knights Landing, CA	6/6/97	E12.46	712.00	6.00	71.00	8.10	200.00	200.00	154.00
Colusa Basin Drain Near Knights Landing, CA	6/17/97	3.6	712.00	9.20	112.00	8.30	190.00	200.00	68.00
Colusa Basin Drain Near Knights Landing, CA	7/10/97	11.33	714.00	5.20	67.00	7.90	230.00	200.00	135.00
Colusa Basin Drain Near Knights Landing, CA	7/28/97	14.33	647.00	5.00	63.00	7.80	220.00	190.00	116.00
Colusa Basin Drain Near Knights Landing, CA	8/24/97	47.29	580.00	5.50	64.00	7.80	190.00	170.00	226.00
Colusa Basin Drain Near Knights Landing, CA	9/18/97	15.66	551.00	6.70	74.00	8.00	180.00	180.00	148.00
Colusa Basin Drain Near Knights Landing, CA	10/30/97	5.41	543.00	8.20	80.00	8.00	170.00	170.00	75.00
Colusa Basin Drain Near Knights Landing, CA	11/12/97	13.06	569.00	5.70	55.00	7.70	210.00	180.00	60.00
Colusa Basin Drain Near Knights Landing, CA	12/17/97	44.46	547.00	8.90	77.00	7.90	150.00	150.00	125.00
Colusa Basin Drain Near Knights Landing, CA	1/21/98	72.22	490.00	7.80	68.00	7.90	140.00	140.00	156.00
Colusa Basin Drain Near Knights Landing, CA	2/26/98	402.14	237.00	9.20	82.00	7.90	91.00	80.00	199.00
Colusa Basin Drain Near Knights Landing, CA	3/11/98	118.94	486.00	10.40	99.00	8.20	170.00	160.00	109.00
Colusa Basin Drain Near Knights Landing, CA	4/15/98	34.83	765.00	8.40	82.00	8.30	230.00	240.00	119.00

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[1] From USGS/NAWQA Data.

USGS
science for a changing world

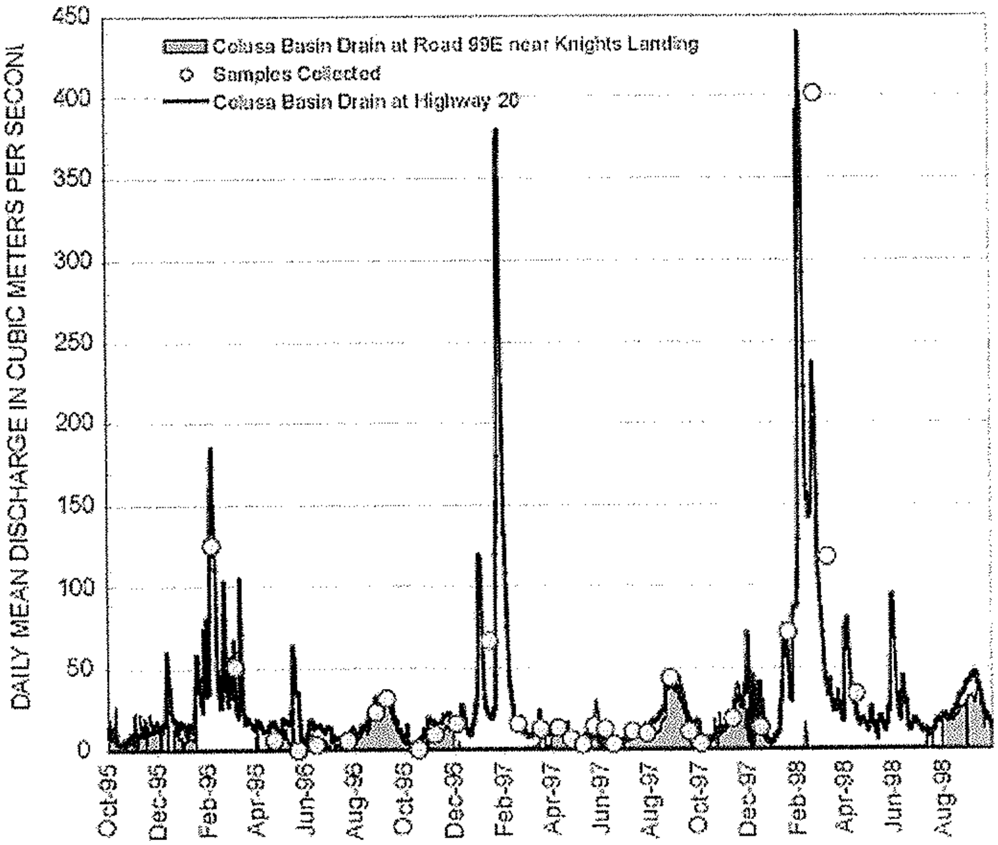
National Water-Quality Assessment (NAWQA)

Water-Quality Assessment of the Sacramento River Basin, California: Water-Quality, Sediment and Tissue Chemistry, and Biological Data, 1995-1998

Hydrograph of daily mean discharge and date of sampling events

Hydrograph of daily mean discharge and date of sampling events. The daily mean discharge hydrograph is for an upstream station because of the difficulty of obtaining reliable discharge data at the sampling site

Colusa Basin Drain at Road 99E near Knights Landing, California



Major Inorganic Compounds
Colusa Basin Drain
from USGS/NAWQA Data

Site Name	Dates	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	Silica as SiO2 (mg/L)	Iron (ug/L)	Total solids (mg/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/24/1997	26	19	51	2.3	26	57	0.31	17	3.4	307
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/9/1997	29	21	63	2.3	28	62	0.37	17	4.8	314
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	32	23	69	2.2	32	87	0.39	19	8.6	394
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/6/1997	36	27	74	2	37	92	0.4	19	4.1	447
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	35	27	79	2.1	41	90	0.38	18	4	404
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	35	27	75	1.8	33	78	0.4	21	<3.0	438
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/28/1997	34	27	66	1.2	28	59	0.37	24	3.7	403
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	32	23	51	3.3	23	33	0.37	24	13	342
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	34	22	53	2.6	25	52	0.32	23	3.5	352
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	31	22	51	4.3	26	56	0.3	25	27	343
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	34	24	53	5.3	24	52	0.29	29	44	367
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	28	20	57	4.9	31	79	0.28	16	35	350
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1998	26	18	50	3.8	24	66	0.33	16	36	310
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	17	9.1	18	2.1	6.5	19	0.17	10	11	140
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	32	20	42	2.4	19	53	0.27	13	< 10	303
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	47	31	73	2.3	37	100	0.35	12	< 10	479

Major Inorganic Compounds
Colusa Basin Drain

from USGS/NAWQA Data

Site Name	Dates	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	Silica as SiO2 (mg/L)	Iron (ug/L)	Total solids (mg/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/7/1996	17	9.7	27	3	13	27	0.2	11	22	175
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/6/1996	31	20	49	2.3	22	58	0.3	14	12	320
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/23/1996	34	24	60	2	29	67	0.3	15	30	341
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/22/1996	24	16	50	2.1	18	65	0.4	15	14	288
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/14/1996	37	27	83	2.9	40	110	0.5	19	11	456
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/23/1996	37	31	84	1.7	39	81	0.5	25	4	451
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/27/1996	35	25	56	1.7	23	43	0.4	25	17	350
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/9/1996	34	25	57	1.9	24	41	0.1	22	13	347
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/18/1996	34	26	70	2.7	32	80	0.3	17	<3.0	424
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/7/1996	33	24	56	5.8	24	62	0.3	25	74	360
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1996	33	25	59	3.7	27	67	0.4	21	24	379
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	32	22	62	3.3	30	84	0.4	18	18	386
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	37	25	72	2.8	37	100	0.4	15	7	436
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	35	23	61	2.4	34	93	0.3	15	<3.0	357
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	34	25	62	2.6	31	75	0.3	15	3	304

Nutrient Concentrations
Colusa Basin Drain
from USGS/NAWQA Data

Site Name	Dates	Times	Dissolved Ammonia (mg/L as N)	Dissolved Nitrite (NO2) (mg/L as N)	Dissolved Ammonia and Organic Nitrogen (mg/L as N)	Total Ammonia and Organic Nitrogen (mg/L as N)	Dissolved Nitrite (NO2) + Nitrate (NO3) (mg/L as N)
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/7/1996	1030	0.02	0.02	0.4	1	0.42
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/6/1996	1030	<0.015	0.03	0.5	0.6	0.53
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/23/1996	1030	0.06	0.03	0.3	0.6	0.92
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/22/1996	1000	<0.015	0.03	0.5	1	0.47
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/14/1996	1000	0.05	0.06	0.5	1.1	0.19
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/23/1996	1000	0.06	0.04	0.5	0.9	0.25
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/27/1996	1000	0.02	0.01	0.4	0.6	0.39
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/9/1996	1030	0.04	0.02	0.3	0.6	0.21
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/18/1996	950	0.02	0.03	0.4	0.7	0.08
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/7/1996	1330	0.08	0.03	0.6	0.9	0.17
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1996	1000	0.11	0.02	0.5	0.8	0.25
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	1130	0.04	0.02	0.6	0.8	0.4
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	1130	0.04	0.03	0.4	0.6	0.66
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	1030	0.08	0.06	0.4	1.1	1.5
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	1100	0.05	0.03	0.3	0.6	1
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/24/1997	940	0.103	0.046	0.34	0.82	0.931
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/9/1997	900	NA	NA	NA	NA	NA
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	1030	0.033	0.039	0.41	0.95	0.487
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/6/1997	1110	0.071	0.048	0.34	0.7	0.757
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	1000	0.021	0.023	0.47	0.86	0.187
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	940	NA	NA	NA	NA	NA
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/28/1997	1100	0.025	0.01	0.42	0.74	0.279
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	1100	<0.015	0.018	0.46	1.3	0.141
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	1000	0.03	0.014	0.4	0.67	0.328
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	1040	<0.015	0.011	0.47	0.75	0.148
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	1130	0.159	0.03	0.63	0.91	0.211
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	1040	0.084	0.015	0.76	1.2	1.26
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1998	1030	0.029	0.027	0.61	0.89	0.76
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	1100	<0.020	<0.010	0.33	0.72	0.389
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	1100	<0.020	<0.010	0.36	0.83	0.462
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	1130	0.035	0.013	0.16	0.49	0.067

Nutrient Concentrations
Colusa Basin Drain

from USGS/NAWQA Data

Site Name	Dates	Total Phosphorus (mg/L as P)	Dissolved Phosphorus (mg/L as P)	Dissolved Ortho Phosphorus (mg/L as P)	Dissolved Organic Carbon (mg/L as C)	Suspended Organic Carbon (mg/L) as C
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/7/1996	0.32	0.11	0.09	8.2	1.4
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/6/1996	0.13	0.09	0.08	6.2	1.3
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/23/1996	0.19	0.1	0.1	4	1.2
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/22/1996	0.21	0.07	0.04	4.5	1.3
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/14/1996	0.3	0.11	0.1	5.2	0.8
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/23/1996	0.11	0.08	0.09	5.8	2.7
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/27/1996	0.15	0.05	0.09	4.7	1.1
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/9/1996	0.15	0.07	0.09	7.9	1
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/18/1996	0.18	0.08	0.09	4.4	1.9
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/7/1996	0.27	0.17	0.16	9.1	1.5
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1996	0.26	0.12	0.12	6.8	0.9
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	0.29	0.14	0.13	7.3	1.4
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	0.12	0.08	0.08	5.1	2.1
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	0.35	0.11	0.11	NA	NA
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	0.25	0.12	0.13	3.2	1.5
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/24/1997	0.256	0.126	0.102	4.6	1.8
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/9/1997	NA	NA	NA	4.5	NA
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	0.27	0.097	0.1	NA	NA
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/6/1997	0.245	0.122	0.099	4.8	1.2
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	0.147	0.02	0.029	5.1	1.3
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	NA	NA	NA	5.6	1.3
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/28/1997	0.206	0.091	0.085	4.7	0.9
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	0.21	0.086	0.074	5.2	1.8
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	0.215	0.097	0.098	3.8	1
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	0.23	0.105	0.109	6.5	1.1
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	0.267	0.145	0.174	8.3	0.7
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	0.36	0.205	0.193	6.5	1.1
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1998	0.299	0.146	0.16	7.5	1
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	0.299	0.083	0.074	3.6	1.5
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	0.208	0.064	0.059	3.7	1
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	0.126	0.012	0.017	2.5	1.4

Pesticide Concentrations
Colusa Basin Drain
from USGS/NAWQA Data

Site Name	Dates	Chloramben (ug/L)	Chlorothalonil (ug/L)	Clopyralid (ug/L)	Dacthal (ug/L)	Dicamba (ug/L)	Dichlobenil (ug/L)	Dichlorprop (ug/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/17/1996	<.011	<.035	<.05	<.017	<.035	<.02	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1997	<.011	<.035	<.05	<.017	<.035	<.02	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	<.011	<.035	<.05	<.017	<.035	<.02	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	<.011	<.035	<.05	<.017	<.035	<.02	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	<.011	<.035	<.05	<.017	<.035	<.02	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	<.011	<.035	<.05	<.017	<.035	<.02	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/24/1997	<.011	<.035	<.05	<.017	<.035	<.02	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/9/1997	<.011	<.035	<.05	<.017	<.035	<.02	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	<.011	<.035	<.05	<.017	<.035	<.02	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	<.011	<.035	<.05	<.017	<.035	<.02	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	<.011	<.035	<.05	<.017	<.035	<.02	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/28/1997	<.011	<.035	<.05	<.017	<.035	<.02	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	<.011	<.035	<.05	<.017	<.035	<.02	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	<.011	<.035	<.05	<.017	<.035	<.02	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	<.011	<.035	<.05	<.017	<.035	<.02	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	<.42	<.48	<.23	<.017	<.035	<1.2	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	<.42	<.48	<.23	<.017	<.035	<1.2	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1998	<.42	<.48	<.23	<.017	<.035	<1.2	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	<.42	<.48	<.23	<.017	<.035	<1.2	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	<.42	<.48	<.23	<.017	<.035	<1.2	<.032
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	<.42	<.48	<.23	<.017	<.035	<1.2	<.032

Pesticide Concentrations
Colusa Basin Drain

from USGS/NAWQA Data

Site Name	Dates	Dinoseb (ug/L)	Diuron (ug/L)	DNOC (ug/L)	Fenuron (ug/L)	Fluometuron (ug/L)	Linuron (ug/L)	MCPA (ug/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/17/1996	<.035	<.020	<.035	<.013	<.035	<.018	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1997	<.035	<.009	<.035	<.013	<.035	<.018	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	<.035	0.35	<.035	<.013	<.035	<.018	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	<.035	0.37	<.035	<.013	<.035	<.018	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	<.035	0.69	<.035	<.013	<.035	<.018	0.94
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	<.035	0.34	<.035	<.013	<.035	<.018	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/24/1997	<.035	0.13	<.035	<.013	<.035	<.018	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/9/1997	<.035	0.08	<.035	<.013	<.035	<.018	E.20
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	<.035	0.07	<.035	<.013	<.035	<.018	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	<.035	0.07	<.035	<.013	<.035	<.018	0.45
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	<.035	0.04	<.035	<.013	<.035	<.018	0.24
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/28/1997	<.035	<.02	<.035	<.013	<.035	<.018	0.16
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	<.035	<.02	<.035	<.013	<.035	<.018	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	<.035	<.02	<.035	<.013	<.035	<.018	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	<.035	<.02	<.035	<.013	<.035	<.018	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	<.035	<.02	<.42	<.013	<.035	<.018	<.17
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	<.035	0.21	<.42	<.013	<.035	<.018	<.17
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1998	<.035	0.31	<.42	<.013	<.035	<.018	<.17
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	<.035	0.2	<.42	<.013	<.035	<.018	0.18
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	<.035	0.16	<.42	<.013	<.035	<.018	0.08
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	<.035	0.25	<.42	<.013	<.035	E.03	<.17

Pesticide Concentrations
Colusa Basin Drain
from USGS/NAWQA Data

Site Name	Dates	MCP (ug/L)	Methiocarb (ug/L)	Methomyl (ug/L)	Neburon (ug/L)	Norfluorazon (ug/L)	Oryzalin (ug/L)	Oxamyl (ug/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/17/1996	<.035	<.026	<.017	<.015	<.024	<.019	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1997	<.035	<.026	<.017	<.015	<.024	<.019	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	<.035	<.026	<.017	<.015	<.024	<.18	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	<.035	<.026	<.017	<.015	<.024	<.019	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	<.035	<.026	<.017	<.015	<.024	E.03	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	<.035	<.026	<.017	<.015	<.024	<.019	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/24/1997	<.035	<.026	<.017	<.015	<.024	<.019	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/9/1997	<.035	<.026	<.017	<.015	<.024	<.019	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	<.035	<.026	<.017	<.015	<.024	<.019	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	<.035	<.026	<.017	<.015	<.024	<.019	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	<.035	<.026	<.017	<.015	<.024	<.019	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/28/1997	<.035	<.026	<.017	<.015	<.024	<.019	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	<.035	<.026	<.017	<.015	<.024	<.019	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	<.035	<.026	<.017	<.015	<.024	<.019	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	<.035	<.026	<.017	<.015	<.024	<.019	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	<.14	<.026	<.017	<.015	<.024	<.31	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	<.14	<.026	<.017	<.015	<.024	<.31	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1998	<.14	<.026	<.017	<.015	<.024	<.31	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	<.14	<.026	<.017	<.015	0.06	<.31	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	<.14	<.026	<.017	<.015	E.02	<.31	<.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	<.14	<.026	<.017	<.015	<.024	<.31	<.018

Pesticide Concentrations
Colusa Basin Drain

from USGS/NAWQA Data

Site Name	Dates	Picloram (ug/L)	Propham (ug/L)	Propoxur (ug/L)	Triclopyr (ug/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/17/1996	<.05	<.035	<.035	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1997	<.05	<.035	<.035	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	<.05	<.035	<.035	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	<.05	<.035	<.035	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	<.05	<.035	<.035	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	<.05	<.035	<.035	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/24/1997	<.05	<.035	<.035	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/9/1997	<.05	<.035	<.035	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	<.05	<.035	<.035	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	<.05	<.035	<.035	0.5
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	<.05	<.035	<.035	1.1
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/28/1997	<.05	<.035	<.035	0.64
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	<.05	<.035	<.035	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	<.05	<.035	<.035	0.22
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	<.05	<.035	<.035	<.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	<.05	<.035	<.035	<.25
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	<.05	<.035	<.035	<.25
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1998	<.05	<.035	<.035	<.25
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	<.05	<.035	<.035	<.25
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	<.05	<.035	<.035	<.25
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	<.05	<.035	<.035	<.25

Pesticide Concentrations
Colusa Basin Drain

from USGS/NAWQA Data

Site Name	Dates	Aldicarb (ug/L)	Aldicarb Sulfone (ug/L)	Aldicarb Sulfoxide (ug/L)	Bentazon (ug/L)	Bromacil (ug/L)	Bromoxynil (ug/L)	Carbaryl (ug/L)	Carbofuran (ug/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/17/1996	<.016	<.016	<.021	<.014	<.035	<.035	<.008	<.028
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1997	<.016	<.016	<.021	0.07	<.035	<.035	<.008	<.028
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	<.016	<.016	<.021	<.014	<.035	<.035	E.0010	<.028
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	<.016	<.016	<.021	0.08	<.035	<.035	<.008	<.028
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	<.016	<.016	<.021	0.1	<.035	<.035	<.008	<.028
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	<.016	<.016	<.021	<.014	<.035	<.035	E.008	<.028
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/24/1997	<.016	<.016	<.021	0.08	<.035	<.035	<.008	0.2
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/9/1997	<.016	<.016	<.021	E.05	<.035	0.06	<.008	0.2
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	<.016	<.016	<.021	0.08	<.035	<.035	<.008	0.15
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	<.016	<.016	<.021	0.09	<.035	<.035	<.008	<.028
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	<.016	<.016	<.021	0.09	<.035	<.035	<.008	<.028
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/28/1997	<.016	<.016	<.021	0.13	<.035	<.035	<.008	<.028
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	<.016	<.016	<.021	<.014	<.035	<.035	<.008	<.028
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	<.016	<.016	<.021	0.11	<.035	<.035	<.008	<.028
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	<.016	<.016	<.021	<.014	<.035	<.035	0.04	<.028
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	<.55	<.1	<.021	<.014	<.035	<.035	<.008	<.12
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	<.55	<.1	<.021	<.014	<.035	<.035	<.008	<.12
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1998	<.55	<.1	<.021	<.014	<.035	<.035	<.008	<.12
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	<.55	<.1	<.021	<.014	<.035	<.035	<.008	<.12
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	<.55	<.1	<.021	<.014	<.035	<.035	<.008	<.12
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	<.55	<.1	<.021	<.014	<.035	<.035	<.008	<.12

Pesticide Concentrations
Colusa Basin Drain

from USGS/NAWQA Data

Site Name	Dates	Times	2,4,5-T (ug/L)	2,4-D (ug/L)	2,4-DB (ug/L)	Silvex (ug/L)	3-Hydroxycarbofuran (ug/L)	Acifluorfen (ug/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/17/1996	1330	<.035	<.035	<.035	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1997	1000	<.035	<.035	<.035	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	1130	<.035	<.035	<.035	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	1130	<.035	0.14	<.035	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	1030	<.035	0.78	<.035	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	1100	<.035	<.035	<.035	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/24/1997	940	<.035	<.035	<.035	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/9/1997	900	<.035	<.035	<.035	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	1030	<.035	<.035	<.035	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	1000	<.035	E.45	<.035	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	940	<.035	<.035	<.035	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/28/1997	1100	<.035	<.035	<.035	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	1100	<.035	<.035	<.035	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	1000	<.035	<.035	<.035	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	1040	<.035	<.035	<.035	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	1130	<.035	<.15	<.24	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	1040	<.035	<.15	<.24	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1998	1030	<.035	<.15	<.24	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	1100	<.035	0.11	<.24	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	1100	<.035	<.15	<.24	<.021	<.014	<.035
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	1130	<.035	<.15	<.24	<.021	<.014	<.035

Pesticide Concentrations
Colusa Basin Drain
from USGS/NAWQA Data

Site Name	Dates	Times	2,6-Diethylaniline (ug/L)	Acetochlor (ug/L)	Alachlor (ug/L)	Atrazine (ug/L)	Methyl Azinphos (ug/L)	Benfluralin (ug/L)	Butylate (ug/L)	Carbaryl (ug/L)	Carbofuran (ug/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/7/1996	1330	<.003	<.002	<.002	<.001	<.001	<.002	<.002	<.003	E.1
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1996	1000	<.003	<.002	<.002	<.001	<.001	<.002	<.002	<.003	E.08
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	1130	<.003	<.002	<.002	<.001	<.001	<.002	<.002	<.003	E.03
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	1130	<.003	<.002	<.002	E.003	<.001	<.002	<.002	E.02	E.03
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	1030	<.003	<.002	<.002	0.005	<.001	<.002	<.002	E.02	E.02
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	1100	<.003	<.002	<.002	0.005	<.001	<.002	<.002	E.08	E.01
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/24/1997	940	<.003	<.002	0.011	<.001	<.001	<.002	<.002	<.003	E.4
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/9/1997	900	<.003	<.002	<.002	<.001	<.001	<.002	<.002	<.003	E.1
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	1030	<.003	<.002	<.002	<.001	<.001	<.002	<.002	<.003	E.1
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	1000	<.003	<.002	<.002	<.001	<.001	<.002	<.002	<.003	E.02
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	940	<.003	<.002	<.002	<.001	<.001	<.002	<.002	<.003	E.04
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/28/1997	1100	<.003	<.002	<.002	<.001	<.001	<.002	<.002	E.03	E.03
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	1100	<.003	<.002	<.002	E.002	<.001	<.002	<.002	E.1	E.2
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	1000	<.003	<.002	<.002	<.001	<.04	<.002	<.002	E.009	E.03
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	1040	<.003	<.002	<.002	<.001	<.001	<.002	<.002	E.1	E.05
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	1130	<.003	<.002	<.002	<.001	<.001	<.002	<.002	E.1	E.09
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	1040	<.003	<.002	<.002	<.001	<.001	<.002	<.002	E.02	E.07
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1997	1030	<.003	<.002	<.002	<.001	<.001	<.002	<.002	<.003	E.03
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	1100	<.003	<.002	<.002	<.001	<.001	<.002	<.002	<.003	E.02
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	1100	<.003	<.002	<.002	<.001	<.001	<.002	<.002	<.003	E.01
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	1130	<.003	<.002	0.012	<.001	<.001	<.002	<.002	<.003	E.01

Pesticide Concentrations
Colusa Basin Drain

from USGS/NAWQA Data

Site Name	Dates	Chlorpyrifos (ug/L)	Cyanazine (ug/L)	DCPA (ug/L)	Desethyl Atrazine (ug/L)	Diazinon (ug/L)	Dieldrin (ug/L)	Disulfoton (ug/L)	EPTC (ug/L)	Ethalfluralin (ug/L)	Ethoprop (ug/L)	Fonofos (ug/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/7/1996	<.004	<.004	<.002	<.002	<.002	<.001	<.017	<.002	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1996	<.004	<.004	<.002	<.002	<.002	<.001	<.017	<.002	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	<.004	<.004	<.002	<.002	0.014	<.001	<.017	<.002	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	<.004	<.004	E.002	<.002	0.05	<.001	<.017	<.002	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	0.016	0.017	0.008	E.003	0.073	<.001	<.017	0.72	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	0.007	<.004	E.002	<.002	0.005	<.001	<.017	E.003	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/24/1997	0.011	<.004	<.002	<.002	E.004	<.001	<.017	0.12	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/9/1997	<.004	0.0086	<.002	<.002	0.014	<.001	<.017	0.0084	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	<.004	0.04	<.002	E.004	E.002	<.001	<.017	0.041	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	<.004	0.022	<.002	<.002	<.002	<.001	<.017	0.017	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	0.012	0.44	<.002	<.002	<.002	<.001	<.017	<.002	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/28/1997	0.015	0.19	<.002	<.002	0.02	<.001	<.017	0.022	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	0.0092	0.043	0.0086	<.002	<.002	<.001	<.017	0.0059	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	<.004	<.004	E.001	<.002	0.0074	<.001	<.017	0.023	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	<.004	<.004	0.007	<.002	E.0020	<.001	<.017	<.002	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	<.004	<.004	E.001	<.002	<.002	<.001	<.017	<.002	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	<.004	<.004	0.0049	<.002	0.0081	<.001	<.017	E.003	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1997	<.004	0.0059	E.003	<.002	0.036	<.001	<.017	<.002	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	<.004	<.004	0.0043	<.002	0.098	<.001	<.017	0.0084	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	<.004	0.005	E.002	<.002	0.034	<.001	<.017	E.004	<.004	<.003	<.003
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	<.004	<.004	<.002	<.002	0.0066	<.001	<.017	<.002	<.004	<.003	<.003

Pesticide Concentrations
Colusa Basin Drain
from USGS/NAWQA Data

Site Name	Dates	Lindane (ug/L)	Linuron (ug/L)	Malathion (ug/L)	Metolachlor (ug/L)	Metribuzin (ug/L)	Molinate (ug/L)	Napropamide (ug/L)	Parathion (ug/L)	Methyl Parathion (ug/L)	Pebulate (ug/L)	Pendimethalin (ug/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/7/1996	<.004	<.002	<.005	E.004	<.004	0.21	<.003	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1996	<.004	<.002	<.005	0.005	<.004	0.1	<.003	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	<.004	<.002	0.015	0.018	<.004	0.088	0.021	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	<.004	<.002	<.005	0.021	0.013	0.085	0.044	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	<.004	<.002	0.054	0.032	0.031	0.016	0.43	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	<.004	<.002	0.028	0.018	0.017	0.009	0.005	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/24/1997	<.004	<.002	<.005	0.2	<.004	0.05	0.005	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/9/1997	<.004	<.002	<.005	0.15	0.019	1.1	<.003	<.004	<.006	0.011	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	<.004	<.002	<.005	0.089	<.004	19	<.003	<.004	<.006	0.011	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	<.004	<.002	<.005	0.12	<.004	5.3	<.003	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	<.004	<.002	<.005	0.39	<.004	0.97	<.003	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/28/1997	<.004	<.002	<.01	0.096	<.004	0.53	<.003	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	<.004	<.002	0.013	0.013	<.004	0.46	<.003	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	<.004	<.002	0.024	0.012	<.004	0.19	<.003	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	<.004	<.002	<.01	<.002	<.004	0.11	<.003	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	<.004	<.002	<.005	<.002	<.004	0.17	<.003	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	<.004	<.002	0.017	0.032	<.004	0.099	0.012	<.004	<.006	<.004	<.020
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1997	<.004	<.002	<.005	0.024	<.004	0.087	E.004	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	<.004	<.002	<.005	0.021	<.004	0.04	<.003	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	<.004	<.002	0.0055	0.025	<.004	0.042	<.003	<.004	<.006	<.004	<.004
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	<.004	<.01	<.005	0.035	<.004	0.028	<.003	<.004	<.006	<.004	<.004

Pesticide Concentrations
Colusa Basin Drain
from USGS/NAWQA Data

Site Name	Dates	Phorate (ug/L)	Prometon (ug/L)	Propachlor (ug/L)	Propanil (ug/L)	Propargite (ug/L)	Pronamide (ug/L)	Simazine (ug/L)	Tebuthiuron (ug/L)	Terbacil (ug/L)	Terbufos (ug/L)	Thiobencarb (ug/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/7/1996	<.002	<.018	<.007	<.004	<.013	<.003	E.004	<.01	<.007	<.013	0.036
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1996	<.002	<.018	<.007	<.004	<.013	<.003	0.012	<.01	<.007	<.013	0.024
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	<.002	<.018	<.007	<.004	<.013	0.033	0.15	<.01	<.007	<.013	0.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	<.002	E.005	<.007	<.004	<.013	0.019	0.07	<.01	<.007	<.013	0.026
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	<.002	E.01	<.007	<.004	<.013	0.019	0.09	<.01	<.007	<.013	<.002
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	<.002	E.006	<.007	<.004	<.013	0.018	0.024	<.01	<.007	<.013	<.002
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/24/1997	<.002	<.018	<.007	<.004	<.013	<.003	0.015	<.01	<.007	<.013	0.017
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/9/1997	<.002	<.018	<.007	<.004	<.013	<.003	0.014	<.01	<.007	<.013	1.3
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	<.002	<.018	<.007	<.004	0.052	<.003	0.0064	<.01	<.007	<.013	4.4
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	<.002	<.018	<.007	<.004	<.013	<.003	0.01	<.01	<.007	<.013	2
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	<.002	<.018	<.007	0.045	<.013	<.003	0.008	<.01	<.007	<.013	0.36
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/28/1997	<.002	<.018	<.007	<.004	<.013	<.003	<.005	<.01	<.007	<.013	0.18
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	<.002	<.018	<.007	<.004	<.013	<.003	E.004	<.01	<.007	<.013	0.15
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	<.002	<.018	<.007	<.004	<.013	<.003	E.003	<.01	<.007	<.013	0.068
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	<.002	<.018	<.007	<.004	<.013	<.003	E.003	<.01	<.007	<.013	0.03
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	<.002	<.018	<.007	<.004	<.013	<.003	E.005	<.01	<.007	<.013	0.041
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	<.002	<.018	<.007	<.004	<.013	0.02	0.093	E.009	<.007	<.013	0.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1997	<.002	<.018	<.007	<.004	<.013	0.02	0.089	<.01	<.007	<.013	0.021
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	<.002	<.018	<.007	<.004	<.013	0.035	0.037	<.01	<.007	<.013	0.016
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	<.002	<.018	<.007	<.004	<.013	0.0094	0.028	<.01	<.007	<.013	0.018
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	<.002	<.018	<.007	<.004	<.013	<.003	0.023	0.013	<.007	<.013	0.014

Pesticide Concentrations
Colusa Basin Drain
from USGS/NAWQA Data

Site Name	Dates	Triallate (ug/L)	Trifluralin (ug/L)	Alpha-BHC (ug/L)	Permethrin (ug/L)	p,p'-DDE (ug/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/7/1996	<.001	<.002	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1996	<.001	<.002	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	<.001	<.002	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	<.001	<.002	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	<.001	0.016	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	<.001	0.005	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/24/1997	<.001	0.012	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/9/1997	<.001	0.012	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	<.001	0.0074	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	<.001	0.0077	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	<.001	0.0092	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/28/1997	<.001	0.0093	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	<.001	<.002	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	<.001	<.002	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	<.001	<.002	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	<.001	<.002	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	<.001	<.002	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1997	<.001	<.002	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	<.001	0.004	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	<.001	E.002	<.002	<.005	<.006
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	<.001	E.002	<.002	<.005	<.006

Metals C entrations
Colusa Basin Drain
from USGS/NAWQA Data

Site Name	Dates	Times	Arsenic (µ/L)	Barium (µ/L)	Beryllium (µ/L)	Cadmium (µ/L)	Chromium (µ/L)	Cobalt (µ/L)	Copper (µ/L)	Lead (µ/L)	Manganese (µ/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/7/1996	1030	2	51	<1.0	<1.0	2	<1.0	3	<1.0	12
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/6/1996	1030	1	64	<1.0	<1.0	2	<1.0	3	<1.0	5
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/23/1996	1030	2	80	<1.0	<1.0	2	<1.0	2	<1.0	31
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/22/1996	1000	2	63	<1.0	<1.0	<1.0	<1.0	4	<1.0	2
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/14/1996	1000	5	108	<1.0	<1.0	2	<1.0	6	<1.0	4
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/23/1996	1000	6	114	<1.0	<1.0	4	<1.0	3	<1.0	29
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/27/1996	1000	5	88	<1.0	<1.0	<1.0	<1.0	2	<1.0	15
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/9/1996	1030	3	80	<1.0	<1.0	2	<1.0	2	<1.0	10
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/18/1996	950	4	90	<1.0	<1.0	2	<1.0	2	<1.0	2
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/7/1996	1330	3	73	<1.0	<1.0	3	<1.0	3	<1.0	26
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1996	1000	2	72	<1.0	<1.0	4	<1.0	2	<1.0	43
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	1130	2	85	<1.0	<1.0	2	<1.0	3	<1.0	4
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	1130	2	91	<1.0	<1.0	1	<1.0	3	<1.0	47
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	1030	2	90	<1.0	<1.0	2	<1.0	2	<1.0	13
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	1100	3	86	<1.0	<1.0	4	<1.0	2	<1.0	32
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	1030	4	94	<1.0	<1.0	3.5	<1.0	2.7	<1.0	17
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	1000	4	95	<1.0	<1.0	2.5	<1.0	4.1	<1.0	1.2
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	940	4	105	<1.0	<1.0	6.3	<1.0	1.7	<1.0	29
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	1100	3	88	<1.0	<1.0	1.2	<1.0	2.8	<1.0	8.3
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	1000	2	87	<1.0	<1.0	3.3	<1.0	2.6	<1.0	18
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	1040	4	73	<1.0	<1.0	2.4	<1.0	2.1	<1.0	62
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	1130	3	76	<1.0	<1.0	4.6	<1.0	2	<1.0	71
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	1040	2	66	<1.0	<1.0	1.3	<1.0	2.9	<1.0	11
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1998	1030	2	65	<1.0	<1.0	4	<1.0	3.1	<1.0	15
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	1100	1	46	<1.0	<1.0	2.8	<1.0	2.5	<1.0	2.2
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	1100	2	80	<1.0	<1.0	1.8	<1.0	2.1	<1.0	15
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	1130	<1	53	<1.0	<1.0	2.6	<1.0	1	<1.0	1.8

Metals C entrations
Colusa Basin Drain
from USGS/NAWQA Data

Site Name	Dates	Molybdenum (μ/L)	Nickel (μ/L)	Silver (μ/L)	Zinc (μ/L)	Antimony (μ/L)	Aluminum (μ/L)	Selenium (μ/L)	Uranium (μ/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/7/1996	<1.0	2	<1.0	<1.0	<1.0	6	<1	<1.0
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/6/1996	2	3	<1.0	<1.0	<1.0	5	<1	<1.0
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/23/1996	2	2	<1.0	<1.0	<1.0	9	<1	1
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/22/1996	2	3	<1.0	<1.0	<1.0	8	<1	<1.0
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/14/1996	4	3	<1.0	2	<1.0	10	<1	1
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/23/1996	4	3	<1.0	<1.0	<1.0	4	<1	1
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/27/1996	3	4	<1.0	<1.0	<1.0	5	<1	<1.0
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/9/1996	2	2	<1.0	<1.0	<1.0	4	<1	<1.0
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/18/1996	2	3	<1.0	<1.0	<1.0	6	<1	1
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/7/1996	2	5	<1.0	4	<1.0	5	<1	<1.0
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1996	2	3	<1.0	<1.0	<1.0	4	<1	<1.0
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	3	4	<1.0	<1.0	<1.0	4	<1	1
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	3	3	<1.0	<1.0	<1.0	5	<1	1
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	2	3	<1.0		<1.0	4	<1	1
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	2	3	<1.0	2	<1.0	5	<1	1
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/23/1997	3.2	2.7	<1.0	<1.0	<1.0	4.4	<1	1.3
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	3.3	3	<1.0	1.5	<1.0	4.7	<1	1.4
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/10/1997	3.2	2.4	<1.0	<1.0	<1.0	4.5	<1	1.1
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	2.7	2.8	<1.0	2.6	<1.0	5.9	<1	<1.0
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	2.3	1.9	<1.0	6.1	<1.0	6.1	<1	<1.0
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	2.3	2.6	<1.0	<1.0	<1.0	6.1	<1	<1.0
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	2.2	2.9	<1.0	2.9	<1.0	6.3	<1	<1.0
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	2	3.3	<1.0	1	<1.0	4.5	<1	<1.0
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1998	1.6	3.6	<1.0	2	<1.0	8.3	<1	<1.0
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	<1.0	2.4	<1.0	<1.0	<1.0	5.7	<1	<1.0
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	1.5	2.7	<1.0	<1.0	<1.0	5.6	<1	<1.0
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	<1.0	1.7	<1.0	1	<1.0	8.7	<1	<1.0

Mercury and Methylmercury Concentrations
Colusa Basin Drain
from USGS/NAWQA Data

Site Name	Dates	Times	Mercury in unfiltered water (ng/L)	Methylmercury in unfiltered water (ng/L)
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/6/1996	1030	14.36	0.217
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/23/1996	1030	5.73	0.082
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/22/1996	1000	11.52	0.146
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/14/1996	1000	9.17	0.134
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/23/1996	1000	6.74	0.156
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/27/1996	1000	5.45	0.097
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/9/1996	1030	7.12	0.037
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/18/1996	950	4.64	0.021
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/7/1996	1330	6.08	0.25
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/3/1996	1000	6.8	0.248
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/14/1997	1130	15.02	NA
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/18/1997	1130	11.77	0.888
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/18/1997	1030	19.27	0.333
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/9/1997	1100	8.14	0.278
Colusa Basin Drain at Road 99E near Knights Landing, CA	5/9/1997	900	9.76	0.177
Colusa Basin Drain at Road 99E near Knights Landing, CA	6/17/1997	1000	6.9	0.191
Colusa Basin Drain at Road 99E near Knights Landing, CA	7/28/1997	1100	7.8	0.098
Colusa Basin Drain at Road 99E near Knights Landing, CA	8/26/1997	1100	12.89	0.092
Colusa Basin Drain at Road 99E near Knights Landing, CA	9/18/1997	1000	7.63	0.134
Colusa Basin Drain at Road 99E near Knights Landing, CA	10/30/1997	1040	6.24	0.299
Colusa Basin Drain at Road 99E near Knights Landing, CA	11/12/1997	1130	5.83	0.377
Colusa Basin Drain at Road 99E near Knights Landing, CA	12/17/1997	1040	9.25	0.184
Colusa Basin Drain at Road 99E near Knights Landing, CA	1/21/1998	1030	10.51	0.256
Colusa Basin Drain at Road 99E near Knights Landing, CA	2/26/1998	1100	10.82	0.236
Colusa Basin Drain at Road 99E near Knights Landing, CA	3/11/1998	1100	7.76	0.472
Colusa Basin Drain at Road 99E near Knights Landing, CA	4/15/1998	1130	10.76	0.218

Pollutant	Sacramento River upstream of drain (Colusa)	CBD	Sacramento River downstream of drain (Verona)	Study used
Ammonia	0.02 mg/L		0.03 mg/L as N	USGS
		0.06 mg/L		SRWP
Arsenic	1 ug/L	2.4 ug/L	1 ug/L	SRWP
	1 ug/L		1 ug/L	USGS
Carbofuran	<31 ng/L	404 ng/L	63 ng/L	USGS
Chromium	<RL		1 ug/L	SRWP
	1.2 ug/L	2.6 - 6.3 ug/L	1.3 ug/L	USGS
Copper	1.4 ug/L	8 - 21.5 ug/L	1.7 ug/L	SRWP
	1.8 ug/L		1.9 ug/L	USGS
Diazinon	E1 - <28 ng/L	55 - 4033 ng/L	76 ng/L	USGS
DOC	1.4 mg/L	5.1 - 10 mg/L	1.6 mg/L	SRWP
	1.4 mg/L		1.6 mg/L	USGS
Iron	10 ug/L	377 - 4280 ug/L	13 ug/L	SRWP
	12 ug/L		12.5 ug/L	USGS
Malathion	E17 - <57 ng/L		E8 - <57 ng/L	USGS
		300 - 1000 ng/L		DPR
Manganese	5 ug/L	118 - 843 ug/L	5 ug/L	SRWP
	4 ug/L	62 - 71 ug/L	5 ug/L	USGS
Mercury	4.4 ng/L	7.1 - 19.27 ng/L	6.4 ng/L	SRWP
	4.57 ng/L		6.36 ng/L	USGS
Methylmercury	0.1 ng/L	0.19 - 0.9 ng/L	0.12 ng/L	SRWP
	0.1 ng/L		0.12 ng/L	USGS
Molinate	E20 - <60 ng/L		514.5 ng/L	USGS
		10300 - 19600 ng/L		DPR
Nickel	1 ug/L	10.1 - 16.9 ug/L	1 ug/L	SRWP
	1.1 ug/L	1.7 - 5 ug/L	1 ug/L	USGS
Thiobencarb	E1 - <38 ng/L	4970 - 5971 ng/L	124.5 ng/L	USGS
TOC	1.9 mg/L	6.7 mg/L	2.2 mg/L	SRWP

USGS = Water-Quality Assessment of the Sacramento River Basin, California: Water-Quality, Sediment and Tissue Chemistry & Biological Data, 1995-1998.http://water.wr.usgs.gov/sac_nawqa/waterindex
SRWP = Sacramento River Watershed Program, 1999-2000 Annual Monitoring Report, http://www.sacriver.org/subcommittees/monitoring/documents/SRWP%20AMR%20App%20A-D.pdf

DPR = Rice Pesticides Monitoring in the Sacramento Valley, 1995 --
Study: http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps/eh9803.pdf
Tables: http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps/eh983tabl.pdf
Rice Pesticides Program 1999 Update, http://www.cdpr.ca.gov/docs/surfwatr/1999.pdf

Pollutant	Standard	Max level	Measurement	Site measured	Notes
TRACE METALS/WATER					
Arsenic					
Drinking water (total)	• Prop 65 Regulatory Level • USEPA Ambient Water Quality Criteria (one-in-a-million cancer risk estimate)	5 µg/L 0.005 mg/L 0.018 µg/L 0.000018 mg/L	USGS: 6 µg/L (highest total observed) USGS: Exceedances ranging from <1-2 µg/L SRWP & SRWP 99/00: 3.6 µg/L (highest total observed), 1.7 µg/L (median), 0.8 µg/L (lowest total observed) USGS: Exceedances ranging from 1-2 µg/L	Colusa Basin Drain Sac River/Verona Sac River/Vet Bridge Yolo Bypass/I-80	Potential health effects from ingestion of water: skin damage, skin legions, circulatory system problems, increased risk of cancer, cellular necrosis, abnormal nerve conduction. Prop 65 lists level as carcinogen and reproductive toxin. PHGs expected by CVRWQCB in the near future.
Chromium					
Drinking water (total)	PHG[1] (for protection against carcinogenicity of chromium VI based on a health protective level of 0.2 µg/L for chromium VI with the assumption that chromium VI was 7.2% of the total)	2.5 µg/L 0.0025 mg/L	USGS: Exceedances ranging from 2.6-6.3 µg/L SRWP & SWRP 99/00: 14.3 µg/L (highest total observed) USGS: Exceedances ranging from 2.7-3.8 µg/L	Colusa Basin Drain Sac River/Vet Bridge Yolo Bypass/I-80	Potential health effects from ingestion of water: some people who use water containing chromium well in excess of the MCL over many years could experience allergic dermatitis.

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[1] Proposal for MCL Revision: There has been much uncertainty as to the typical balance of chromium III to chromium VI in drinking water sources. The little data that exist indicate that the percentage of chromium VI present is usually much higher than that assumed by OEHHA in its PHG derivation. This appears to be particularly true for groundwater sources, because they generally have much higher total chromium levels than surface waters. To evaluate the percentage of total chromium that is chromium VI, DHS conducted a study in winter of 1999 by collecting samples for analysis for total chromium and chromium VI by DHS' Sanitation and Radiation Laboratory. Previous DHS sampling had indicated that chromium VI accounted for 0 to 91% of the total chromium; additional sampling by a consulting firm showed a range of 58 to 100% chromium VI. DHS' 1999 study showed chromium VI present as 44 to 100% of the total chromium in ground water. Only one surface water source was sampled and with a reporting level of 0.5 µg/L, no chromium VI was detected in samples with up to 8.7 µg/L total chromium.

					Chromium VI is assumed by OEHHA to pose a carcinogenic risk when ingested USGS: CBD contained among the highest concentrations recorded.
Copper					
Aquatic life (dissolved, freshwater)	2000 USEPA Calif. Toxic Rule	CBD: 4.8 µg/L	SRWP 99/00: 8 µg/L	Colusa Basin Drain	Met CTR standard 99.4% of the time (SRWP).
Beneficial uses (total)	CVRBP	10 µg/L (0.01 mg/L)	SRWP 99/00: 21.5 µg/L SRWP & SRWP 99/00: 16.9 µg/L (highest total observed)	Colusa Basin Drain Sac River/Vet Bridge	
Mercury					
Aquatic life (total, freshwater)	SFBRWQCB 1995 Basin Plan – 4-day (SFERMP)	0.025 µg/L	USGS: 0.2 µg/L	Yolo Bypass/I-80	
Drinking Water (total inorganic mercury)	USEPA California Toxics Rule Criteria (30-day average)	50 ng/L[2] 0.05 µg/L	SRWP 99/00: 223.7 ng/L USGS: 223.71 ng/L (highest total observed)	Yolo Bypass/near Woodland Yolo Bypass/I-80	USEPA intends to re-evaluate and revise its 304(a) Ambient Water Quality Criteria for mercury by 2002, and it may range from 2 ng/L to 5 ng/L Potential health effects: kidney damage based on animal studies
Total – human health	• USEPA 1985 National Water Quality Criteria • USEPA 1995 National Toxics	12 ng/L 0.012 µg/L[2]	SRWP: 19.27 ng/L (highest total observed) SRWP 99/00: 19.3 ng/L SRWP: 39.80 ng/L (highest total observed)	Colusa Basin Drain Colusa Basin Drain Sac River/Verona	

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[2] Represents the 30-day average not to be exceeded more than once in three years.

	Rule, superceded by USEPA 1999 Criteria		SRWP: 25 ng/L (highest total observed) SRWP 99/00: 34.9 ng/L USGS: 30.6 ng/L (median), 17.86 ng/L (lowest total observed) 17.9-30.6 ng/L	Sac River/Vet Bridge Sac River/Vet Bridge Yolo Bypass/I-80 Yolo Bypass/near Woodland	
Total – human health	USEPA 1997 Great Lakes Standard/ Mercury Report to Congress	3.1 ng/L 0.0031 µg/L	SRWP 99/00: 7.1 ng/L SRWP: 4.64 ng/L (lowest total observed), 7.97 ng/L (median) SRWP & SRWP 99/00: 6.4 ng/L (median) SRWP: 4.11 ng/L (lowest total observed), 9 ng/L (median) SRWP 99/00: 3.4-8.3 ng/L	Colusa Basin Drain Colusa Basin Drain Sac River/Verona Sac River/Vet Bridge Sac River/Vet Bridge	
Total – wildlife[3]	- USEPA 1995 Great Lakes Standard - USEPA 1997 Mercury Report to Congress	1.3 ng/L 0.91 ng/L 0.0009 µg/L	SRWP 99/00: 1.6-19.3 ng/L SRWP: 2.46 ng/L (lowest total observed) SRWP 99/00: 2.5-39.8 ng/L SRWP 99/00: 17.9-223.7 ng/L	Colusa Basin Drain Sac River/Verona Sac River Verona Yolo Bypass/near Woodland	
Methyl – human health	USEPA 1997 Great Lakes Standard/ Mercury Report to Congress	0.24 ng/L	SRWP & SRWP 99/00: 0.9 ng/L (highest total observed) SRWP & SRWP 99/00: 1.98 ng/L (highest total observed)	Colusa Basin Drain Sac River/Verona	Exceeded 20-26% of the time – CBD (SRWP)
Methyl – wildlife[3]	USEPA 1997 Mercury Report to Congress/ Proposed TMDL – SFBRWQCB Report to USEPA, 2000	0.05 ng/L	SRWP 99/00: 0.19-0.9 ng/L SRWP 99/00: 0.12-1.98 ng/L	Colusa Basin Drain Sac River/Verona	

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[3] Lowest average criterion, based on the average for all mammalian wildlife species studied in Mercury Report to Congress. No wildlife-based water quality objectives have been adopted for mercury in California nor has the USEPA issued wildlife-based advisory criteria for mercury in water (SRWP, 1998-99 Monitoring Report).

Nickel					
Drinking water (total)	PHG (Proposed 1999/2000 PHG=0.003 mg/L)	1000 ng/L 1 µg/L 0.001 mg/L	USGS: Exceedances ranging from 1.7-5 µg/L	Colusa Basin Drain	Potential health effects from long-term exposure: heart and liver damage based on animal tests, decreased body weight, skin irritation.
			SRWP 99/00: Exceedances ranging from 10.1-16.9 µg/L	Colusa Basin Drain	
			SWRP & SRWP 99/00: 22.5 µg/L (highest total observed), 5 µg/L (median), 1.1 µg/L (lowest total observed)	Sac River/Vet Bridge	
			USGS: Exceedances ranging from 1.2-2 µg/L	Sac River/Verona	
			USGS: Exceedances ranging from 1.4-2.6 µg/L	Yolo Bypass/I-80	
GENERAL CONSTITUENTS					
Alkalinity				Colusa Basin Drain	Exhibited noticeably elevated (2-2.8-fold) total concentrations as compared to Sac River (SRWP).
Calcium				Colusa Basin Drain	Exhibited substantially elevated median concentrations (2-3-fold greater) as compared to Sac River (SRWP).
Chloride					
Drinking water (total)				Colusa Basin Drain	Exhibited substantially elevated median concentrations (2.8-8.5-fold greater) as compared to Sac River, but did not exceed standard (SRWP).
Iron					
Drinking water (total)	DHS, USEPA	300 µg/L	SRWP 99/00: Exceedances	Colusa Basin Drain	

	Secondary Drinking Water Standard MCL	0.3 mg/L	ranging from 377-4280 µg/L SRWP 99/00: 356-2000 µg/L	Sac River/Vet Bridge	
Beneficial uses (total)	CVRBP	30 µg/L 0.03 mg/L	USGS: Exceedances ranging from 35-74 µg/L USGS: Exceedances ranging from 51-110 µg/L	Colusa Basin Drain Sac River/Verona	
Magnesium				Colusa Basin Drain	Exhibited slightly to substantially elevated median concentrations as compared to Sac River (SRWP).
Manganese	DHS, USEPA Secondary Drinking Water Standard MCL, CVRBP	50 µg/L 0.05 mg/L	USGS: Exceedances ranging from 62-71 µg/L SRWP 99/00: Exceedances ranging from 118-843 µg/L SRWP 99/00: 107 µg/L	Colusa Basin Drain Colusa Basin Drain Sac River/Vet Bridge	93% of data meets water quality objective (7.4% exceedance for dissolved Manganese) -- CBD (SRWP).
Organic Carbon					
Dissolved Organic Carbon (DOC)[4]	Concentrations in excess of 3 mg/L (or 3000 µg/L) are more likely to produce trihalomethane concentrations approaching or exceeding drinking water standards		SRWP: 5.1 mg/L (median), 9.1 mg/L (highest total observed) SRWP 99/00: Exceedances rangin from 5.2-10 mg/L USGS: Exceedances ranging from 3.2-3.6 mg/L SRWP 99/00: 3.6 mg/L	Colusa Basin Drain Colusa Basin Drain Sac River/Verona Sac River/Verona	Health risks of total trihalomethanes: liver, kidney or central nervous systems problems, increased risk of cancer
Total Organic Carbon (TOC)	Disinfectants/ Disinfection By-products Rule Treatment Threshold (exceedances may	2,000 µg/L 2 mg/L	SRWP: 3.9 mg/L (lowest total observed), 6.7 mg/L (median), 10.6 mg/L (highest total observed) SRWP 99/00: Exceedances	Colusa Basin Drain Colusa Basin Drain	0% of data meets water quality goal – CBD. A primary source of increased organic

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[4] Delta waters contain elevated concentrations of dissolved organic carbon (DOC) and bromide (Br) and can, at times, exceed the U.S. Environmental Protection Agency's (USEPA's) maximum contaminant level (MCL) for trihalomethanes (THMs) of 0.100 milligrams per liter (mg/L) (U.S. Environmental Protection Agency, 1994) if chlorinated for drinking water (Amy and others, 1990; California Department of Water Resources, 1994a). This constraint will become more stringent when stage one of the Disinfectant-Disinfection Byproducts rule is implemented (originally scheduled for June 1998), under which the MCL for THMs will be decreased to 0.080 mg/L (Pontius, 1991; Means and Krasner, 1993).

	require utilities to remove up to 35% if TOC in their source water)		ranging from 3.9-10.8 mg/L SRWP & SRWP 99/00: 2.2 mg/L (median), 4.4 mg/L (highest total observed)	Sac River/Verona	carbon in the Sac River is agricultural inflows. Median TOC concentrations in CBD are 2.5-3.5-fold higher than in the Sac River. (SRWP)
Potassium				Colusa Basin Drain	Exhibited slightly to substantially elevated median concentrations as compared to Sac River (SRWP).
Silica				Colusa Basin Drain	Exhibited median dissolved concentrations similar to those of Sac River (SRWP).
Sodium				Colusa Basin Drain	Exhibited substantially elevated median concentrations (2.5-26-fold greater) as compared to Sac River (SRWP).
Sulfate				Colusa Basin Drain	Exhibited slightly to substantially elevated median concentrations as compared to Sac River, but did not exceed standard (SRWP).
NUTRIENTS					
Ammonia					
Drinking water (total)	USEPA Taste & Odor Thresholds	500 µg/L 0.5 mg/L	SRWP 99/00: 0.64 mg/L	Colusa Basin Drain	
Nitrogen (organic)	No standard			Colusa Basin Drain	Median concentrations higher than in Sac River (SRWP).
Orthophosphate (dissolved)	No standard			Colusa Basin Drain	Median concentrations higher

					than in Sac River (SRWP).
Phosphorus (total)	No standard			Colusa Basin Drain	Median concentrations higher than in Sac River (SRWP).
AQUATIC TOXICITY TESTING					
Pimephales	Significant toxicity: increased mortality and/or decreased growth[5]		SRWP: 8% of samples exhibited significant toxicity	Colusa Basin Drain	Episodic events most commonly associated with observed toxicity are application and runoff from dormant-spray pesticides from agricultural areas and seasonal hydrologic events such as first-flush storms in areas affected by urban runoff (SRWP).
TRACE ORGANICS/ PESTICIDES					
Carbofuran	1990 CVRWQCB/ DPR performance goal	400 ng/L 0.4 µg/L	DPR (1995): Exceedances up to 0.7 µg/L (25% of time) USGS(2): 404 ng/L DPR (1999): Exceedances ranging from 0.65 µg/L to 3.6 µg/L SRWP 99/00: 0.41 µg/L	Colusa Basin Drain Colusa Basin Drain Colusa Basin Drain Colusa Basin Drain	CBD on 303(d) list for this pesticide Potential health effects: damage to nervous/reproductive systems based on animal studies; humans exposed to large amounts over their working careers suffered nerve damage; blood damage.
Chlordane					CBD listed on 303(d) list for Group A Pesticides – chlordane

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[5] Significantly different from controls at a 95% statistical confidence level.

					is one
Diazinon					
Aquatic life (freshwater)	• USEPA Ambient Water Quality Criteria • SFERMP, 1-hour; Calif. Fish & Game acute value • CDFG • Calif. Fish & Game chronic value • SFERMP 4-day	90 ng/L 0.09 µg/L 80 ng/L 0.08 µg/L 0.051 µg/L 50 ng/L 0.05 µg/L 40 ng/L 0.04 µg/L	SRWP 99/00: 100 ng/L USGS(1): 0.098 µg/L (max.) (additional exceedances from 0.05 µg/L) USGS(2): 55-4033 ng/L DPR (1997): 0.07-0.11 µg/L DPR (1998): 0.058-0.17 µg/L USGS(2): 55.1-97 ng/L SRWP 99/00: 0.05 µg/L USGS (1): 0.053 µg/L (max.)	Colusa Basin Drain Colusa Basin Drain Colusa Basin Drain Sac River near Feather River Sac River/Alamar Marina Sac River/Verona Sac River/Vet Bridge Yolo Bypass/I-80	Sacramento and Feather Rivers were placed on the Clean Water Act section 303 (d) list of impaired waterbodies in 1994, 1996 and 1998 due to diazinon. TMDL for diazinon in the Sacramento and Feather Rivers are due in June of 2002 (SRWP). Human health risks: death at high levels. Highly toxic to birds and fish. Used as dormant spray in winter on prunes, almonds, walnuts.
Dieldrin					CBD listed on 303(d) list for Group A Pesticides – dieldrin is one
Malathion	1990 CVRWQCB/ DPR performance goal	0.1 µg/L	DPR (1995): 1.0 µg/L DPR (1999): 0.3 µg/L	Colusa Basin Drain Colusa Basin Drain	CBD listed on 303(d) list for Group A Pesticides – malathion is one. Health risks: immune system problems, death from very high doses, developmental/ reproductive effects from high doses in test animals.
Methyl Parathion					CBD listed on 303(d)

					list for Group A Pesticides – methyl parathion is one. Health risks: death from very high doses; low birthrate, increase in stillbirths in animal studies. Highly toxic to birds.
Molinate	• DHS primary MCL • 1990 CVRWQCB/ DPR performance goal	0.02 mg/L[6] 20,000 ng/L 10 µg/L	DPR (1995): Exceedances up to 25 µg/L (45% of time) USGS(1): 19 µg/L (max.) DPR (1999): 10.3-19.6 µg/L	Colusa Basin Drain Colusa Basin Drain Colusa Basin Drain	Health risks: gastrointestinal illness
Thiobencarb	• 1990 CVRWQCB/ DPR performance goal • DHS primary MCL	1500 ng/L 1.5 µg/L 70 µg/L	USGS(2): 4970-5971 ng/L DPR (1995): Exceedances up to 3.5 µg/L (20% of time) DPR (1999): 1.6-10.9 µg/L USGS(1): 2-4.4 µg/L	Colusa Basin Drain Colusa Basin Drain Colusa Basin Drain Colusa Basin Drain	CBD listed on 303(d) list for Group A Pesticides – thiobencarb is one
TISSUE CHEMICAL CHARACTERISTICS					
Mercury[7]					
Human Health	USEPA 1995 Screening Value	0.6 mg/kg or µg/g	SRWP: 0.8 mg/kg (largemouth bass)	Colusa Basin Drain	
Human Health	USEPA 1997 Mercury Report to Congress[8]	0.33 mg/kg or µg/g	SRWP: 0.553 mg/kg (white catfish)	Sac River/Vet Bridge	
Human Health	SFERMP (1995 USEPA Screening Value)[9]/OEHHA & SFEI 1999 Screening Value	0.23 mg/kg or µg/g (wet)	SWRP 99/00: 0.3 mg/kg (white catfish)	Colusa Basin Drain	SRWP: Exceeded standard at most samples collected from Sac River/Colusa to Cache

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[6] 0.2 on DHS Web site (but doesn't affect exceedances results)

[7] Human consumption of mercury-contaminated fish is a concern because methylmercury, the primary form of mercury in fish, is a potent neurotoxin. Consumption of contaminated fish can cause blindness, paralysis, gingivitis, loss of muscular control, birth defects, and death. Watershed Management of Mercury in the San Francisco Bay Estuary: Total Maximum Daily Load Report to U.S. EPA California Regional Water Quality Control Board San Francisco Bay Region June 30, 2000.

[8] Assumes 60 kg individual and 18 g/day consumption. 60 kg is used by USEPA as default body weight for adult female in calculations of RfD (USEPA 1997). 18 g/day is default fish intake rate proposed by USEPA for protection of the general population and sport anglers (USEPA 1998).

[9] Calculated using USEPA Guidance, 30 g/day consumption rate, and an updated reference dose

					Slough nr Ryer Island Ferry
Wildlife (see footnote 3)	USEPA 1997 Mercury Report to Congress • Hg criterion in trophic level 4 fish • Hg criterion in trophic level 3 fish	0.34 mg/kg or µg/g 0.08 mg/kg or µg/g	SRWP: 0.8 mg/kg (largemouth bass) SWRP 99/00: 0.3 mg/kg (white catfish) USGS: 0.2 µg/g SRWP: 0.12 mg/kg (average) SWRP: 0.1 mg/kg (carp) SRWP: 0.553 mg/kg (white catfish) SRWP 99/00: 0.098 mg/kg (Sacramento sucker)	Colusa Basin Drain Colusa Basin Drain Colusa Basin Drain Colusa Basin Drain Colusa Basin Drain Sac River/Vet Bridge Sac River/Vet Bridge	
Organochlorines					
DDTs (sum of)	• USEPA 1995 Screening Value • OEHHA 1999 Screening Value • SFERMP (1995 USEPA Screening Value)[13]	300 ng/g or µg/kg 100 ng/g or µg/kg 69 ng/g or µg/kg (wet)	SRWP: 684 µg/kg wet (carp)	Colusa Basin Drain	
Dieldrin	• USEPA 1995 Screening Value • OEHHA 1999 Screening Value • SFERMP (1995 USEPA Screening Value)	7 ng/g or µg/kg 2 ng/g or µg/kg 1.5 ng/g or µg/kg (wet)	USGS: 18 µg/kg (carp) SRWP: 20 µg/kg wet (carp)	Colusa Basin Drain Colusa Basin Drain	CBD listed on 303(d) list for Group A Pesticides – dieldrin is one

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KEY TO ABBREVIATIONS:

CDFG = California Department of Fish and Game, 2000

CVRBP = Central Valley Region Basin Plan standards for impairment of beneficial uses (i.e., pollution has occurred) under Porter-Cologne Water Quality Control Act.

DHS = California Department of Health Services.

DPR (1995) = Department of Pesticide Regulation, Environmental Hazards Assessment Program, Rice Pesticide Monitoring in the Sacramento Valley, 1995 (1998).

DPR (1997) = Sacramento River, private dock, 2.5 miles downstream of confluence of Sacramento and Feather Rivers, and 1 mile downstream of DWR gauging station at Verona.

DPR (1998) = Sacramento River at Alamar Marina, 9 miles below the confluence of the Feather River/Sacramento River. Receives discharge from major agricultural tributaries, but above confluence of non-agricultural American River.

DPR (1999) = updated monitoring of rice pesticides.

MCL = Maximum Contaminant Level. Maximum permissible level of a contaminant in water which is delivered to any user of a public water system. MCLs are enforceable standards.

OEHHA = Office of Environmental Health Hazard Assessment.

PHG = California Public Health Goal in Drinking Water (Office of Environmental Health Hazard Assessment).

Prop 65 Regulatory Levels are estimated under California's Safe Drinking Water and Toxic Enforcement Act of 1986 for known human carcinogens and reproductive toxins.

SFBRWQCB = San Francisco Bay Regional Water Quality Control Board

SFEI = San Francisco Estuary Institute

SFERMP = San Francisco Estuary Regional Monitoring Program, 1998

SFERMP (1995 USEPA Screening Value) = concentrations of target analytes in fish or shellfish tissue that are of potential public health concern. Exceedance of screening values should be taken as an indication that more intensive site-specific monitoring and/or evaluation of human health risk should be conducted.

SFERMP Fish Report: Contaminant Concentrations in Fish from San Francisco Bay, 1997.

SRWP = Sacramento River Watershed Program Annual Monitoring Report 1998-99 (June 23, 2000).

SRWP 99/00 = Updated monitoring results released June 2001.

TMDL = a plan that allocates the maximum load of a contaminant allowed to be discharged in order to reduce concentrations to water quality standards or targets.

USEPA Ambient Water Quality Criteria = Under Section 304(a) of the Clean Water Act (also called the National Recommended Water Quality Criteria).

USEPA California Toxics Rule Criteria do not apply to waters subject to water quality objectives in Tables III- 2A and III- 2B of the San Francisco Bay Regional Water Quality Control Board's 1986 Basin Plan.

USEPA Secondary Drinking Water Standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects, such as skin or tooth discoloration, or aesthetic effects, such as taste, odor, or color, in drinking water. States may choose to adopt them as enforceable standards and both primary and secondary standards have been adopted by reference in the Central Valley Basin Plan.

USGS = National Assessment of Water Quality for the Sacramento River Watershed (September 1999): USGS (1) Analyzed by gas chromatography/mass spectrometry. USGS (2) Analyzed by gas chromatography/ion trap mass spectrometry.

WOOD RODGERS

ENGINEERING ▪ PLANNING ▪ MAPPING ▪ SURVEYING

Sizing Criteria for the West Adams Canal

Appendix C

WOOD RODGERS

MEMORANDUM

TO: Fran Borcalli

FROM: Jonathan Kors

C:

DATE: 10/11/02

SUBJECT: YCFCWCD/YZWD – Sizing Criteria for the West Adams Canal

ANALYSIS

E_T Rate

A composite E_T Rate for crops in the Yolo County Flood Control & Water Conservation District (District) was determined using E_T Rates presented in Reference (1), Attachment 1. for Sacramento Valley crops during the month of July (month of peak demand for the majority of crops). A composite E_T Rate, based upon a weighted average of the major crops in the District, was calculated at 8.27 for 30 days for 1989 Land Use Data (Attachment 2) and 8.43 for 30 days for 1997 Land Use Data (Attachment 3). Both composite E_T Rates, corrected to cfs/acre and divided by 70% efficiency, yield a peak consumptive use "r" value of 0.017 cfs/acre.

Canal Capacity Based on "Clement" Equation

A determination of required capacity at all West Adam Canal laterals and reaches (reach being a stretch of canal or canal lateral between existing check structures) was made using the equation contained in Reference (2), Attachment 4.

$$Q = \left(\frac{RA}{r}\right)\left(1 + U\sqrt{(\frac{1}{m}) - (\frac{1}{n})}\right)$$

A U value of 1.645 (95% probability of adequate functioning) was used as Reference (2) notes this is the usual value. A value for the equation was determined by $u = A^1/A$, where A^1 is taken as the average farm size for each leteral of the system, based upon 2001 District raw data. "m" was determined by $m = \frac{RA}{rq}$, where q is taken as the average highest turnout flow rate based upon 2001 District raw data. The A^1 and q values are composite values for the lateral being evaulated and all tributary laterals, based upon area served by the lateral and tributary laterals (weighted averages).

Clemmens "Surface Arranged" and "Surface Demand" Equations

For comparison against design capacities determined by the Clement equations contained in Reference (3), Attachment 5

Surface Demand*: $Q = 4\ A_n + 1$ for $A_n < 1$
$Q = 1.5\ A_n + 3.5$ for $A_n > 1$

*Surface Demand" - Farmer can turn on and off water without coordination with the District.

Surface Arranged**: $Q = 1.6\ An + 1$ for $A_n <$
$Q = 1.0\ A_n + 1.6$ for $A_n > 1$

** Surface Arranged" - Farmer coordinates with District in shutting on and off water.

A_n was considered 116.6 acreas, based upon all West Adams canal average farm sizes from 2001 District raw data.

A plot of the Clement equation and surface and demand caurves from the Clemmens equation is included as Attachement 6. Source data for the Clement equation points is included as Attachment 7, and theoretical data backup for the Clemmens equation is included as Attachment 8.

Seepage Losses

The capacity plots do not consider seepage losses. These losses are shown on Attachment 7 and were determined as the difference of system inflow, water sales, and operational spills (Attachment 9).

Table 22. ESTIMATED GROWING SEASON EVAPOTRANSPIRATION FOR PRINCIPAL CROPS - SACRAMENTO VALLEY1/
In inches

Mont	Potential ET 2/	Alfalfa (Hay)	Barley	Beans (Dry)	Corn (Field)	Deciduous Orchard Except Almonds	Almonds 3/	Grain Sorghum	Pasture (Improved)	Potatoes	Rice	Subtropical Orchard 3/	Sugar Beets	Tomatoes (Canning) 4/	Vineyard (Table Grapes)
Jan	1.1	-	1.0	-	-	-	-	-	-	-	-	1.1	-	-	-
Feb	1.8	-	2.3	-	-	-	-	-	-	-	-	1.3	-	-	-
Mar	3.0	2.7	3.2	-	-	1.8	1.4 5/	-	~~3.0~~	-	-	1.9	-	-	-
Apr	4.4	4.0	2.8	-	-	3.1	2.3	-	4.4	-	2.2 5/	2.6	-	-	-
May	5.8	5.3	1.5	-	-	4.9	3.7	-	5.8	6.2	6.3	3.5	3.8 5/	1.6	3.4
Jun	7.3	6.8	-	3.9	4.5	6.5	4.9	2.4	7.3	8.7	9.2	4.4	[illegible]	5.5	5.7
Jul	7.9	7.7	-	8.6	9.5	7.6	5.7	9.2	7.9	4.9	9.1	4.7	5.3	8.0	6.8
Aug	6.7	6.9	-	3.7	7.2	6.4	4.8	7.0	6.7	-	7.8	4.1	6.2	7.1	[illegible]
Sep	5.2	5.4	-	-	3.4	4.8	3.6	2.7	5.2	-	5.6	2.9	6.3	4.2	3.7
Oct	3.4	3.5	-	-	-	2.8	2.1 5/	-	3.4	-	1.3 5/	2.1	3.7	-	1.5
Nov	1.6	-	0.2 5/	-	-	-	-	-	-	-	-	1.6	1.6	-	-
Dec	1.0	-	0.4	-	-	-	-	-	-	-	-	1.0	1.0 5/	-	-
Total	49.2	42.3	11.4	16.2	24.6	37.9	28.5	21.3	43.7	19.8	42.0	31.2	29.4	27.4	26.7

1/ Calculated from average evaporation (irrigated pasture environment) for Valley and observed ET/Ep ratios.
2/ ET of large plot of well-watered, clipped grass.
3/ No ET measurements available. ET estimates based upon crop development and prevalent cultural and irrigation practice data.
4/ Machine-harvested varieties.
5/ Assume mid-month planting or harvest. ET for 1/2 month.

Table 23. ESTIMATED EVAPOTRANSPIRATION OF APPLIED WATER FOR PRINCIPAL CROPS - SACRAMENTO VALLEY1/

Crop	Estimated Growing Season ET, AF/A	Rainfall Zone, Average Annual Precipitation - Inches							
		12-14	14-16	16-18	18-20	20-22	22-24	24-28	28-32
		ET of Applied Water, AF/A							
falfa	3.5	2.8	2.7	2.6	2.4	2.3	-	-	-
arley	1.0	0.1	0.0	0.0	0.0	0.0	0.0	-	-
Beans (Dry)	1.4	1.2	1.1	1.1	1.1	1.1	1.1	-	-
Corn (Field)	2.0	1.9	1.8	1.8	1.8	1.8	1.7	-	-
Deciduous Orchard 2/	3.2	2.5	2.4	2.2	2.0	1.9	1.9	1.8	1.8
Almonds 3/	2.4	-	1.7	1.6	1.4	1.3	-	-	-
Grain Sorghum (Milo)	1.8	1.6	1.5	1.4	1.4	1.4	1.3	-	-
Pasture (Improved)	3.6	3.0	3.0	2.9	2.9	2.8	2.8	2.7	2.6
Potatoes	1.6	1.5	1.4	-	-	-	-	-	-
Rice	3.5	3.3	3.3	3.3	3.3	-	-	-	-
Subtropical Orchard 4/	2.6	-	-	1.6	1.6	-	-	-	-
Sugar Beets	2.5	2.0	1.9	1.7	1.6	1.5	1.5	-	-
Tomatoes 5/	2.3	2.0	1.9	1.7	-	-	-	-	-
Vineyard 6/	2.2	1.9	1.8	1.7	1.6	1.5	1.4	1.4	1.4

1/ Averages for entire Valley floor - differences in crop cultural practices may result in small variations from reported amounts.
2/ Deciduous orchard, except almonds.
3/ Not based upon crop ET measurements. Almond ET estimated as .75 x ET deciduous orchard.
4/ ET citrus estimated from: ET citrus = 0.60 x PET for active growing season, ET maximum = PET winter 12-month growing season.
5/ Machine-harvested canning tomatoes.
6/ Table grapes - use as maximum for vineyard, wine grapes may be lower.

ATTACHMENT 2

COMPOSITE EVAPOTRANSPIRATION CALCULATION BASED ON YCFCWCD LAND USE FOR 1989

LAND USE	AREA (ACRES)	ESTIMATED EVAPOTRANSPIRATION (ET) FOR JULY (IN)[1]	AxET
Almonds	4835	5.7	27559.5
Walnuts	5124	7.6	38942.4
Alfalfa	16945	7.7	130476.5
Mixed Pasture	1496	7.9	11818.4
Beans	549	8.6	4721.4
Corn	5566	9.5	52877
Peppers	0	0	0
Tomatoes	28561	8.9	254192.9
Rice	2152	9.1	19583.2
Vineyards	643	6.8	4372.4
TOTAL:	65871		544543.7

COMPOSITE VALUE (IN):	8.27	
R Value:	0.012	=8.53*43560/(12*2592000)
With Efficiency Adjustment:	0.017	=0.012/0.7

---

[1] EVAPOTRANSPIRATION RATES TAKEN FROM DEPARTMENT OF WATER RESOURCES BULLETIN NO. 113-3

COMPOSITE EVAPOTRANSPIRATION CALCULATION BASED ON YCFCWCD LAND USE FOR 1997

LAND USE	AREA (ACRES)	ESTIMATED EVAPOTRANSPIRATION (ET) FOR JULY (IN)[1]	AxET
Almonds	3461	5.7	19727.7
Walnuts	5985	7.6	45486
Alfalfa	18400	7.7	141680
Mixed Pasture	1874	7.9	14804.6
Beans	1059	8.6	9107.4
Corn	17832	9.5	169404
Peppers	173	0	0
Tomatoes	23885	8.9	212576.5
Rice	3480	9.1	31668
Vineyards	1431	6.8	9730.8
TOTAL:	77580		654185

COMPOSITE VALUE (IN):	8.43	
R Value:	0.012	=8.53*43560/(12*2592000)
With Efficiency Adjustment:	0.017	=0.012/0.7

1. EVAPOTRANSPIRATION RATES TAKEN FROM DEPARTMENT OF WATER RESOURCES BULLETIN NO. 113-3

ATTACHMENT 4

Albert B. Cutler Jr.
8543 East Mitchell Drive
Scottsdale, Arizona 85251

December 2, 1977

Mr. Frank Borcalli
Frederiksen, Kamine & Assoc.
1900 Point West Way
Sacramento, California 95815

Dear Frank:

Enclosed is a copy of the canal capacity equation we discussed over the phone last Monday. It is the best approach I have found to date in that it permits looking at and assessing each of the major parameters encountered in irrigation system operation. I hope it is of help to you. If you use it I would appreciate a copy of the conversion values you come up with in the converting to the English Unit System.

Incidentally, I have reopened my own office at home (above address), telephone (602) 946-5413. I still serve as counsel to Coe and Van Loo, but as a consultant, not as an employee. Messages left with their receptionists usually get to me, but you are more likely to catch me at my own office.

I am pleased to hear Hal and Tuck are making out well enough to start to expand. Personally I find the international market less attractive and am turning more towards work in the States. So far this year I have had more work than I really care for, but I discount that a bit as one of the peaks of "feast or famine" which is part of the water resource consultancy game. If I can help out in other ways I'm available.

Janet joins me in sending our best to Judy and the children. We would certainly love to see all of you again one of these days.

Sincerely,

Albert B. Cutler Jr.

ABC:jc
Encl.

CORPORACION AUTONOMA REGIONAL DEL CAUCA

MEMORANDUM

TO : Design Section

FROM : A. B. Cutler

DATE : October 6, 1961

SUBJECT : Proposed method for the calculation of Canal Capacities.

The equation from which canal capacities may be calculated is:

$$Q = (RA/r)\ (1 + U\sqrt{1/m - 1/n}\ )$$

Where:

cfs

Q = canal capacity in lt/sec at the point where the irrigation system serves A [illegible];

R = continuous delivery requirement during the peak demand period (0.[illegible] lt/sec/ha);

cfs/ac

acres A = area in hectares served below the point where the canal has a capacity of Q lt/sec;

acres A' = area of farm unit in hectares served by a farm turnout with a capacity of q lt/sec;

1.0/25 ac

r = T'/T = fraction of time that the irrigation system is in actual use during the peak demand period T;

1/25 ac.

100% or 1.0

m = RA/rq = average number of farm turnouts simultaneously operating below the point where the canal has a capacity of Q lt/sec;

n = A/A' = total number of farm turnouts of capacity q lt/sec in the irrigation system at point where the canal has a capacity of Q lt/sec;

cfs

q = capacity of the farm turnout in lt/sec;

x = $m(1 + U\sqrt{1/m - 1/n}$ = number of farm turnouts probably operating below the point where the canal system has a capacity of Q lt/sec;

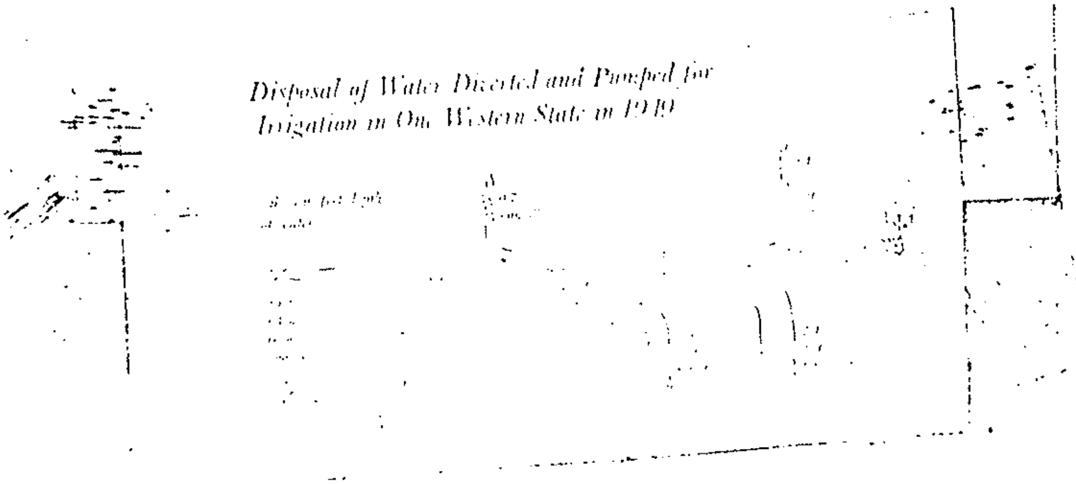
U = a coefficient which depends on the probability of adequate functioning of the canal system; that is, the quality of functioning selected for the canal systems under consideration. A usual value for U = 1.645.

Probability of adequate functioning of the canal system in percent	U
70	0.525
80	0.842
90	1.282
95	1.645
99	2.324
99.9	3.09

*Clement, R., Le Calcul des Debits dans les Canalisations d'Irrigations. Journees d'Etudes sur l'Irrigations, 27-30 June, 1955, Association amicale des Ingenieurs du Genie rural, Paris 19, Avenue du Maine, pp. 29-40, 1956.

PROJECT EFFICIENCY

Of 22 projects in USBR serving 8.192 million acres an average efficiency of 60.3% was obtained. Efficiencies did vary from 47.5% to 96.2%. No relationship between project size or acre feet delivered could be established.



Disposal of Water Diverted and Pumped for Irrigation in One Western State in 1919

ENGLISH

Frederiksen, Kamine and Associates
- SACRAMENTO -

SHEET 1 OF 2

PROJECT Yolo County Irrigation Proposal

FEATURE ______ BY Mark DATE 4/18/78

ITEM Canal Capacity Equation CHECKED ______ DATE ______

$$R = 1.0 \text{ LT/sec/Hec} \times \frac{.03532}{2.464} = .014 \text{ CFS/ACRE}$$

A = Area ,

$A' = 160$ ACRES

$r =$ DIMENSIONLESS T'/T

$$m = RA/rq = \boxed{\frac{0.014\,A}{rq} = m}$$

$q =$ CFS

$U =$ usually 1.645

$n =$ Dimensionless A/A'

$$\boxed{Q = \left(\underbrace{\boxed{0.014}}_{R}A/r\right)\left(1 + U\sqrt{rq/(\underbrace{\boxed{0.014}}_{R}A) - 1/n}\right.}$$

$$\boxed{x = \frac{0.014\,A}{rq}\left(1 + U\sqrt{rq/0.014\,A - 1/n}\right.}$$

CHECK

$$\underbrace{(0.014\ \text{CFS}/\cancel{\text{ACRE}})(\cancel{\text{ACRE}})}_{\text{DIMENSIONLESS \#}}\left(1 + 1.645\sqrt{\frac{(T)(\text{CFS})}{0.014\text{CFS}/\text{Acre}} - 1/_{\text{DIMENSIONLESS}}}\right)$$

UNITS CHECK OUT

Frederiksen, Kamine and Associates
SACRAMENTO

SHEET 2 OF 2

PROJECT Yolo County Irrigation Proposal
FEATURE
BY Mark DATE 4/18/78
ITEM Canal Capacity Equation CHECKED DATE

BASIC Equation (METRIC) = $Q = (RA/r)(1+U\sqrt{1/m-1/n})$

Where

Q = Canal = canal capacity Lt/sec @ the point where the irrigation system serves A hectores=2.5 acres

CFS/AC R = continuous delivery requirement during the peak demand period (1.0 Lt/sec/hec)

Acres A. = Area in hectares served below the point where the canal has a capacity of . LT/sec

160 A' = Area of farm unit in hectares served by a farm turnout with a capacity of q Lt/sec

r = T'/T = fraction of time that the irrigation system is in actual use during the peak demand period T

m = RA/rq = average number of farm turnouts simultaneously operating below the point where the canal has a capacity of Q

n = A/A' = TOTAL number of farm turnouts of capacity q LT/sec

q = capacity of the farm turnout in Lt/sec cfs

$x = m(1+U\sqrt{1/m-1/n}$ = number of farm turnouts probably operating below the point where the canal system has a capacity of Q Lt/sec

U = a coefficient which depends on the probability of adequate functioning of the canal system that is, the quality of functioning selected for the canal systems under consideration
A usual value for U = 1.645

$1\ m^3/sec = 35.4$ CFS

$1\ m^3 =$

ATTACHMENT 5

1192

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IRRIGATION AND DRAINAGE DIVISION

CANAL CAPACITIES FOR DEMAND UNDER SURFACE IRRIGATION

By Albert J. Clemmens,[1] M. ASCE

ABSTRACT: Providing water to users on demand usually requires an increase in canal capacity over the same volume of water delivered at a uniform rate. A simulation model was used to develop demand patterns for hypothetical surface irrigation conditions. These results were used to determine the canal capacity required to meet various levels of demand. A modification to these results was hypothesized to be appropriate for delivery schedules where delivery is arranged. These results are expressed in simple, nondimensional terms and compared to capacities for continuous flow and rotation systems and to capacities from Clement's demand formulas. It is shown that Clement's formulas which were developed for sprinkler irrigation are inappropriate for surface irrigation demand since they do not account for the wide variations in possible conditions. Results are particularly inappropriate for small relative service areas. Simple canal capacity equations were developed for demand and arranged surface irrigation distribution systems for a 90% level of service (i.e., water is available 90% of the time when demanded).

INTRODUCTION

Some irrigation projects are built to supply water to farms that apply water with surface irrigation methods. Water is often distributed to farmers within the project through a network of canals. Canals are used because they can be constructed more inexpensively than other available methods and because local labor and materials can be used. The simplest method of distributing water in a canal network is to supply a continuous flow of water to each farmer. The farmer is then responsible for distributing this water over different parts of his farm. This continuous flow system is simple to operate because once flow into the canal system is set, it does not change. However, since plants use water at different rates over the growing season, a continuous flow system would supply too much water early in the season and perhaps not enough water later in the season. Where available water is in short supply, this type of inefficiency is not reasonable. Some continuous flow systems adjust the supply flow rate periodically to try to more closely match plant water needs.

For surface irrigation, it is not practical to supply water at the rate at which the plants need water. For example, plants may use water at a rate of 2–10 mm/day, whereas surface irrigation systems generally are designed to apply from 50–150 mm/irrigation, which will generally be applied in a period of 1–48 hrs. This is dictated by soil water holding capacities, root zone depths, soil infiltration rates, and efficient irrigation stream sizes. Thus to achieve even a reasonable efficiency, an available

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[1] Research Hydr. Engr., U.S. Water Conservation Lab., USDA-ARS, Phoenix, AZ 85040.

Note.—Discussion open until April 1, 1987. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on November 14, 1985. This paper is part of the *Journal of Irrigation and Drainage Engineering*, Vol. 112, No. 4, November, 1986. ©ASCE, ISSN 0733-9437/86/0004-0331/$01.00. Paper No. 21051.

ir a stream must be rotated between different areas of land. If a fa s land area is large enough, he may be able to handle a continuous flow, otherwise it is more practical to rotate the available irrigation stream among neighboring farmers. Operation of the canal distribution system for a rotation system does not change from that of a continuous flow system except where water is actually turned into the farms. Rotation systems may also be inefficient if inflows are not adjusted through the season to match plant water requirements.

If the same stream that was once split among eight farmers, for example, is now given to one farmer one day out of eight days, his farm canals and the structure which turns water out of the project supply canal must be able to handle eight times the flow rate. However, the entrance canal capacity which brings water to these eight farmers has not changed in size. Now if farm water use efficiencies (water required/water delivered) have been improved, the farm canal size could be reduced somewhat from the eight-fold increase. In addition, this increase in efficiency could potentially reduce the size of the project supply canal. A change in delivery method, while it may require larger canals on the farm, can improve efficiency and may also result in smaller project supply canals or a larger project area being serviced.

Surface irrigation systems are generally designed to be efficient within a small range of application depths. Since crop water use rates vary widely over the season, the period between irrigations should also change. Thus variations in frequency rather than flow rate are necessary to adjust a rotation schedule to match plant needs for surface irrigation. An adjustable frequency rotation system is somewhat difficult to develop. In addition, variations in soil characteristics and differences in crop selections will cause different fields within a rotation unit to require different rotation intervals during the same part of the season, a nearly impossible task even for an adjustable frequency rotation scheme.

It has been known for several decades that to be efficient in water use and productive in yields, the delivery system must be flexible in rate, frequency and duration (6). An extreme case of this flexibility is a demand system where any quantity of water is delivered whenever desired for any duration desired. Obviously such systems must operate within some practical bounds, e.g., within a range of flow rates and within an overall seasonal water allocation. Returning to our example of the eight farmers serviced by one project supply canal, if all eight demanded water at the same time, the supply canal to those eight farmers would have to be eight times as large as for a rotational system. If each farmer wanted double the usual flow, say for half the duration, the canal would have to be 16 times as large. One alternative is to use farm reservoirs to accept water given in rotation, and apply it when needed. Another alternative is for farmers to arrange water deliveries in an effort to reduce the amount of overlap in demand. In real situations, the probability that all eight farmers would want water at the same time would be fairly low.

Arranged delivery schedules are used in many irrigation districts in the western U.S. Typically water is ordered from one to three days ahead of time. Flow rates are generally limited by structure and canal capacities. Durations are either continuously variable or set to fixed intervals such as 12 or 24 hrs. Replogle and Merriam (6) have listed a number of categories of delivery schedules in terms of constraint ed on rate, frequency, and duration.

Several questions come to mind regarding canal capacities: How large a canal is necessary for a demand system, for example, if you want to be able to supply demand, say, 70 or 80% of the time? How is this overlap in demand mitigated by arranged schedules? What should canal capacities be under these circumstances? This paper discusses these issues and presents analytical results from computer simulation in an attempt to provide useful methods for determining canal capacities for demand and arranged delivery schedules.

CANAL CAPACITY RELATIONSHIPS

Canal capacities are based on the peak water use period and on the land area which they service. The peak water use rate, W_u, is defined as the peak consumptive use in volume per unit area per unit time divided by the irrigation efficiency. It represents the amount of water to be delivered. Now, given a turnout delivery flow rate Q_t which is established as an average (or maximum) for design of farm turnouts, the area, A_t, that can be serviced by a continuous flow system would be

$$A_t = \frac{Q_t}{W_u} \quad \text{.......... (1)}$$

with appropriate units conversion. This is also the area serviced by a single rotation of a rotation system. If this area is broken up into N_r fields (or farms) each with area A_g which is serviced by one turn in the rotation from a single turnout with capacity Q_t, then the rotation frequency

$$F = \frac{1}{N_r} = \frac{A_g}{A_r} \quad \text{.......... (2)}$$

It is useful to define these variables in relative terms. The flow rate of a canal, Q, is referenced to the average turnout design flow rate, Q_t, to give a relative flow rate

$$Q_n = \frac{Q}{Q_t} \quad \text{.......... (3)}$$

Similarly, the size of a canal service area, A, is referenced to the rotation unit size, A_t, to give a relative service area A_n

$$A_n = \frac{A}{A_t} \quad \text{.......... (4)}$$

From Eqs. 1, 3, and 4 for a rotation or continuous flow system, we get

$$A_n = \frac{A}{A_t} = \frac{\frac{Q}{W_u}}{\frac{Q_t}{W_u}} = \frac{Q}{Q_t} = Q_n \quad \text{.......... (5)}$$

ince $A =$ [illegible] which is analogous to Eq. 1.

If the ar[illegible]viced, A_r, is equal to a rotation area, A_t, then $A_\pi = 1$. rom Eq. 4 for rotation and continuous flow systems, $Q_\pi = 1$ as well.)peration of demand and arranged delivery schedules, will require Q_π > 1. But how much greater? Twice as much? Irrigation projects which lelivery water in a similar manner, but with different crop consumptive ise values and different delivery flow rates would be expected to need imilar proportionate increases in canal capacities. Thus A_π and Q_π are onvenient for analyzing the changes in canal capacity required for flexble (arranged and demand) delivery over that for the rigid (continuous low or rotation) delivery schemes.

LEMENT'S DEMAND FORMULAS

Clement (1) developed two formulas for analyzing the demand reuirements for irrigation. These formulas were developed for an iriation project which used primarily sprinkler irrigation. Thus a particlar field delivery point has flow either on or off for a given day. Given hat there are R delivery points, the first demand formula is used to find he system capacity in terms of the number of users N such that the robability that N or fewer users will be using the system simultaeously is greater than some desired probability P_q. This is a supplierriented view since it considers a time-based frequency of meeting caacity, (that is, the portion of time that the capacity is sufficient). Thus $_q$ is a time-based service measure. The second demand formula finds he system capacity N such that the probability of the user finding the ystem at capacity or busy when (s)he wants water (congestion) is less han some desired probability, P_s. This is a more user-oriented view ince it considers a use or demand frequency of having insufficient caacity, (i.e., how often is service available when it is demanded?). Thus, $_s$ is a demand-based service measure. Clement's first demand fornula is

$$V = Rp + U\sqrt{Rpq} \quad\text{.......} \quad (6)$$

n which N = number of users; R = total number of delivery points; p = average frequency of irrigation, $q = 1 - p$; and U is defined from P_q = $\pi(U)$ in which the function π = the normal cumulative distribution unction. This equation was derived by initially assuming that the probability of a particular farm unit being operated during a given day is described by a binomial probability distribution. A binomial distribution assumes that the probability of irrigating a given field on any particular day is independent of the past history of irrigations. This says that an irrigation would be just as likely today if we irrigated yesterday or a week ago. This does not seem reasonable for surface irrigation, nor for sprinkler irrigation in many areas. Next, it was assumed that if R was large, the binomial distribution could be approximated with a normal distribution. This approximation is appropriate only for $Rp > 5$ (7). This formula supplies continuous values of N while in general, capacities are usually discrete multiples of the delivery rate. Clement's second demand formula is given by

$$N = Rp + U'\sqrt{Rpq} \quad\text{.......} \quad (7)$$

in which U' is found from

$$P_s\sqrt{Rpq} = \frac{\psi(U')}{\pi(U')} \quad\text{.......} \quad (8)$$

in which $\psi(U')$ = the normal probability density function. Some values for $\psi(U')/\pi(U')$ are given in Table 1. This formula was derived from a binomial distribution as a Poisson pure birth/death process. Again for large R, the binomial was replaced with a normal distribution. Clement

TABLE 1.—Values of $\psi(U')/\pi(U')$ and $\pi(U)$ for Use in Clement's Demand Formulas

U or U' (1)	$\psi(U')/\pi(U')$ (2)	$\pi(U)$ (3)
0.0	0.798	0.500
0.1	0.735	0.540
0.2	0.635	0.579
0.3	0.617	0.618
0.4	0.562	0.655
0.5	0.509	0.692
0.6	0.459	0.726
0.7	0.412	0.758
0.8	0.367	0.788
0.9	0.326	0.816
1.0	0.287	0.841
1.1	0.252	0.864
1.2	0.219	0.885
1.3	0.190	0.903
1.4	0.163	0.919
1.5	0.139	0.933
1.6	0.117	0.945
1.7	0.0984	0.955
1.8	0.0819	0.964
1.9	0.0675	0.971
2.0	0.0553	0.977
2.1	0.0448	0.982
2.2	0.0360	0.986
2.3	0.0286	0.989
2.4	0.0226	0.992
2.5	0.0176	0.994
2.6	0.0137	0.995
2.7	0.0104	0.996
2.8	0.0079	0.997
2.9	0.0060	0.998
3.0	0.0044	0.999
3.1	0.0033	0.999
3.2	0.0024	0.999
3.3	0.0017	0.999
3.4	0.0012	1.000

Note: $\psi(U')$ = normal probability density function; and $\pi(U)$ = cumulative normal distribution function.

recom[illegible] the first demand formula for $R < 100$ and the second for $R > 100$[illegible]en demand is greater than capacity this excess demand must be handled in later periods. However, no adjustments were made for users who could not receive service. Clement recommends that the second formula (Eqs. 7 and 8) be used with $P_a = 0.01$. This also applies to the first formula (Eq. 5) where the P_q must be very high, say 0.99. Appropriate levels of performance are discussed in a later section.

Clement's formulas can be written in the terminology of the previous section since by definition $R = A_f = A_n/F$, $N = Q_n$, $p = F$, $q = 1 - F$, where Clement's terms are stated to the left of the equal sign. Eqs. 6, 7 and 8 become, respectively

$$Q_n = A_n + U\sqrt{A_n(1-F)} \quad \text{.......} \quad (9)$$

$$Q_n = A_n + U'\sqrt{A_n(1-F)} \quad \text{.......} \quad (10)$$

$$P_u\sqrt{A_n(1-F)} = \frac{\phi(U')}{\pi(U')} \quad \text{.......} \quad (11)$$

Thus the second term in Eqs. 9 and 10 represent the excess capacity needed for a demand delivery capability.

These formulas give the instantaneous canal capacity required at a given point in the system. Below any given bifurcation, the required capacity would decrease since the service area is reduced.

The binomial (and then assumed normal) distribution used in the development of these formulas which were derived for sprinkler irrigation systems do not appear to be appropriate for surface irrigation. Also, Clement's formulas are meant to apply only for relatively large scale systems ($A_n > 5$) and for large performance measures (congestion of 1%). However, lesser performance levels may be more appropriate for surface irrigation systems, particularly where arranged schedules are used. A simulation model was developed to simulate the demand for water under surface irrigation in order to test Clement's formula and to determine what actual demand capacities are needed.

SURFACE IRRIGATION DEMAND SIMULATION

To develop statistical relations between area serviced and canal capacity for a demand system, a long record of actual demand patterns for a variety of crops, soils, irrigation strategies, etc., must be obtained. However, since very few actual demand systems exist, historical data is not available from which to make these predictions. An alternative is to generate demand patterns from simulations. There were three steps taken in this simulation process. First, weather data were generated to simulate variations in climatic conditions. Historical records could also have been used. Second, daily evapotranspiration (ET) was simulated based on climatic conditions and available soil water. Irrigation soil depletion strategies then were used to determine when to refill the root zone. This gave a series of irrigation events for each simulation year. This step was repeated for a variety of crops, soils and irrigation strategies, each representing a single field. Finally, individual fields were randomly selected in combinations to produce a distribution of demands for di[illegible] service areas (different numbers of fields).

Weather data for a 20-yr simulation were developed with the program WGEN (Weather Generator) based on the climate at Phoenix, Arizona (5 and "WGEN: A Model for Generating Daily Weather Variables," by C. W. Richardson and P. A. Wright, USDA/ARS, Grasslands, Soil and Water Research Laboratory, Temple, Tex., 1984, unpublished).

This model did a good job of simulating Phoenix weather (Ref. 5 for details). An arid climate was chosen because it is more typical of areas which are water short and in need of conservation measures. The CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems) model (4), as modified by Reinink (5) to provide different irrigation strategies, was used to develop irrigation schedules for each of 60 fields for each year. CREAMS was selected since it simulates changes in soil moisture storage and predicts ET from crop and soil data.

The 60 fields consisted of combinations of 4 crops as shown in Table 2, five soils with varying water holding capacities as shown in Table 3, and 3 depletion levels, namely 45, 55 and 65% of available water, at which irrigation was initiated. CREAMS uses daily values of water use so that only the day of irrigation and the depth to refill the root zone is given as output. The crops were chosen to give a wide variety of consumptive use patterns and still be typical of crops grown in the area. The input to CREAMS (rooting depths and leaf area index) was adjusted to give consumptive use values in agreement with those published by

TABLE 2.—Crops Used in CREAMS Model with Rooting Depths as Input and Resulting Consumptive Use over the 92-Day Period of June, July and August

Crop (1)	Effective Rooting Depth in. (2)	Effective Rooting Depth m (3)	Representative Consumptive Use of 92-Day Period in. (4)	Representative Consumptive Use of 92-Day Period mm (5)
Alfalfa	78	1.98	32.1	815
Cotton	60	1.52	26.1	663
Citrus	54	1.37	19.1	485
Sorghum (double cropped)	60	1.52	26.7	678

TABLE 3.—Soils Chosen and Water Holding Capacities for Input to CREAMS Model

Soil type (1)	Available Water Percentage (2)	Available Water mm/m (3)	Available Water in./ft (4)
Loamy sand	8.4	84	1.0
Sandy loam	10.9	109	1.3
Very find sandy loam	14.3	143	1.72
Loam	16.5	165	1.98
Silty clay loam	19.9	199	2.39

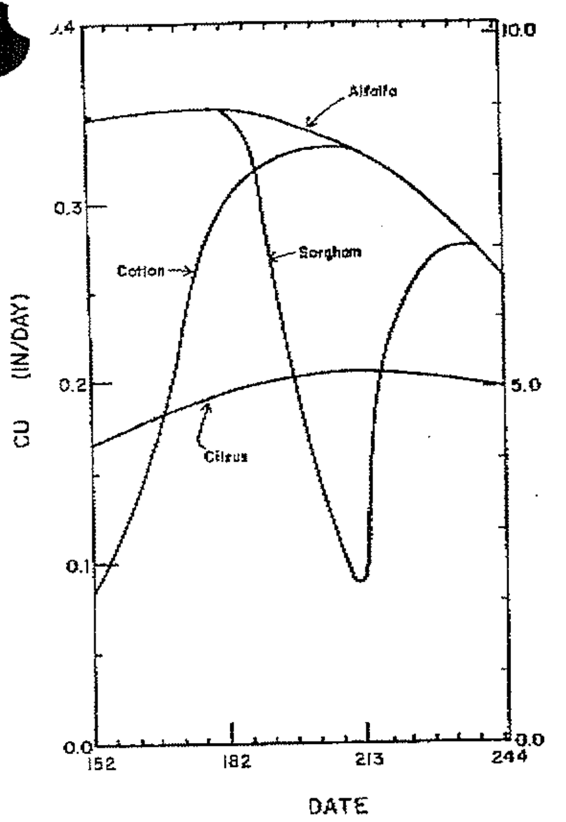

FIG. 1.—Representative Consumptive Use during Peak Use Period of June, July and August (Days 152 to 243) for the Four Crops Used in the Simulation

Erie, et al. (3), (see Table 2 and Fig. 1). Soils were chosen to represent a variety of water holding capacities (Table 3).

The fields were taken in groups of two, three, four, etc., up to 60 in groups by which 60 is evenly divisible in order to simulate canals with different downstream service areas. This was done day by day during the peak use period of June, July, and August (Days 152–243) for each year of the 20-yr simulation for a total of 1,840 days. The order (and thus groupings) of fields was chosen randomly. The average depth applied per irrigation was 113 mm (4.45 in.) with a standard deviation of 42 mm (1.65 in.). No adjustment was made for efficiency since only relative numbers are of significance. The average interval between irrigations was 16.3 days ($F = 0.061$), the standard deviation of average interval for the sites was 10.7 days. For the 60 sites, there was an average of 3.43 irrigations per day or 6,311 irrigations over the 92-day interval for 20 yrs.

Two sets of output statistics were collected. The first set represents continuous variations in demand. It was based on spreading the total demand for the canal over the 24-hr period, thus depth ap[illegible] would have a significant influence. The second was based strictly o[illegible] number of fields being irrigated on a particular day, and thus represented discrete increments of demand. The statistics collected included the time-based frequency of demand at a series of capacities and the demand-based frequency at the same series of capacities. From this, the capacity representing a particular value of cumulative frequency could be determined for comparison with Clement's formula.

There is some question about the appropriateness of time-based frequency of having sufficient capacity (i.e., percent of time that the capacity is not exceeded) as a service measure. For example, if a field is irrigated one day out of ten ($F = 0.1$) on the average, then the farm canal will not be in use 90% of the time ($P_q = 0.9$). For the simple statistics used here, a canal capacity of zero would satisfy the demand for any service measure, $P_q < 90\%$. A relative frequency, P_r, was developed to adjust, P_q, for this problem. When $A_n < 1$, A_n is also the expected time a canal with $Q_n = 1$ is busy. P_r is found from the relation

$$A_n = \frac{1 - P_q}{1 - P_r} \qquad A_n < 1 \quad \text{(12)}$$

Now the time-based frequency is found relative to the expected busy time rather than total time. Suppose for example, $A_n = 0.5$ and $P_q = 80\%$. From Eq. 12, solving for P_r

$$P_r = 1 - \frac{1 - P_q}{A_n} = 1 - \frac{1 - 0.80}{0.5} = 0.60$$

Thus the computed capacity will be adequate only 60% of the time that the canal is expected to be in service.

RESULTS

The results of the simulation model for a time-based service frequency (that is, percent of time capacity not exceeded) of 80% is shown in Fig. 2 for continuous variations in capacity. Also for $P_a = 80\%$, simulation results are presented for both discrete and continuous capacities with results also shown for capacity with idle time removed ($A_n < 1$ only). For $P_a = 95\%$, continuous simulation results and Clement's first formula are shown for $A_n > 1$, and adjusted simulation results are shown for $A_n < 1$. Canal capacities for continuous flow and rotation systems are also shown. Values obtained from the simulation model with variations in applied depth and from Clement's first formula are in very close agreement over the entire range. This indicates that the assumptions used to develop this formula are reasonable even for surface irrigation. (However, there is some serious question about a time-based service frequency as a service measure.) Note that below a relative service area of approximately $A_n = 0.45$, the relative canal capacity drops below one. The canal capacities for the relative time-based frequency, P_r, are also shown in Fig. 2. This form of time-based frequency is more user oriented

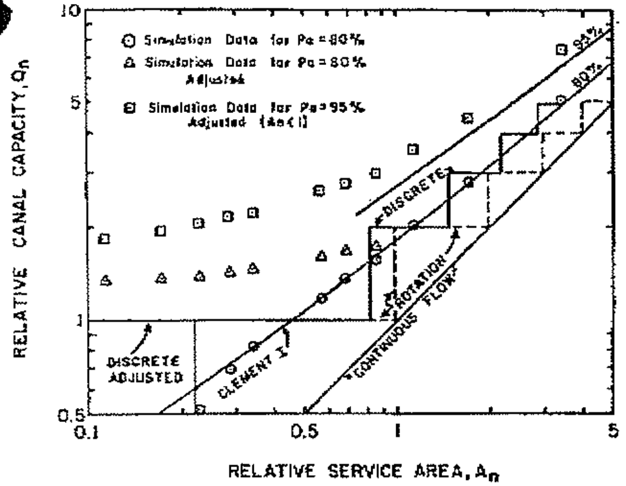

FIG. 2.—Comparison of Canal Capabilities for Time (Supply) Based Service Levels of 80 and 95% from Simulation and from Clement's First Formula (Clement I)

as shown by the increased capacity.

The simulation model results for demand with discrete variations in capacity are also shown in Fig. 2, where only the number of fields being irrigated is of concern. Note that the line for continuous variations in demand falls through the middle of the stair stepping pattern. Note also that the stair stepping pattern for demand is shifted to the left of the stair stepping pattern for a rotation system. This would indicate that canal capacities would only need to be increased over part of the distribution system. Also shown in Fig. 2 are the adjusted simulation results for $P_q = 95\%$ along with Clement's first formula over part of the range for comparison. Agreement is not as good here as it was at $P_q = 80\%$.

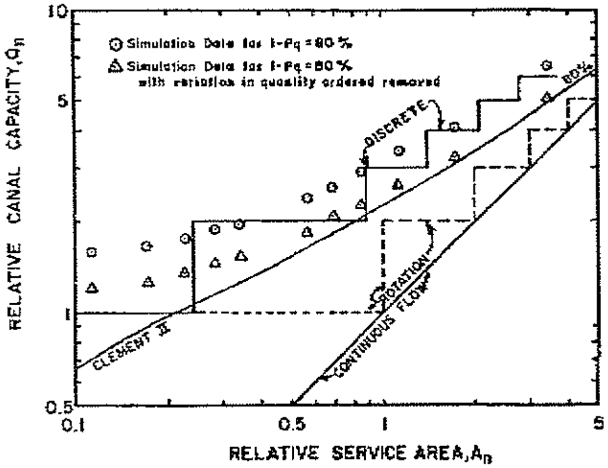

FIG. 3.—Comparison of Canal Capacities for Demand-Based Service Level of 80% from Simulation for Both Continuous and Discrete Capacities and from Clement's Second Formula (Clement II)

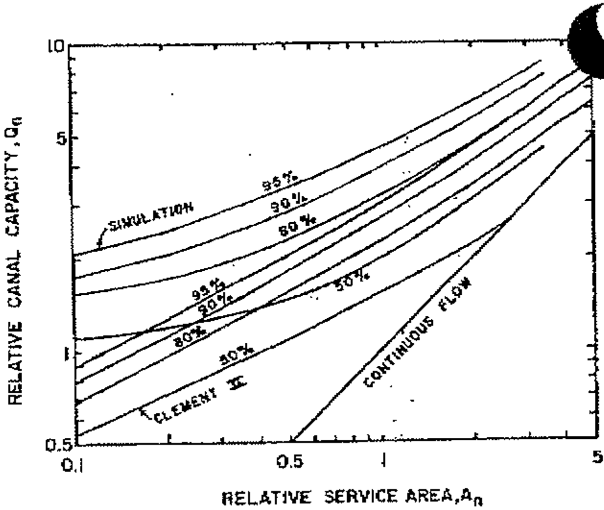

FIG. 4.—Comparison of Canal Capacities for Demand-Based Service Levels of 50, 80, 90 and 95% from Simulation and from Clement's Second Formula

The results of the simulation for a demand-based service frequency are shown in Fig. 3 along with Clement's second formula. The capacities from the simulation model at an 80% service level are significantly higher than Clement's formula. This is not too surprising since Clement's formula does not consider any variations in quantity or depth delivered to each user. The increased capacity caused by depth variations can be removed from the results if the distribution of depths is known. A cumulative probability of 80% for this distribution occurs at 147.3 mm (5.8 in.). Thus the capacity for a uniform application (and the same timing distribution) would be in direct proportion to the mean or $(113/147.3) \cdot 100 = 76.7\%$ of the simulation output. These values are plotted in Fig. 3 and show much better agreement with Clement's formula, particularly at high A_n values. The stair stepping pattern for discrete demand is to the left of Clement's formula, again indicating the effect of variations in demand quantity. Note also that capacities for Clement's formula drop below unity, while for the simulation they do not.

A comparison of the demand-based results of the simulation and Clement's formula for demand service levels of 50, 80, 90 and 95% are shown in Fig. 4. The simulation results are considerably different from Clement's second formula throughout the entire range.

ANALYSIS

Discrete versus Continuous Capacities.—It was noted earlier that all th[illegible]ion results show Q_n values greater than unity while Clement[illegible]ulas show values of Q_n less than unity. A relative canal capacity of 1 would normally be used with a rotation system. In fact, for a strict rotation system, canal capacities would be in discrete increments of the delivery rate, Q_f, or would be integer values of Q_n. Thus, rather than the straight line (i.e. $Q_n = A_n$) of a continuous flow system, a strict rotation system would have a stair stepping pattern. In this case as A_n approaches zero, Q_n approaches one. This pattern is shown in all the simulation results, even though this was not stipulated as a requirement. This makes sense since even the smallest area to which water is delivered should receive the design delivery rate. For Clement's formulas, Q_n approaches zero as A_n approaches zero. Thus, Clement's formulas are not appropriate below $A_n = 1$. However, it may be appropriate to design canals in noninteger multiples of Q_f for arranged and demand delivery systems. If the delivery flow rate is fixed by policy, then it is not appropriate. However, if flexibility in flow rate is allowed, then it makes sense since the farmers can order a flow rate which is efficient for the current conditions. In some cases it may be above Q_f, and in others it may be below Q_f.

Efficiency Considerations.—It should be emphasized that arranged and demand schedules can often result in higher farm irrigation efficiencies. This, of course, depends upon the capabilities of the farmers. Increasing flexibility can make canal operations more difficult resulting in lower conveyance efficiencies caused by the inability to uniformly distribute water. Automatic controls can greatly reduce this problem. Without automatic controls, conveyance losses due to regulation (not seepage) for nonautomated canal systems with arranged schedules are on the order of 10–15% (2). This is generally as good as water is distributed in most rotation systems. In general, the increase in efficiency on farm will offset the increase in relative canal capacity. The tendency is for larger delivery rates, larger quaternary canals, slightly larger tertiary canals and smaller main canals when comparing flexible (arranged) to rigid (rotation) schedules.

Effects of Congestion.—This analysis has ignored the fact that when congestion occurs, those waiting for service potentially can cause more congestion in later periods. Thus the actual congestion is higher. We can assume that by selecting a capacity with a simple probability of 1% congestion, increased congestion by this 1% will be negligible. However, for a capacity at a simple probability of 50%, increased congestion is certain to be significant and the actual congestion higher than 50%. This makes the true capacity required for 50% demand service higher than indicated here, thus bringing these capacity curves farther apart. The magnitude of this shift in capacity has not been evaluated here.

Arranged Schedules.—The nature of demand is influenced by specific site conditions. If capacities are based on supplying water for 24-hr periods, 7 days a week and irrigators will only work daylight hours, 5 days a week, the canals will probably not be capable of meeting the demand. More serious is the problem of controlling a canal system under this form of demand, but this is beyond the scope of this paper. Such practical considerations, however, often make arranged delivery schedules more practical for surface irrigation than demand schedules.

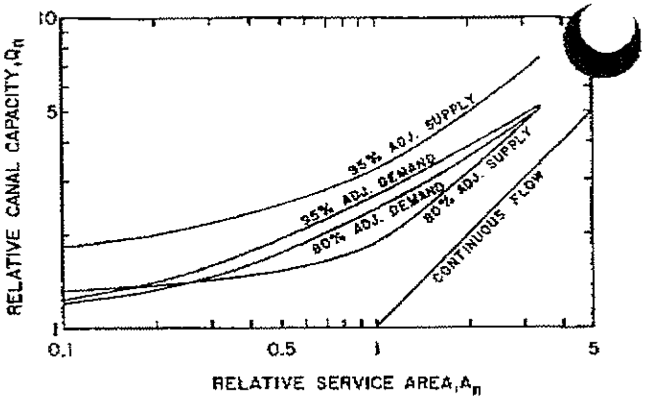

FIG. 5.—Canal Capacities for Service Levels of 80 and 95% for Supply-Based Service Levels Adjusted for Demand (ADJ SUPPLY) and for Demand-Based Service Levels Adjusted for Supply (ADJ DEMAND) from Simulation

Arranged schedules are used to reduce the capacity requirements of a demand schedule and to allow supply-oriented operation of canals. Arranged schedules are a combination of supply and demand oriented systems. Different arrangement schemes allow different types and degrees of flexibility. Earlier, the time-based service capacities were adjusted to account for canal nonuse periods, a more demand-oriented approach. Also, demand capacities were reduced by removing the fluctuations in quantities ordered, a more supply oriented approach. The results of these two approaches is shown in Fig. 5 for 80 and 95% service measures. These two approaches are in reasonably close agreement on required canal capacity, being different mixtures of supply and demand orientation. Thus it may be reasonable to use these adjusted demand capacities for arranged delivery systems.

Appropriate Service Levels.—It is difficult to judge what level of service or performance is necessary for the efficient operation of a canal system. It may be useful to compare these results with the actual capacities of existing irrigation projects with flexible delivery schedules. Fig. 6 shows data from two different canal systems: the Salt River Project (SRP) in central Arizona and the Wellton-Mohawk Irrigation and Drainage District (W-M) in southwestern Arizona. Data for SRP was taken from laterals off the Eastern Canal for 1978 acreages (2). The high relative capacities are partially due to land which has been taken out of production by urban growth. However, SRP capacities are still significantly higher than W-M capacities. SRP operates on a more flexible schedule than W-M with 1-day rather than 3-day lead times and fewer conflicts in arrangements.

However, with 3-day lead times, delivery within ±1 day can allow arrangements to reduce peak demand. This is not meant to imply that arranged schedules require long lead times. The arranged and demand curves shown represent the simulation results for 90% service level for the adjusted (with depth variations removed) and original capacities.

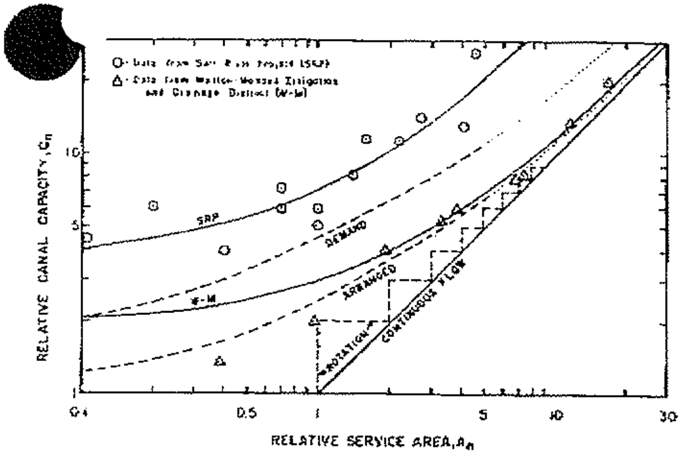

FIG. 6.—Canal Capacities from Actual Irrigation Projects Compared to Rotation, Arranged and Demand Schedules, the Latter Two at 90% Service Levels

Capacities for 80 and 95% service levels are only slightly different from that for 90%. The Wellton Mohawk Irrigation and Drainge District appears to have been designed with an equation of the form $Q = 30 + 0.01875A$ as a guide (C. W. Slocum, personal communication, Jan., 1980). When translated to the notation used here, with Q_d = 425 L/s (15 cu ft/sec), W_n = 11.33 mm/day (0.446 in./day), and A_t = 324 ha (800 acres) this equation becomes $Q_n = A_n + 2$. This equation is shown in Fig. 6 along with some actual capacities for canals in the project. It appears that the equation was used only for the larger canals (say ($A_n > 1.5$) and probably rightfully so since the equation gave increasingly better service for very small A_n. It appears that actual capacities for small service areas may have been a little low, or at least representing lower service capabilities than the larger canals. Capacity problems have arisen for canals with small service areas. Even so, this project operates very efficiently on an arranged schedule with flexibility in rate, frequency and duration.

From Fig. 4, the capacities required for a 90% service level are about 10–20% lower than those for a 95% service level and about 10–20% higher than those for an 80% service level for the demand simulation. From Fig. 5, the variation in adjusted demand capacity, as recommended for arranged capacities, from 80–95% is only about 10%. For many design situations, the differences are not significant. And judging from the performance of the two irrigation projects discussed here, a 90% service level is sufficient for canal capacity determination, particularly for the arranged systems.

Recommended Capacity Equations.—Many of the conditions represented by this simulation may be slightly unrealistic in that they do not represent an actual location. However, they may be viewed as a worst case situation since the variations in conditions were more than usual. On the other hand, farmer timing of irrigations would likely vary from that assumed here and more overlap could occur. Thus, for any given situation where a pure-demand system is desired, (that is, no limitations

on rate, frequency and duration), the results presented here m[illegible] be appropriate.

However, all future possibilities are generally not known at the time of design, such that more site specific simulations may not be justified. It is not known how demand patterns vary for conditions significantly different from those assumed for this simulation. It is not expected that they would vary greatly from those developed here. The major exception to this would be situations where early season irrigations require higher capacities than the period of peak ET use.

With these limitations in mind, the following curves shown in Fig. 7 are recommended for the determination of canal capacities for arranged and demand delivery schedules (based on 90% service levels). For the arranged schedules this curve can be approximated by

$$Q_n = 1.6\,A_n + 1 \quad \text{for} \quad A_n \le 1 \qquad (13a)$$

$$Q_n = A_n + 1.6 \quad \text{for} \quad A_n \ge 1 \qquad (13b)$$

Note that this is very similar in form to the W-M equation, at least for

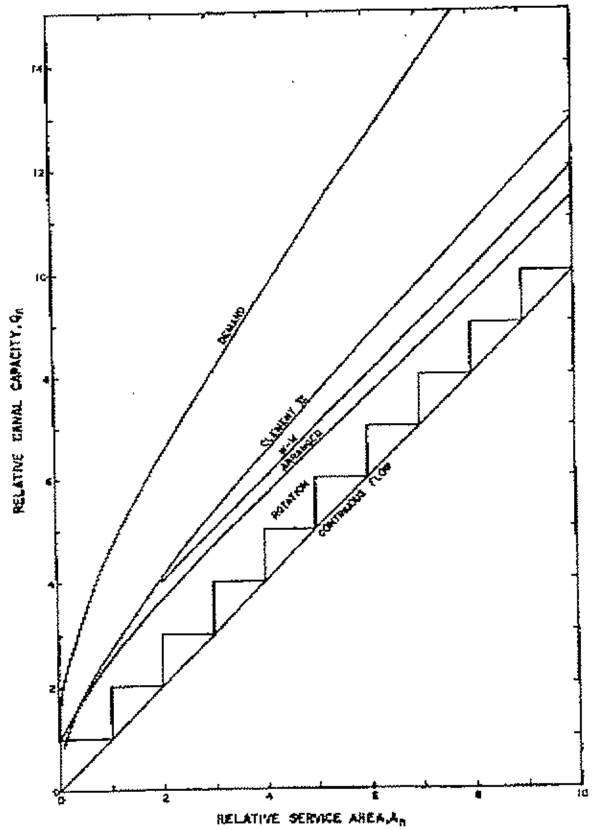

FIG. 7.—Canal Capacity Design Relations

$A_n >$ [illegible] emand curve can be approximated by

$$Q_n = 4 \ldots + 1 \quad \text{for} \quad A_n \le 1 \qquad (14a)$$

$$Q_n = 1.5\,A_n + 3.5 \quad \text{for} \quad A_n \ge 1 \qquad (14b)$$

which is also of a similar form.

Several other canal capacity relations are also shown in Fig. 7 for comparison. Note that the arranged schedule requires only a small increase in canal capacities over the rotation and continuous flow schedules. These differences may easily be overcome by increases in efficiency for most lateral and main canals. A demand system, however, requires considerably greater capacities being 2–3 times (for $A_n > 2$) greater than that required for continuous flow. It is doubtful that the flexibility offered alone could improve efficiencies that much. Thus arranged systems can be justified by reductions in system costs and improved operations, while expanding canals to handle demand may not be easily justified. Farm reservoirs provide an attractive alternative when demand operation is required.

Also shown in Fig. 7 are the design curve for W-M and the results of Clement's second formula (Clement II) for $P_a = 0.10$ and $F = 1/16.3$. Note that Clement II falls between the demand and arranged schedules. Clement II is only useful for arranged schedules at this service level from $0.2 < A_n < 2$, with values 10–15% higher than the arranged curve for $A_n > 2$. The W-M design curve is relatively good for $A_n > 2$. For $A_n < 2$ it gives overly conservative results.

CONCLUSIONS

The modified CREAMS simulation model did a reasonably good job of developing demand patterns for surface irrigation. These demand patterns would likely vary for different crop mixes, climatic areas and seasons. However, the resulting canal capacity relations developed should still be reasonable for slightly different conditions.

Clement's two equations for canal capacity are clearly not appropriate for demand under surface irrigation. As stated by Clement, the development of these equations is appropriate only for $A_n > 5$. The results are particularly bad for $A_n < 1$ since Q_n is allowed to go below 1. These results fall closer to the arranged capacities developed.

The capacity relationships developed for arranged delivery systems appear to be reasonable. However, the exact type of restrictions on an arranged system may cause differences in required capabilities. This point has not been adequately studied. In some sense, these arranged capacities are speculative.

The approximate equations developed for demand and arranged canal capacities at a 90% service level are simple to use. The selection of this service level has a minor effect on arranged capacities, but can have a significant effect on demand capacities. Also, the wide range of conditions used in simulation may have produced demand capacities higher than necessary. The arranged capacities should not be affected.

Finally, these relations do not consider the additional congestion caused by restricting capacity. At very high service levels (e.g., 99% [illegible] is not a significant problem. The service level at which this produ[illegible] significant impact is not known.

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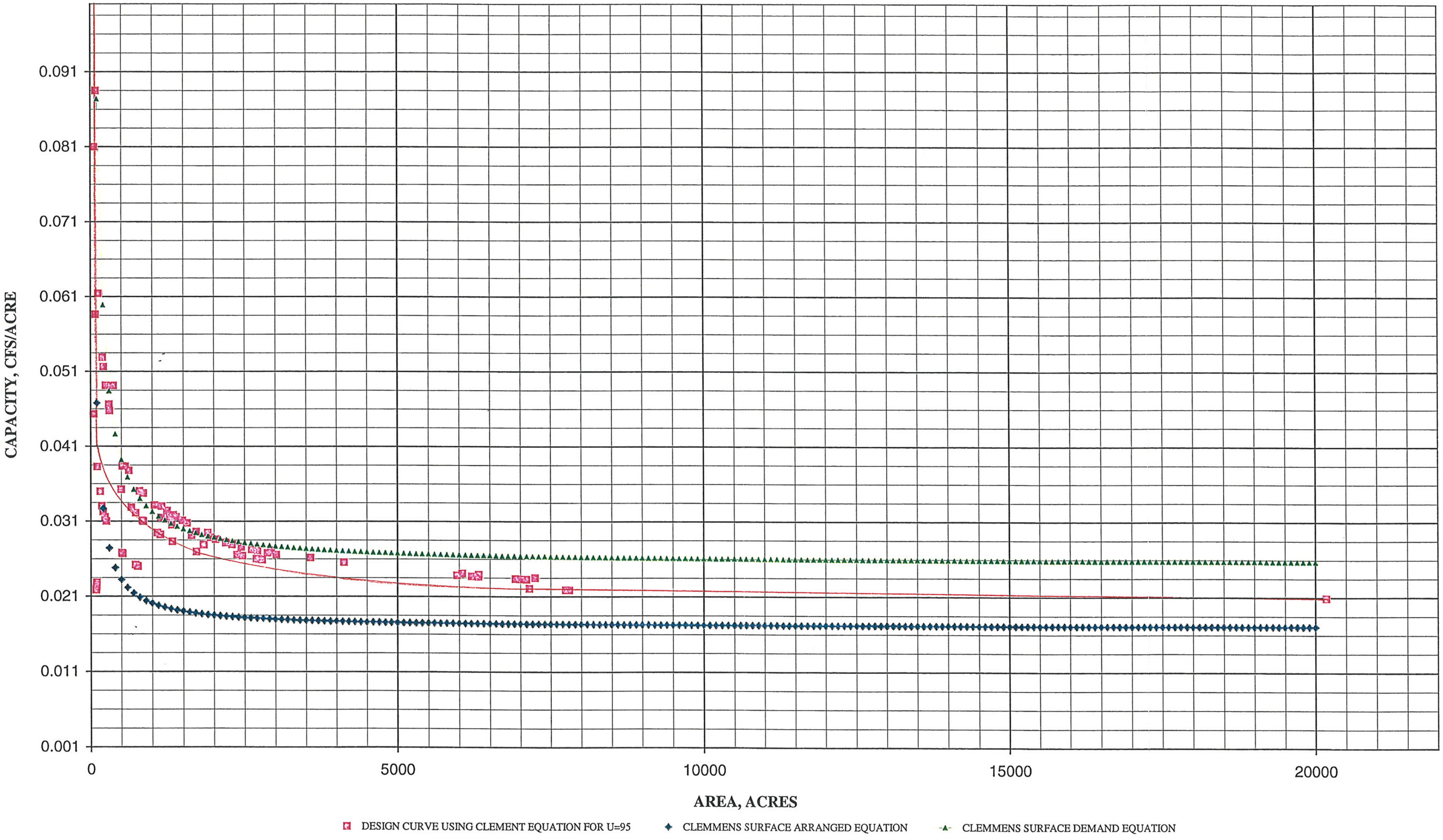
CONJUNCTIVE WATER USE FEASIBILITY STUDY

WEST ADAMS CANAL – DESIGN CAPACITY
COMPARISON OF CLEMENT AND CLEMMENS EQUATIONS



NOTE: CURVES DO NOT ACCOUNT FOR SEEPAGE LOSSES

FIGURE 8

ATTACHMENT 7

WEST ADAMS CANAL
SUMMARY OF DESIGN CAPACITIES

A (ACRES) W/ TRIBUTARIES	BRANCH	US BRANCH	TIE-IN STA	R (CFS/ACRE) CLMNT&CLEMNS	A' (Acres) CLMNT	q (CFS) CLEMNS	q_t (CFS) CLMNT	m CLEMENT	n	(1/m)-(1/n)	BRANCH LENGTH	D/S MILES	D/S SEEPAGE LOSS (CFS)	CLEMMENS ARRANGED				CLEMMENS DEMAND			CEMENT Q (CFS) W/O SEEPAGE			CLEMENT Q (CFS), WITH SEEPAGE			Q (CFS/ACRE) W/O SEEPAGE			Q (CFS/ACRE) W/ SEEPAGE		
														An	Qn	Q	Q/A	Qn	Q	Q/A	U=90	U=95	U=99	U=90	U=95	U=99	U=90	U=95	U=99	U=90	U=95	U=99
84	Hayes (at Head)	Clover	2.81	0.017	28.00	3.60	1.99	0.40	3.00	2.165	1.00	1.00	0.610	0.724	2.16	4.90	0.058	3.90	8.36	0.100	4.16	4.93	6.36	4.77	5.54	6.97	0.049	0.059	0.076	0.0567	0.0659	0.0830
162	Reiff (at Head)	Clover	0.64	0.017	54.00	2.04	1.99	1.36	3.00	0.400	1.20	1.20	0.732	1.397	3.00	6.69	0.041	5.59	11.86	0.073	5.03	5.67	6.86	5.76	6.40	7.59	0.031	0.035	0.042	0.0356	0.0395	0.0469
208	Acacia (at Head)	East Adams	1.68	0.017	52.00	1.92	1.99	1.86	4.00	0.288	0.84	0.84	0.512	1.793	3.39	7.26	0.035	6.19	12.82	0.062	6.02	6.71	8.01	6.53	7.22	8.52	0.029	0.032	0.039	0.0314	0.0347	0.0410
188	STA 070			0.017	52.00	1.92	1.99	1.68	3.62	0.318	0.84	0.14	0.085	1.621	3.22	6.49	0.035	5.93	11.88	0.063	5.55	6.21	7.45	5.64	6.30	7.53	0.030	0.033	0.040	0.0300	0.0335	0.0401
60	STA 084			0.017	52.00	1.92	1.99	0.54	1.15	0.998	0.84	0.00	0.000	0.517	1.83	3.63	0.061	3.07	6.10	0.102	2.35	2.72	3.42	2.35	2.72	3.42	0.039	0.045	0.057	0.0391	0.0453	0.0569
251	Ross (At Head)	Moore	7.58	0.017	62.75	6.61	1.99	0.65	4.00	1.286	1.71	1.71	1.043	2.164	3.76	8.53	0.034	6.75	14.46	0.058	10.56	12.33	15.64	11.60	13.37	16.69	0.042	0.049	0.062	0.0462	0.0533	0.0665
201	STA 040			0.017	62.75	6.61	1.99	0.52	3.20	1.606	1.71	1.31	0.799	1.733	3.33	7.43	0.037	6.10	12.93	0.064	9.04	10.63	13.60	9.84	11.43	14.39	0.045	0.053	0.068	0.0490	0.0569	0.0716
131	STA 086			0.017	62.75	6.61	1.99	0.34	2.09	2.465	1.71	0.85	0.519	1.129	2.73	5.95	0.045	5.19	10.85	0.083	6.77	8.05	10.44	7.28	8.56	10.96	0.052	0.061	0.080	0.0556	0.0654	0.0836
63	STA 099			0.017	62.75	6.61	1.99	0.16	1.00	5.125	1.71	0.72	0.439	0.543	1.87	4.16	0.066	3.17	6.75	0.107	4.21	5.10	6.76	4.65	5.54	7.20	0.067	0.081	0.107	0.0739	0.0880	0.1143
1	STA 146			0.017	62.75	6.61	1.99	0.00	0.02	322.877	1.71	0.25	0.153	0.009	1.01	2.17	2.169	1.03	2.21	2.210	0.41	0.52	0.73	0.56	0.68	0.89	0.412	0.524	0.733	0.5645	0.6764	0.8855
260	Magnolia (at Head)	Moore	2.71	0.017	52.00	1.97	1.99	2.26	5.00	0.242	1.54	1.54	0.939	2.241	3.84	8.58	0.033	6.86	14.59	0.056	7.27	8.06	9.55	8.21	9.00	10.49	0.028	0.031	0.037	0.0316	0.0346	0.0403
240	STA 067			0.017	52.00	1.97	1.99	2.09	4.62	0.262	1.54	0.87	0.531	2.069	3.67	7.83	0.033	6.60	13.66	0.057	6.81	7.58	9.01	7.34	8.11	9.54	0.028	0.032	0.038	0.0306	0.0338	0.0397
112	STA 100			0.017	52.00	1.97	1.99	0.98	2.15	0.561	1.54	0.54	0.329	0.966	2.54	5.39	0.048	4.86	10.00	0.089	3.76	4.29	5.26	4.09	4.61	5.59	0.034	0.038	0.047	0.0365	0.0412	0.0499
1	STA 129			0.017	52.00	1.97	1.99	0.01	0.02	62.820	1.54	0.25	0.153	0.009	1.01	2.17	2.169	1.03	2.21	2.210	0.19	0.24	0.33	0.34	0.39	0.49	0.191	0.241	0.333	0.3438	0.3932	0.4854
90	Rogers (at Head)	Magnolia	1.29	0.017	45.00	10.64	1.99	0.14	2.00	6.399			0.000	0.776	2.24	4.46	0.050	4.10	8.16	0.091	6.55	7.96	10.61	6.55	7.96	10.61	0.073	0.088	0.118	0.0727	0.0885	0.1179
376	Farmers Central (At Head)			0.017	125.33	10.44	1.99	0.62	3.00	1.287			0.000	3.241	4.84	9.63	0.026	8.36	16.63	0.044	15.82	18.47	23.44	15.82	18.47	23.44	0.042	0.049	0.062	0.0421	0.0491	0.0623
376	STA 100			0.017	125.33	10.44	1.99	0.62	3.00	1.287			0.000	3.241	4.84	9.63	0.026	8.36	16.63	0.044	15.82	18.47	23.44	15.82	18.47	23.44	0.042	0.049	0.062	0.0421	0.0491	0.0623
776	Clover (at Head)	Hungry Hollow	9	0.017	74.63	2.31	1.99	5.75	10.40	0.078	6.01	8.21	5.008	6.690	8.29	21.49	0.028	13.53	31.92	0.041	18.06	19.40	21.92	23.06	24.41	26.93	0.023	0.025	0.028	0.0297	0.0315	0.0347
736	STA 065			0.017	74.63	2.31	1.99	5.46	9.86	0.082	6.01	8.05	4.911	6.345	7.94	20.71	0.028	13.02	30.80	0.042	17.25	18.56	21.01	22.16	23.47	25.92	0.023	0.025	0.029	0.0301	0.0319	0.0352
767	STA 226			0.017	74.63	2.31	1.99	5.68	10.27	0.079	6.01	7.69	4.691	6.609	8.21	21.01	0.027	13.41	31.36	0.041	17.87	19.20	21.71	22.56	23.89	26.40	0.023	0.025	0.028	0.0294	0.0312	0.0344
516	STA 281			0.017	74.63	2.31	1.99	3.82	6.91	0.117	6.01	7.69	4.691	4.448	6.05	16.72	0.032	10.17	24.92	0.048	12.72	13.82	15.87	17.41	18.51	20.56	0.025	0.027	0.031	0.0337	0.0359	0.0398
527	Mast (at Head)	Hungry Hollow	4.38	0.017	74.63	2.31	1.99	3.91	7.06	0.114	0.11	0.11	0.067	4.542	6.14	12.28	0.023	10.31	20.58	0.039	12.95	14.06	16.13	13.02	14.13	16.20	0.025	0.027	0.031	0.0247	0.0268	0.0307
801	East Adams (at Head)	West Adams	13.02	0.017	62.28	6.58	1.99	2.09	12.86	0.402	2.40	3.24	1.976	6.905	8.51	18.89	0.024	13.86	29.53	0.037	24.89	28.05	33.96	26.87	30.03	35.93	0.031	0.035	0.042	0.0335	0.0375	0.0449
800	STA 028			0.017	62.28	6.58	1.99	2.08	12.84	0.402	2.40	2.96	1.806	6.897	8.50	18.70	0.023	13.84	29.34	0.037	24.87	28.02	33.93	26.67	29.83	35.73	0.031	0.035	0.042	0.0333	0.0373	0.0447
570	STA 102			0.017	62.28	6.58	1.99	1.48	9.15	0.565	2.40	2.22	1.354	4.914	6.51	14.31	0.025	10.87	22.97	0.040	19.18	21.85	26.83	20.54	23.20	28.19	0.034	0.038	0.047	0.0360	0.0407	0.0495
313	STA 152			0.017	62.28	6.58	1.99	0.81	5.03	1.028	2.40	1.72	1.049	2.698	4.30	9.60	0.031	7.55	16.06	0.051	12.34	14.32	18.01	13.39	15.36	19.06	0.039	0.046	0.058	0.0428	0.0491	0.0609
215	STA 227			0.017	62.28	6.58	1.99	0.56	3.45	1.497	2.40	0.13	0.079	1.853	3.45	6.95	0.032	6.28	12.57	0.058	9.47	11.10	14.17	9.55	11.18	14.24	0.044	0.052	0.066	0.0444	0.0520	0.0663
1642	Goodnow (at Head)	Hungry Hollow	3.42	0.017	182.49	8.20	1.99	3.43	9.00	0.180	1.22	1.22	0.744	14.159	15.76	32.08	0.020	24.74	49.94	0.030	43.48	47.82	55.94	44.22	48.56	56.68	0.026	0.029	0.034	0.0269	0.0296	0.0345
1322	STA 013			0.017	182.49	8.20	1.99	2.76	7.25	0.224	1.22	1.22	0.744	11.400	13.00	26.60	0.020	20.60	41.71	0.032	36.42	40.31	47.60	37.16	41.06	48.34	0.028	0.030	0.036	0.0281	0.0310	0.0366
1146	STA 068			0.017	182.49	8.20	1.99	2.40	6.28	0.258	1.22	1.22	0.744	9.883	11.48	23.58	0.021	18.32	37.18	0.032	32.46	36.08	42.86	33.20	36.83	43.61	0.028	0.031	0.037	0.0290	0.0321	0.0380
524	STA 117			0.017	182.49	8.20	1.99	1.09	2.87	0.565	1.22	1.22	0.744	4.515	6.11	12.90	0.025	10.27	21.17	0.040	17.63	20.08	24.66	18.38	20.83	25.41	0.034	0.038	0.047	0.0351	0.0398	0.0485
1721	South Fork (at Head)	Maple	3.79	0.017	86.03	5.04	1.99	5.85	20.00	0.121	2.81	2.81	1.714	14.832	16.43	34.39	0.020	25.75	52.92	0.031	42.64	46.36	53.32	44.35	48.08	55.04	0.025	0.027	0.031	0.0258	0.0279	0.0320
1721	STA 379			0.017	86.03	5.04	1.99	5.85	20.00	0.121	2.81	2.81	1.714	14.832	16.43	34.39	0.020	25.75	52.92	0.031	42.64	46.36	53.32	44.35	48.08	55.04	0.025	0.027	0.031	0.0258	0.0279	0.0320
1721	STA 401			0.017	86.03	5.04	1.99	5.85	20.00	0.121	2.81	2.59	1.580	14.832	16.43	34.26	0.020	25.75	52.78	0.031	42.64	46.36	53.32	44.22	47.94	54.90	0.025	0.027	0.031	0.0257	0.0279	0.0319
1332	STA 429			0.017	86.03	5.04	1.99	4.53	15.48	0.156	2.81	2.30	1.404	11.478	13.08	27.41	0.021	20.72	42.60	0.032	34.39	37.66	43.79	35.79	39.07	45.19	0.026	0.028	0.033	0.0269	0.0293	0.0339
1135	STA 494			0.017	86.03	5.04	1.99	3.86	13.19	0.183	2.81	1.66	1.013	9.780	11.38	23.64	0.021	18.17	37.15	0.033	30.12	33.15	38.80	31.14	34.16	39.81	0.027	0.029	0.034	0.0274	0.0301	0.0351
1086	STA 520			0.017	86.03	5.04	1.99	3.69	12.62	0.192	2.81	1.40	0.854	9.360	10.96	22.65	0.021	17.54	35.73	0.033	29.06	32.01	37.54	29.91	32.87	38.40	0.027	0.029	0.035	0.0275	0.0303	0.0354
862	STA 555			0.017	86.03	5.04	1.99	2.93	10.02	0.241	2.81	1.05	0.641	7.429	9.03	18.60	0.022	14.64	29.76	0.035	24.08	26.71	31.64	24.72	27.35	32.28	0.028	0.031	0.037	0.0287	0.0317	0.0375
848	STA 563			0.017	86.03	5.04	1.99	2.88	9.85	0.245	2.81	0.97	0.592	7.308	8.91	18.31	0.022	14.46	29.35	0.035	23.76	26.37	31.26	24.35	26.96	31.85	0.028	0.031	0.037	0.0287	0.0318	0.0376
739	STA 577			0.017	86.03	5.04	1.99	2.51	8.59	0.281	2.81	0.83	0.506	6.369	7.97	16.35	0.022	13.05	26.46	0.036	21.28	23.72	28.28	21.78	24.22	28.79	0.029	0.032	0.038	0.0295	0.0328	0.0390
670	STA 583			0.017	86.03	5.04	1.99	2.28	7.79	0.310	2.81	0.77	0.470	5.776	7.38	15.14	0.023	12.16	24.66	0.037	19.69	22.01	26.36	20.16	22.48	26.83	0.029	0.033	0.039	0.0301	0.0336	0.0400
504	STA 594			0.017	86.03	5.04	1.99	1.71	5.86	0.413	2.81	0.66	0.403	4.345	5.94	12.22	0.024	10.02	20.32	0.040	15.75	17.77	21.54	16.16	18.17	21.94	0.031	0.035	0.043	0.0321	0.0361	0.0435
504	STA 624			0.017	86.03	5.04	1.99	1.71	5.86	0.413	2.81	0.36	0.220	4.345	5.94	12.04	0.024	10.02	20.14	0.040	15.75	17.77	21.54	15.97	17.99	21.76	0.031	0.035	0.043	0.0317	0.0357	0.0432
504	STA 644			0.017	86.03	5.04	1.99	1.71	5.86	0.413	2.81	0.16	0.098	4.345	5.94	11.92	0.024	10.02	20.02	0.040	15.75	17.77	21.54	15.85	17.87	21.64	0.031	0.035	0.043	0.0315	0.0355	0.0429
2792	Maple (at Head)	Moore	4	0.017	71.70	5.78	1.99	8.28	38.94	0.095	3.79	6.60	4.026	24.066	25.67	55.06	0.020	39.60	82.77	0.030	66.78	72.13	82.15	70.80	76.16	86.18	0.024	0.026	0.029	0.0254	0.0273	0.0309
2738	STA 056			0.017	71.70	5.78	1.99	8.12	38.18	0.097	3.79	6.04	3.684	23.600	25.20	53.80	0.020	38.90	81.04	0.030	65.67	70.97	80.89	69.35	74.65	84.58	0.024	0.026	0.030	0.0253	0.0273	0.0309
2698	STA 074			0.017	71.70	5.78	1.99	8.00	37.62	0.098	3.79	5.86	3.575	23.256	24.86	53.00	0.020	38.38	79.90	0.030	64.84	70.11	79.96	68.42	73.68	83.53	0.024	0.026	0.030	0.0254	0.0273	0.0310
2469	STA 108			0.017	71.70	5.78	1.99	7.32	34.43	0.108	3.79	5.52	3.367	21.281	22.88	48.87	0.020	35.42	73.81	0.030	60.11	65.15	74.57	63.48	68.51	77.94	0.024	0.026	0.030	0.0257	0.0278	0.0316
2385	STA 139			0.017	71.70	5.78	1.99	7.07	33.26	0.111	3.79	5.21	3.178	20.557	22.16	47.24	0.020	34.34	71.46	0.030	58.36	63.32	72.58	61.54	66.49	75.75	0.024	0.027	0.030	0.0258	0.0279	0.0318
1843	STA 209			0.017	71.70	5.78	1.99	5.47	25.70	0.144	3.79	4.51	2.751	15.884	17.48	37.52	0.020	27.33	57.09	0.031	46.96	51.31	59.45	49.71	54.06	62.20	0.025	0.028	0.032	0.0270	0.0293	0.0338
1833	STA 242			0.017	71.70	5.78	1.99	5.44	25.56	0.145	3.79	4.18	2.550	15.797	17.40	37.15	0.020	27.20	56.63	0.031	46.74	51.08	59.20	49.29	53.63	61.75	0.026	0.028	0.032	0.0269	0.0293	0.0337
7105	Moore (at Head)	Alder	0.81	0.017	79.48	7.11	1.99	17.14	89.39	0.047	10.00	18.14	11.065	61.247	62.85	136.04	0.019	95.37	200.72	0.028	155.70	165.31	183.27	166.77	176.37	194.33	0.022	0.023	0.026	0.0235	0.0248	0.0274
6994	STA 026			0.017	79.48	7.11	1.99	16.87	87.99	0.048	10.00	17.88	10.907	60.290	61.89	133.98	0.019	93.94	197.70	0.028	153.54	163.06	180.88	164.44	173.97	191.79	0.022	0.023	0.026	0.0235	0.0249	0.0274
6926	STA 187			0.017	79.48	7.11	1.99	16.70	87.14	0.048	10.00	16.27	9.925	59.704	61.30	131.83	0.019	93.06	194.97	0.028	152.21	161.69	179.42	162.13	171.61	189.34	0.022	0.023	0.026	0.0234	0.0248	0.0273
6319	STA 271			0.017	79.48	7.11	1.99	15.24	79.50	0.053	10.00	13.89	8.473	54.471	56.07	119.97	0.019	85.21	177.91	0.028	140.30	149.35	166.29	148.77	157.83	174.77	0.022	0.024	0.026	0.0235	0.0250	0.0277
6212	STA 320			0.017	79.48	7.11	1.99	14.98	78.15	0.054	10.00	13.40	8.174	53.549	55.15	117.84	0.019	83.82	174.86	0.028	138.19	147.17	163.97	146.37	155.35	172.14	0.022	0.024	0.026	0.0236	0.0250	0.0277
5972	STA 368			0.017	79.48	7.11	1.99	14.40	75.13	0.056	10.00	12.92	7.881	51.480	53.08	113.43	0.019	80.72	168.40	0.028	133.46	142.26	158.73	141.34	150.14	166.61	0.022	0.024	0.027	0.0237	0.0251	0.0279
3019	STA 403			0.017	79.48	7.11	1.99	7.28	37.98	0.111	10.00	5.97	3.642	26.024	27.62	58.57	0.019	42.54	88.23	0.029	73.85	80.11	91.82	77.50	83.76	95.46	0.024	0.027	0.030	0.0257	0.0277	0.0316
2877	STA 438			0.017	79.48	7.11	1.99	6.94	36.20	0.116	10.00	5.62	3.428	24.800	26.40	55.93	0.019	40.70	84.36	0.029	70.89	77.00	88.43	74.32	80.43	91.86	0.025	0.027	0.031	0.0258	0.0280	0.0319
2717	STA 473			0.017	79.48	7.11	1.99	6.55	34.18	0.123	10.00	5.27	3.215	23.420	25.02	52.97	0.019	38.63	80.03	0.029	67.54	73.48	84.59	70.76	76.69	87.80	0.025	0.027	0.031	0.0260	0.0282	0.0323
2622	STA 498			0.017	79.48	7.11	1.99	6.32	32.99	0.128	10.00	5.02	3.062	22.601	24.20	51.19	0.020	37.40	77.44	0.030	65.54	71.38	82.29	68.61	74.44	85.35	0.025	0.027	0.031	0.0262	0.0284	0.0326
2452	STA 526			0.017	79.48	7.11	1.99	5.91	30.85	0.137	10.00	4.74	2.891	21.136	22.74	48.10	0.020	35.20	72.90	0.030	61.95	67.59	78.14	64.84	70.48	81.03	0.025	0.028	0.032	0.0264	0.0287	0.0331
2302	STA 552			0.017	79.48	7.11	1.99	5.55	28.96	0.146	10.00	4.48	2.733	19.843	21.44	45.37	0.020	33.26	68.88	0.030	58.76	64.23	74.45	61.49	66.96	77.18	0.026	0.028	0.032	0.0267	0.0291	0.0335
2198	STA 584			0.017	79.48	7.11	1.99	5.30	27.65	0.152	10.00	4.16	2.538	18.946	20.55	43.40	0.020	31.92	66.01	0.030	56.54	61.88	71.87	59.07	64.41	74.40	0.026	0.028	0.033	0.0269	0.0293	0.0339
2035	STA 640			0.017	79.48	7.11	1.99	4.91	25.60	0.165	10.00	3.60	2.196	17.541	19.14	40.26	0.020	29.81	61.48	0.030	53.03	58.17	67.78	55.23	60.36	69.98	0.026	0.029	0.033	0.0271	0.0297	0.0344
1955	STA 666			0.017	79.48	7.11	1.99	4.71	24.59	0.171	10.00	3.34	2.037	16.851	18.45	38.73	0.020	28.78	59.26	0.030	51.30	56.33	65.75	53.33	58.37	67.79	0.026	0.029	0.034	0.0273	0.0299	0.0347
1715	STA 682			0.017	79.48	7.11	1.99	4.14	21.57	0.195	10.00	3.18	1.940	14.782	16.38	34.52	0.020	25.67	52.99	0.031	46.06	50.77	59.60	48.00	52.71	61.54	0.027	0.030	0.035	0.0280	0.0307	0.0359
1287	STA 760			0.017	79.48	7.11	1.99	3.10	16.20	0.260	10.00	2.40	1.464	11.097	12.70	26.71	0.021	20.15	41.52	0.032	36.50	40.59	48.23	37.97	42.05	49.70	0.028	0.032	0.037	0.0295	0.0327	0.0386
1042	STA 822			0.017	79.48	7.11	1.99	2.51	13.11	0.322	10.00	1.78	1.086	8.985	10.58	22.13	0.021	16.98	34.85	0.033	30.86	34.53	41.41	31.94	35.62	42.50	0.030	0.033	0.040	0.0306	0.0342	0.0408
860	STA 846			0.017	79.48	7.11	1.99	2.07	10.82	0.390	10.00	1.54	0.939	7.416	9.02	18.87	0.022	14.62	30.02	0.035	26.55	29.89	36.14	27.49	30.83	37.08	0.031	0.035	0.042	0.0320	0.0358	0.0431
628	STA 907			0.017	79.48	7.11	1.99	1.51	7.90	0.534	10.00	0.93	0.567	5.409	7.01	14.51	0.023	11.61	23.66	0.038	20.84	23.69	29.03	21.40	24.26	29.59	0.033	0.038	0.046	0.0341	0.0387	0.0472
307	STA 922			0.017	79.48	7.11	1.99	0.74	3.86	1.093	10.00	0.78	0.476	2.642	4.24	8.91	0.029	7.46	15.32	0.050	12.30	14.29	18.02	12.77	14.77	18.50	0.040	0.047	0.059	0.0417	0.0482	0.0604
1	STA 957			0.017	79.48	7.11	1.99	0.00	0.01	335.111	10.00	0.43	0.262	0.009	1.01	2.28	2.278	1.03	2.32	2.319	0.42	0.53	0.75	0.68	0.80	1.01	0.419	0.533	0.746	0.6818	0.7957	1.0088
7246	Hungry Hollow (at Head	West Adams	1.69	0.017	147.21	8.78	1.99	14.15	49.22	0.05	9.00	18.54	11.309	62.464	64.06	138.71	0.019	97.20	204.59	0.028	159.94	170.06	188.98	171.25	181.37	200.29	0.022	0.023	0.026	0.0236	0.0250	0.0276

WEST ADAMS CANAL
SUMMARY OF DESIGN CAPACITIES

A (ACRES) W/ TRIBUTARIES	BRANCH	US BRANCH	TIE-IN STA	R (CFS/ACRE) CLMNT&CLEMNS	A' (Acres) CLMNT	q (CFS) CLEMNS	q_l (CFS) CLMNT	m CLEMENT	n	(1/m)-(1/n)	BRANCH LENGTH	D/S MILES	D/S SEEPAGE LOSS (CFS)	CLEMMENS ARRANGED				CLEMMENS DEMAND			CEMENT Q (CFS) W/O SEEPAGE			CLEMENT Q (CFS), WITH SEEPAGE			Q (CFS/ACRE) W/O SEEPAGE			Q (CFS/ACRE) W/ SEEPAGE		
														An	Qn	Q	Q/A	Qn	Q	Q/A	U=90	U=95	U=99	U=90	U=95	U=99	U=90	U=95	U=99	U=90	U=95	U=99
6325	STA 168			0.017	147.21	8.78	1.99	12.36	42.97	0.06	9.00	15.91	9.705	54.525	56.13	121.31	0.019	85.29	179.31	0.028	141.81	151.26	168.94	151.51	160.96	178.64	0.022	0.024	0.027	0.0240	0.0254	0.0282
6058	STA 263			0.017	147.21	8.78	1.99	11.83	41.15	0.06	9.00	15.05	9.181	52.224	53.82	116.21	0.019	81.84	171.92	0.028	136.52	145.77	163.07	145.70	154.95	172.25	0.023	0.024	0.027	0.0241	0.0256	0.0284
4130	STA 349			0.017	147.21	8.78	1.99	8.07	28.05	0.09	9.00	13.83	8.436	35.600	37.20	82.41	0.020	56.90	121.58	0.029	97.76	105.40	119.69	106.20	113.84	128.12	0.024	0.026	0.029	0.0257	0.0276	0.0310
3580	STA 391			0.017	147.21	8.78	1.99	6.99	24.32	0.10	9.00	13.41	8.180	30.863	32.46	72.73	0.020	49.79	107.20	0.030	86.48	93.60	106.90	94.66	101.78	115.08	0.024	0.026	0.030	0.0264	0.0284	0.0321
2936	STA 438			0.017	147.21	8.78	1.99	5.74	19.95	0.12	9.00	12.94	7.893	25.314	26.91	61.41	0.021	41.47	90.36	0.031	73.08	79.52	91.57	80.98	87.42	99.46	0.025	0.027	0.031	0.0276	0.0298	0.0339
1906	STA 500			0.017	147.21	8.78	1.99	3.72	12.95	0.19	9.00	12.21	7.448	16.433	18.03	43.31	0.023	28.15	63.43	0.033	51.00	56.19	65.90	58.45	63.64	73.34	0.027	0.029	0.035	0.0307	0.0334	0.0385
1566	STA 516			0.017	147.21	8.78	1.99	3.06	10.64	0.23	9.00	12.05	7.351	13.502	15.10	37.38	0.024	23.75	54.58	0.035	43.46	48.16	56.96	50.81	55.51	64.31	0.028	0.031	0.036	0.0324	0.0354	0.0411
1492	STA 523			0.017	147.21	8.78	1.99	2.91	10.13	0.24	9.00	11.98	7.308	12.859	14.46	36.06	0.024	22.79	52.62	0.035	41.78	46.37	54.96	49.09	53.68	62.26	0.028	0.031	0.037	0.0329	0.0360	0.0417
1388	STA 600			0.017	147.21	8.78	1.99	2.71	9.43	0.26	9.00	11.21	6.838	11.967	13.57	33.82	0.024	21.45	49.49	0.036	39.43	43.86	52.14	46.27	50.70	58.98	0.028	0.032	0.038	0.0333	0.0365	0.0425
1340	STA 750			0.017	147.21	8.78	1.99	2.62	9.10	0.27	9.00	9.71	5.923	11.552	13.15	32.08	0.024	20.83	47.34	0.035	38.34	42.69	50.82	44.26	48.61	56.75	0.029	0.032	0.038	0.0330	0.0363	0.0423
1244	STA 800			0.017	147.21	8.78	1.99	2.43	8.45	0.29	9.00	9.21	5.618	10.722	12.32	30.12	0.024	19.58	44.56	0.036	36.12	40.31	48.15	41.74	45.93	53.77	0.029	0.032	0.039	0.0336	0.0369	0.0432
1155	STA 815			0.017	147.21	8.78	1.99	2.26	7.84	0.32	9.00	9.06	5.527	9.955	11.55	28.50	0.025	18.43	42.18	0.037	34.06	38.10	45.65	39.58	43.62	51.18	0.029	0.033	0.040	0.0343	0.0378	0.0443
7810	Alder (At Head)	West Adams	10.55	0.017	76.65	5.04	1.99	26.57	101.89	0.028	0.81	18.95	11.560	67.326	68.93	148.62	0.019	104.49	219.34	0.028	162.51	170.62	185.79	174.07	182.18	197.35	0.021	0.022	0.024	0.0223	0.0233	0.0253
7755	STA 010			0.017	76.65	5.04	1.99	26.38	101.17	0.028	0.81	18.85	11.499	66.852	68.45	147.62	0.019	103.78	217.87	0.028	161.47	169.55	184.66	172.97	181.05	196.16	0.021	0.022	0.024	0.0223	0.0233	0.0253
7154	STA 077			0.017	76.65	5.04	1.99	24.34	93.33	0.030	0.81	18.18	11.090	61.673	63.27	136.91	0.019	96.01	202.01	0.028	150.04	157.80	172.32	161.13	168.89	183.41	0.021	0.022	0.024	0.0225	0.0236	0.0256
20185	West Adams	-		0.017	116.60	8.05	1.99	42.97	173.11	0.02	13.02	53.75	32.79	174.006	175.61	381.99	0.019	264.51	558.78	0.028	404.70	421.32	452.40	437.49	454.10	485.18	0.020	0.021	0.022	0.0217	0.0225	0.0240
19967	STA 170			0.017	116.60	8.05	1.99	42.50	171.24	0.02	13.02	52.75	32.18	172.129	173.73	377.65	0.019	261.69	552.57	0.028	400.65	417.18	448.09	432.83	449.36	480.27	0.020	0.021	0.022	0.0217	0.0225	0.0241
12991	STA 240			0.017	116.60	8.05	1.99	27.65	111.41	0.03	13.02	32.42	19.78	111.991	113.59	245.66	0.019	171.49	360.79	0.028	269.78	283.11	308.04	289.55	302.88	327.82	0.021	0.022	0.024	0.0223	0.0233	0.0252
13071	STA 267			0.017	116.60	8.05	1.99	27.82	112.10	0.03	13.02	32.15	19.61	112.678	114.28	246.86	0.019	172.52	362.68	0.028	271.29	284.66	309.67	290.90	304.27	329.28	0.021	0.022	0.024	0.0223	0.0233	0.0252
12822	STA 314			0.017	116.60	8.05	1.99	27.29	109.96	0.03	13.02	31.68	19.32	110.532	112.13	242.31	0.019	169.30	355.99	0.028	266.57	279.81	304.58	285.89	299.13	323.90	0.021	0.022	0.024	0.0223	0.0233	0.0253
12582	STA 351			0.017	116.60	8.05	1.99	26.78	107.90	0.03	13.02	31.31	19.10	108.463	110.06	237.97	0.019	166.19	349.59	0.028	262.01	275.13	299.67	281.11	294.23	318.77	0.021	0.022	0.024	0.0223	0.0234	0.0253
12458	STA 390			0.017	116.60	8.05	1.99	26.52	106.84	0.03	13.02	30.92	18.86	107.394	108.99	235.60	0.019	164.59	346.16	0.028	259.66	272.71	297.13	278.52	291.57	315.99	0.021	0.022	0.024	0.0224	0.0234	0.0254
12223	STA 470			0.017	116.60	8.05	1.99	26.02	104.82	0.03	13.02	30.12	18.37	105.368	106.97	231.09	0.019	161.55	339.63	0.028	255.19	268.12	292.31	273.57	286.50	310.68	0.021	0.022	0.024	0.0224	0.0234	0.0254
12223	STA 559			0.017	116.60	8.05	1.99	26.02	104.82	0.03	13.02	29.23	17.83	105.368	106.97	230.54	0.019	161.55	339.09	0.028	255.19	268.12	292.31	273.02	285.95	310.14	0.021	0.022	0.024	0.0223	0.0234	0.0254
11717	STA 636			0.017	116.60	8.05	1.99	24.94	100.49	0.03	13.02	28.46	17.36	101.010	102.61	221.41	0.019	155.02	325.62	0.028	245.57	258.23	281.91	262.93	275.59	299.27	0.021	0.022	0.024	0.0224	0.0235	0.0255
11065	STA 665			0.017	116.60	8.05	1.99	23.55	94.90	0.03	13.02	28.17	17.18	95.390	96.99	210.05	0.019	146.58	308.68	0.028	233.14	245.44	268.45	250.32	262.62	285.63	0.021	0.022	0.024	0.0226	0.0237	0.0258
11009	STA 701			0.017	116.60	8.05	1.99	23.43	94.42	0.03	13.02	27.81	16.96	94.907	96.51	208.87	0.019	145.86	307.02	0.028	232.07	244.34	267.29	249.03	261.30	284.25	0.021	0.022	0.024	0.0226	0.0237	0.0258
10807	STA 789			0.017	116.60	8.05	1.99	23.00	92.68	0.03	13.02	26.93	16.43	93.161	94.76	204.87	0.019	143.24	301.27	0.028	228.19	240.35	263.09	244.62	256.78	279.52	0.021	0.022	0.024	0.0226	0.0238	0.0259
10691	STA 830			0.017	116.60	8.05	1.99	22.76	91.69	0.03	13.02	26.52	16.18	92.161	93.76	202.63	0.019	141.74	298.04	0.028	225.97	238.07	260.68	242.15	254.24	276.86	0.021	0.022	0.024	0.0227	0.0238	0.0259
9306	STA 903			0.017	116.60	8.05	1.99	19.81	79.81	0.04	13.02	25.79	15.73	80.222	81.82	178.44	0.019	123.83	261.98	0.028	199.37	210.65	231.75	215.10	226.38	247.48	0.021	0.023	0.025	0.0231	0.0243	0.0266
8881	STA 975			0.017	116.60	8.05	1.99	18.90	76.16	0.04	13.02	25.07	15.29	76.558	78.16	170.72	0.019	118.34	250.61	0.028	191.16	202.18	222.80	206.46	217.48	238.09	0.022	0.023	0.025	0.0232	0.0245	0.0268

ATTACHMENT 8

SURFACE ARRANGED AND DEMAND FLOWS
BASED ON CLEMMENS EQUATIONS

			SURFACE DEMAND				SURFACE ARRANGED			
A	At	An	Qn	Qt	Q	Q/A	Qn	Qt	Q	Q/A
100	116.6	0.86	4.43	1.972	8.74	0.087	2.37	1.972	4.68	0.0468
200	116.6	1.72	6.07	1.972	11.98	0.060	3.32	1.972	6.54	0.0327
300	116.6	2.57	7.36	1.972	14.51	0.048	4.17	1.972	8.23	0.0274
400	116.6	3.43	8.65	1.972	17.05	0.043	5.03	1.972	9.92	0.0248
500	116.6	4.29	9.93	1.972	19.59	0.039	5.89	1.972	11.61	0.0232
600	116.6	5.15	11.22	1.972	22.12	0.037	6.75	1.972	13.30	0.0222
700	116.6	6.00	12.51	1.972	24.66	0.035	7.60	1.972	14.99	0.0214
800	116.6	6.86	13.79	1.972	27.20	0.034	8.46	1.972	16.69	0.0209
900	116.6	7.72	15.08	1.972	29.73	0.033	9.32	1.972	18.38	0.0204
1000	116.6	8.58	16.36	1.972	32.27	0.032	10.18	1.972	20.07	0.0201
1100	116.6	9.43	17.65	1.972	34.81	0.032	11.03	1.972	21.76	0.0198
1200	116.6	10.29	18.94	1.972	37.34	0.031	11.89	1.972	23.45	0.0195
1300	116.6	11.15	20.22	1.972	39.88	0.031	12.75	1.972	25.14	0.0193
1400	116.6	12.01	21.51	1.972	42.42	0.030	13.61	1.972	26.83	0.0192
1500	116.6	12.86	22.80	1.972	44.96	0.030	14.46	1.972	28.52	0.0190
1600	116.6	13.72	24.08	1.972	47.49	0.030	15.32	1.972	30.22	0.0189
1700	116.6	14.58	25.37	1.972	50.03	0.029	16.18	1.972	31.91	0.0188
1800	116.6	15.44	26.66	1.972	52.57	0.029	17.04	1.972	33.60	0.0187
1900	116.6	16.30	27.94	1.972	55.10	0.029	17.90	1.972	35.29	0.0186
2000	116.6	17.15	29.23	1.972	57.64	0.029	18.75	1.972	36.98	0.0185
2100	116.6	18.01	30.52	1.972	60.18	0.029	19.61	1.972	38.67	0.0184
2200	116.6	18.87	31.80	1.972	62.71	0.029	20.47	1.972	40.36	0.0183
2300	116.6	19.73	33.09	1.972	65.25	0.028	21.33	1.972	42.05	0.0183
2400	116.6	20.58	34.37	1.972	67.79	0.028	22.18	1.972	43.75	0.0182
2500	116.6	21.44	35.66	1.972	70.32	0.028	23.04	1.972	45.44	0.0182
2600	116.6	22.30	36.95	1.972	72.86	0.028	23.90	1.972	47.13	0.0181
2700	116.6	23.16	38.23	1.972	75.40	0.028	24.76	1.972	48.82	0.0181
2800	116.6	24.01	39.52	1.972	77.93	0.028	25.61	1.972	50.51	0.0180
2900	116.6	24.87	40.81	1.972	80.47	0.028	26.47	1.972	52.20	0.0180
3000	116.6	25.73	42.09	1.972	83.01	0.028	27.33	1.972	53.89	0.0180
3100	116.6	26.59	43.38	1.972	85.55	0.028	28.19	1.972	55.58	0.0179
3200	116.6	27.44	44.67	1.972	88.08	0.028	29.04	1.972	57.28	0.0179
3300	116.6	28.30	45.95	1.972	90.62	0.027	29.90	1.972	58.97	0.0179
3400	116.6	29.16	47.24	1.972	93.16	0.027	30.76	1.972	60.66	0.0178
3500	116.6	30.02	48.53	1.972	95.69	0.027	31.62	1.972	62.35	0.0178
3600	116.6	30.87	49.81	1.972	98.23	0.027	32.47	1.972	64.04	0.0178
3700	116.6	31.73	51.10	1.972	100.77	0.027	33.33	1.972	65.73	0.0178
3800	116.6	32.59	52.39	1.972	103.30	0.027	34.19	1.972	67.42	0.0177
3900	116.6	33.45	53.67	1.972	105.84	0.027	35.05	1.972	69.11	0.0177
4000	116.6	34.31	54.96	1.972	108.38	0.027	35.91	1.972	70.81	0.0177
4100	116.6	35.16	56.24	1.972	110.91	0.027	36.76	1.972	72.50	0.0177
4200	116.6	36.02	57.53	1.972	113.45	0.027	37.62	1.972	74.19	0.0177
4300	116.6	36.88	58.82	1.972	115.99	0.027	38.48	1.972	75.88	0.0176
4400	116.6	37.74	60.10	1.972	118.52	0.027	39.34	1.972	77.57	0.0176
4500	116.6	38.59	61.39	1.972	121.06	0.027	40.19	1.972	79.26	0.0176
4600	116.6	39.45	62.68	1.972	123.60	0.027	41.05	1.972	80.95	0.0176
4700	116.6	40.31	63.96	1.972	126.14	0.027	41.91	1.972	82.64	0.0176
4800	116.6	41.17	65.25	1.972	128.67	0.027	42.77	1.972	84.34	0.0176
4900	116.6	42.02	66.54	1.972	131.21	0.027	43.62	1.972	86.03	0.0176
5000	116.6	42.88	67.82	1.972	133.75	0.027	44.48	1.972	87.72	0.0175
5100	116.6	43.74	69.11	1.972	136.28	0.027	45.34	1.972	89.41	0.0175
5200	116.6	44.60	70.40	1.972	138.82	0.027	46.20	1.972	91.10	0.0175
5300	116.6	45.45	71.68	1.972	141.36	0.027	47.05	1.972	92.79	0.0175
5400	116.6	46.31	72.97	1.972	143.89	0.027	47.91	1.972	94.48	0.0175
5500	116.6	47.17	74.25	1.972	146.43	0.027	48.77	1.972	96.17	0.0175

			SURFACE DEMAND				SURFACE ARRANGED			
A	At	An	Qn	Qt	Q	Q/A	Qn	Qt	Q	Q/A
5600	116.6	48.03	75.54	1.972	148.97	0.027	49.63	1.972	97.87	0.0175
5700	116.6	48.89	76.83	1.972	151.50	0.027	50.49	1.972	99.56	0.0175
5800	116.6	49.74	78.11	1.972	154.04	0.027	51.34	1.972	101.25	0.0175
5900	116.6	50.60	79.40	1.972	156.58	0.027	52.20	1.972	102.94	0.0174
6000	116.6	51.46	80.69	1.972	159.11	0.027	53.06	1.972	104.63	0.0174
6100	116.6	52.32	81.97	1.972	161.65	0.027	53.92	1.972	106.32	0.0174
6200	116.6	53.17	83.26	1.972	164.19	0.026	54.77	1.972	108.01	0.0174
6300	116.6	54.03	84.55	1.972	166.73	0.026	55.63	1.972	109.70	0.0174
6400	116.6	54.89	85.83	1.972	169.26	0.026	56.49	1.972	111.40	0.0174
6500	116.6	55.75	87.12	1.972	171.80	0.026	57.35	1.972	113.09	0.0174
6600	116.6	56.60	88.41	1.972	174.34	0.026	58.20	1.972	114.78	0.0174
6700	116.6	57.46	89.69	1.972	176.87	0.026	59.06	1.972	116.47	0.0174
6800	116.6	58.32	90.98	1.972	179.41	0.026	59.92	1.972	118.16	0.0174
6900	116.6	59.18	92.27	1.972	181.95	0.026	60.78	1.972	119.85	0.0174
7000	116.6	60.03	93.55	1.972	184.48	0.026	61.63	1.972	121.54	0.0174
7100	116.6	60.89	94.84	1.972	187.02	0.026	62.49	1.972	123.23	0.0174
7200	116.6	61.75	96.12	1.972	189.56	0.026	63.35	1.972	124.93	0.0174
7300	116.6	62.61	97.41	1.972	192.09	0.026	64.21	1.972	126.62	0.0173
7400	116.6	63.46	98.70	1.972	194.63	0.026	65.06	1.972	128.31	0.0173
7500	116.6	64.32	99.98	1.972	197.17	0.026	65.92	1.972	130.00	0.0173
7600	116.6	65.18	101.27	1.972	199.70	0.026	66.78	1.972	131.69	0.0173
7700	116.6	66.04	102.56	1.972	202.24	0.026	67.64	1.972	133.38	0.0173
7800	116.6	66.90	103.84	1.972	204.78	0.026	68.50	1.972	135.07	0.0173
7900	116.6	67.75	105.13	1.972	207.32	0.026	69.35	1.972	136.76	0.0173
8000	116.6	68.61	106.42	1.972	209.85	0.026	70.21	1.972	138.46	0.0173
8100	116.6	69.47	107.70	1.972	212.39	0.026	71.07	1.972	140.15	0.0173
8200	116.6	70.33	108.99	1.972	214.93	0.026	71.93	1.972	141.84	0.0173
8300	116.6	71.18	110.28	1.972	217.46	0.026	72.78	1.972	143.53	0.0173
8400	116.6	72.04	111.56	1.972	220.00	0.026	73.64	1.972	145.22	0.0173
8500	116.6	72.90	112.85	1.972	222.54	0.026	74.50	1.972	146.91	0.0173
8600	116.6	73.76	114.13	1.972	225.07	0.026	75.36	1.972	148.60	0.0173
8700	116.6	74.61	115.42	1.972	227.61	0.026	76.21	1.972	150.29	0.0173
8800	116.6	75.47	116.71	1.972	230.15	0.026	77.07	1.972	151.99	0.0173
8900	116.6	76.33	117.99	1.972	232.68	0.026	77.93	1.972	153.68	0.0173
9000	116.6	77.19	119.28	1.972	235.22	0.026	78.79	1.972	155.37	0.0173
9100	116.6	78.04	120.57	1.972	237.76	0.026	79.64	1.972	157.06	0.0173
9200	116.6	78.90	121.85	1.972	240.29	0.026	80.50	1.972	158.75	0.0173
9300	116.6	79.76	123.14	1.972	242.83	0.026	81.36	1.972	160.44	0.0173
9400	116.6	80.62	124.43	1.972	245.37	0.026	82.22	1.972	162.13	0.0172
9500	116.6	81.48	125.71	1.972	247.91	0.026	83.08	1.972	163.82	0.0172
9600	116.6	82.33	127.00	1.972	250.44	0.026	83.93	1.972	165.52	0.0172
9700	116.6	83.19	128.29	1.972	252.98	0.026	84.79	1.972	167.21	0.0172
9800	116.6	84.05	129.57	1.972	255.52	0.026	85.65	1.972	168.90	0.0172
9900	116.6	84.91	130.86	1.972	258.05	0.026	86.51	1.972	170.59	0.0172
10000	116.6	85.76	132.14	1.972	260.59	0.026	87.36	1.972	172.28	0.0172
10100	116.6	86.62	133.43	1.972	263.13	0.026	88.22	1.972	173.97	0.0172
10200	116.6	87.48	134.72	1.972	265.66	0.026	89.08	1.972	175.66	0.0172
10300	116.6	88.34	136.00	1.972	268.20	0.026	89.94	1.972	177.35	0.0172
10400	116.6	89.19	137.29	1.972	270.74	0.026	90.79	1.972	179.05	0.0172
10500	116.6	90.05	138.58	1.972	273.27	0.026	91.65	1.972	180.74	0.0172
10600	116.6	90.91	139.86	1.972	275.81	0.026	92.51	1.972	182.43	0.0172
10700	116.6	91.77	141.15	1.972	278.35	0.026	93.37	1.972	184.12	0.0172
10800	116.6	92.62	142.44	1.972	280.88	0.026	94.22	1.972	185.81	0.0172
10900	116.6	93.48	143.72	1.972	283.42	0.026	95.08	1.972	187.50	0.0172
11000	116.6	94.34	145.01	1.972	285.96	0.026	95.94	1.972	189.19	0.0172
11100	116.6	95.20	146.30	1.972	288.50	0.026	96.80	1.972	190.88	0.0172
11200	116.6	96.05	147.58	1.972	291.03	0.026	97.65	1.972	192.58	0.0172
11300	116.6	96.91	148.87	1.972	293.57	0.026	98.51	1.972	194.27	0.0172

			SURFACE DEMAND				SURFACE ARRANGED			
A	At	An	Qn	Qt	Q	Q/A	Qn	Qt	Q	Q/A
11400	116.6	97.77	150.16	1.972	296.11	0.026	99.37	1.972	195.96	0.0172
11500	116.6	98.63	151.44	1.972	298.64	0.026	100.23	1.972	197.65	0.0172
11600	116.6	99.49	152.73	1.972	301.18	0.026	101.09	1.972	199.34	0.0172
11700	116.6	100.34	154.01	1.972	303.72	0.026	101.94	1.972	201.03	0.0172
11800	116.6	101.20	155.30	1.972	306.25	0.026	102.80	1.972	202.72	0.0172
11900	116.6	102.06	156.59	1.972	308.79	0.026	103.66	1.972	204.41	0.0172
12000	116.6	102.92	157.87	1.972	311.33	0.026	104.52	1.972	206.11	0.0172
12100	116.6	103.77	159.16	1.972	313.86	0.026	105.37	1.972	207.80	0.0172
12200	116.6	104.63	160.45	1.972	316.40	0.026	106.23	1.972	209.49	0.0172
12300	116.6	105.49	161.73	1.972	318.94	0.026	107.09	1.972	211.18	0.0172
12400	116.6	106.35	163.02	1.972	321.47	0.026	107.95	1.972	212.87	0.0172
12500	116.6	107.20	164.31	1.972	324.01	0.026	108.80	1.972	214.56	0.0172
12600	116.6	108.06	165.59	1.972	326.55	0.026	109.66	1.972	216.25	0.0172
12700	116.6	108.92	166.88	1.972	329.09	0.026	110.52	1.972	217.94	0.0172
12800	116.6	109.78	168.17	1.972	331.62	0.026	111.38	1.972	219.64	0.0172
12900	116.6	110.63	169.45	1.972	334.16	0.026	112.23	1.972	221.33	0.0172
13000	116.6	111.49	170.74	1.972	336.70	0.026	113.09	1.972	223.02	0.0172
13100	116.6	112.35	172.02	1.972	339.23	0.026	113.95	1.972	224.71	0.0172
13200	116.6	113.21	173.31	1.972	341.77	0.026	114.81	1.972	226.40	0.0172
13300	116.6	114.07	174.60	1.972	344.31	0.026	115.67	1.972	228.09	0.0171
13400	116.6	114.92	175.88	1.972	346.84	0.026	116.52	1.972	229.78	0.0171
13500	116.6	115.78	177.17	1.972	349.38	0.026	117.38	1.972	231.47	0.0171
13600	116.6	116.64	178.46	1.972	351.92	0.026	118.24	1.972	233.17	0.0171
13700	116.6	117.50	179.74	1.972	354.45	0.026	119.10	1.972	234.86	0.0171
13800	116.6	118.35	181.03	1.972	356.99	0.026	119.95	1.972	236.55	0.0171
13900	116.6	119.21	182.32	1.972	359.53	0.026	120.81	1.972	238.24	0.0171
14000	116.6	120.07	183.60	1.972	362.06	0.026	121.67	1.972	239.93	0.0171
14100	116.6	120.93	184.89	1.972	364.60	0.026	122.53	1.972	241.62	0.0171
14200	116.6	121.78	186.18	1.972	367.14	0.026	123.38	1.972	243.31	0.0171
14300	116.6	122.64	187.46	1.972	369.68	0.026	124.24	1.972	245.00	0.0171
14400	116.6	123.50	188.75	1.972	372.21	0.026	125.10	1.972	246.70	0.0171
14500	116.6	124.36	190.04	1.972	374.75	0.026	125.96	1.972	248.39	0.0171
14600	116.6	125.21	191.32	1.972	377.29	0.026	126.81	1.972	250.08	0.0171
14700	116.6	126.07	192.61	1.972	379.82	0.026	127.67	1.972	251.77	0.0171
14800	116.6	126.93	193.89	1.972	382.36	0.026	128.53	1.972	253.46	0.0171
14900	116.6	127.79	195.18	1.972	384.90	0.026	129.39	1.972	255.15	0.0171
15000	116.6	128.64	196.47	1.972	387.43	0.026	130.24	1.972	256.84	0.0171
15100	116.6	129.50	197.75	1.972	389.97	0.026	131.10	1.972	258.53	0.0171
15200	116.6	130.36	199.04	1.972	392.51	0.026	131.96	1.972	260.23	0.0171
15300	116.6	131.22	200.33	1.972	395.04	0.026	132.82	1.972	261.92	0.0171
15400	116.6	132.08	201.61	1.972	397.58	0.026	133.68	1.972	263.61	0.0171
15500	116.6	132.93	202.90	1.972	400.12	0.026	134.53	1.972	265.30	0.0171
15600	116.6	133.79	204.19	1.972	402.66	0.026	135.39	1.972	266.99	0.0171
15700	116.6	134.65	205.47	1.972	405.19	0.026	136.25	1.972	268.68	0.0171
15800	116.6	135.51	206.76	1.972	407.73	0.026	137.11	1.972	270.37	0.0171
15900	116.6	136.36	208.05	1.972	410.27	0.026	137.96	1.972	272.06	0.0171
16000	116.6	137.22	209.33	1.972	412.80	0.026	138.82	1.972	273.76	0.0171
16100	116.6	138.08	210.62	1.972	415.34	0.026	139.68	1.972	275.45	0.0171
16200	116.6	138.94	211.90	1.972	417.88	0.026	140.54	1.972	277.14	0.0171
16300	116.6	139.79	213.19	1.972	420.41	0.026	141.39	1.972	278.83	0.0171
16400	116.6	140.65	214.48	1.972	422.95	0.026	142.25	1.972	280.52	0.0171
16500	116.6	141.51	215.76	1.972	425.49	0.026	143.11	1.972	282.21	0.0171
16600	116.6	142.37	217.05	1.972	428.02	0.026	143.97	1.972	283.90	0.0171
16700	116.6	143.22	218.34	1.972	430.56	0.026	144.82	1.972	285.59	0.0171
16800	116.6	144.08	219.62	1.972	433.10	0.026	145.68	1.972	287.29	0.0171
16900	116.6	144.94	220.91	1.972	435.63	0.026	146.54	1.972	288.98	0.0171
17000	116.6	145.80	222.20	1.972	438.17	0.026	147.40	1.972	290.67	0.0171
17100	116.6	146.66	223.48	1.972	440.71	0.026	148.26	1.972	292.36	0.0171

			SURFACE DEMAND				SURFACE ARRANGED			
A	**At**	**An**	**Qn**	**Qt**	**Q**	**Q/A**	**Qn**	**Qt**	**Q**	**Q/A**
17200	116.6	147.51	224.77	1.972	443.25	0.026	149.11	1.972	294.05	0.0171
17300	116.6	148.37	226.06	1.972	445.78	0.026	149.97	1.972	295.74	0.0171
17400	116.6	149.23	227.34	1.972	448.32	0.026	150.83	1.972	297.43	0.0171
17500	116.6	150.09	228.63	1.972	450.86	0.026	151.69	1.972	299.12	0.0171
17600	116.6	150.94	229.92	1.972	453.39	0.026	152.54	1.972	300.82	0.0171
17700	116.6	151.80	231.20	1.972	455.93	0.026	153.40	1.972	302.51	0.0171
17800	116.6	152.66	232.49	1.972	458.47	0.026	154.26	1.972	304.20	0.0171
17900	116.6	153.52	233.77	1.972	461.00	0.026	155.12	1.972	305.89	0.0171
18000	116.6	154.37	235.06	1.972	463.54	0.026	155.97	1.972	307.58	0.0171
18100	116.6	155.23	236.35	1.972	466.08	0.026	156.83	1.972	309.27	0.0171
18200	116.6	156.09	237.63	1.972	468.61	0.026	157.69	1.972	310.96	0.0171
18300	116.6	156.95	238.92	1.972	471.15	0.026	158.55	1.972	312.65	0.0171
18400	116.6	157.80	240.21	1.972	473.69	0.026	159.40	1.972	314.35	0.0171
18500	116.6	158.66	241.49	1.972	476.22	0.026	160.26	1.972	316.04	0.0171
18600	116.6	159.52	242.78	1.972	478.76	0.026	161.12	1.972	317.73	0.0171
18700	116.6	160.38	244.07	1.972	481.30	0.026	161.98	1.972	319.42	0.0171
18800	116.6	161.23	245.35	1.972	483.84	0.026	162.83	1.972	321.11	0.0171
18900	116.6	162.09	246.64	1.972	486.37	0.026	163.69	1.972	322.80	0.0171
19000	116.6	162.95	247.93	1.972	488.91	0.026	164.55	1.972	324.49	0.0171
19100	116.6	163.81	249.21	1.972	491.45	0.026	165.41	1.972	326.18	0.0171
19200	116.6	164.67	250.50	1.972	493.98	0.026	166.27	1.972	327.88	0.0171
19300	116.6	165.52	251.78	1.972	496.52	0.026	167.12	1.972	329.57	0.0171
19400	116.6	166.38	253.07	1.972	499.06	0.026	167.98	1.972	331.26	0.0171
19500	116.6	167.24	254.36	1.972	501.59	0.026	168.84	1.972	332.95	0.0171
19600	116.6	168.10	255.64	1.972	504.13	0.026	169.70	1.972	334.64	0.0171
19700	116.6	168.95	256.93	1.972	506.67	0.026	170.55	1.972	336.33	0.0171
19800	116.6	169.81	258.22	1.972	509.20	0.026	171.41	1.972	338.02	0.0171
19900	116.6	170.67	259.50	1.972	511.74	0.026	172.27	1.972	339.71	0.0171
20000	116.6	171.53	260.79	1.972	514.28	0.026	173.13	1.972	341.41	0.0171

ATTACHMENT 9

YOLO-ZAMORA CONJUNCTIVE USE PROJECT
SUMMARY OF CANAL LOSSES - WEST ADAMS SYSTEM

YEAR	TOTAL LOSS (AC FT)	WEST ADAMS LOST (AC-FT)	SYSTEM MILES	SEASON START	SEASON END	OPERATIONAL DAYS	LOSS (ACRE FT/DAY)	LOSS (CFS)	LOSS (CFS/MILE)
2001	17,748	7,152	54.03	3/27/01	10/4/01	191	37.45	18.88	0.35
2000	45,834	18,471	54.03	3/24/00	11/2/00	223	82.83	41.76	0.77
1999	39,578	15,950	54.03	4/15/99	11/5/99	204	78.19	39.42	0.73
1998	38,116	15,361	54.03	4/19/98	10/30/98	194	79.18	39.92	0.74
1997	38,655	15,578	54.03	3/3/97	11/5/97	247	63.07	31.80	0.59
1996	37,215	14,998	54.03	3/28/96	12/20/96	267	56.17	28.32	0.52
1995	32,191	12,973	54.03	4/6/95	11/5/95	213	60.91	30.71	0.57
AVE:	35,620	14,355			AVE:	220		AVE:	**0.61**

WOOD RODGERS

ENGINEERING ▪ PLANNING ▪ MAPPING ▪ SURVEYING

Plan & Profile Drawings- Demand Flow

Appendix D

EVALUATION/IMPROVEMENT PLANS FOR

WEST ADAMS CANAL - DEMAND FLOW

YCFCWCD & YZWD CONJUCTIVE WATER USE FEASIBILITY STUDY

SCALE: 1" = 100'

ENGINEER

WOOD-RODGERS INC.
3301 C STREET, SUITE 100B
SACRAMENTO, CA 95816
PHONE: (916) 341~7760

NOTE:

UNDER THE "DEMAND" SYSTEM THE WATER USER CAN OPEN AND PLACE THE TURNOUT WITHOUT COORDINATION WITH THE DISTRICT.

SITE PLAN

SHEET LAYOUT

DRAFT

REVISIONS

NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ________
DESCRIPTION: Survey Datum - The coordinates shown on the drawing are based on the Cache Creek Record of Survey(March-April 2002). Elevations are based on the North American Vertical Datum of 1988 (NAVD 1988) Yolo County GPS Subsidence Survey. Horizontal Coordinates are based on the North American Datum of 1983 (NAD 83), California State Plane Coordinates Zone 2.

SCALE

YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: JB
DATE ________
DESIGNED BY: ________
R.C.E. ________ DATE ________
CHECKED BY: ________
R.C.E. ________ DATE ________

WOOD RODGERS
ENGINEERING - MAPPING - PLANNING - SURVEYING
3301 C St, Bldg. 100-B Tel 916.341.7760
Sacramento, CA 95816 Fax 916.341.7767

YCFCWCD/YZWD CONJUNCTIVE WATER USE FEASIBILITY STUDY
WEST ADAMS CANAL - DEMAND FLOW
TITLE SHEET

SHEET
1
OF
32

J:\Jobs\8108-YCFC_WCD\W_Adams_Canal\Acad\Civil\Dwg\FDP\FDP_G01.dwg 7/30/03 1:07pm lcurd

LIST OF DRAWINGS

1. TITLE SHEET
2. LIST OF DRAWING AND ABBREVIATIONS
3. PLAN PROFILE SHEET – STA. 10+00 TO STA. 60+00
4. PLAN PROFILE SHEET – STA. 60+00 TO STA. 110+00
5. PLAN PROFILE SHEET – STA. 110+00 TO STA. 160+00
6. PLAN PROFILE SHEET – STA. 160+00 TO STA. 210+00
7. PLAN PROFILE SHEET – STA. 210+00 TO STA. 260+00
8. PLAN PROFILE SHEET – STA. 260+00 TO STA. 310+00
9. PLAN PROFILE SHEET – STA. 310+00 TO STA. 360+00
10. PLAN PROFILE SHEET – STA. 360+00 TO STA. 410+00
11. PLAN PROFILE SHEET – STA. 410+00 TO STA. 460+00
12. PLAN PROFILE SHEET – STA. 460+00 TO STA. 510+00
13. PLAN PROFILE SHEET – STA. 510+00 TO STA. 560+00
14. PLAN PROFILE SHEET – STA. 560+00 TO STA. 610+00
15. PLAN PROFILE SHEET – STA. 610+00 TO STA. 660+00
16. PLAN PROFILE SHEET – STA. 660+00 TO STA. 697+73.51
17. PLAN PROFILE SHEET – STA. 10+00 TO STA. 55+00
18. PLAN PROFILE SHEET – STA. 55+00 TO STA. 97+37.36
19. PLAN PROFILE SHEET – STA. 10+00 TO STA. 55+00
20. PLAN PROFILE SHEET – STA. 55+00 TO STA. 86+23.89
21. PLAN PROFILE SHEET – STA. 10+00 TO STA. 50+00
22. PLAN PROFILE SHEET – STA. 50+00 TO STA. 100+00
23. PLAN PROFILE SHEET – STA. 100+00 TO STA. 145+00
24. PLAN PROFILE SHEET – STA. 145+00 TO STA. 190+00
25. PLAN PROFILE SHEET – STA. 190+00 TO STA. 235+00
26. PLAN PROFILE SHEET – STA. 235+00 TO STA. 280+00
27. PLAN PROFILE SHEET – STA. 280+00 TO STA. 325+00
28. PLAN PROFILE SHEET – STA. 325+00 TO STA. 370+00
29. PLAN PROFILE SHEET – STA. 370+00 TO STA. 415+00
30. PLAN PROFILE SHEET – STA. 415+00 TO STA. 460+00
31. PLAN PROFILE SHEET – STA. 460+00 TO STA. 510+00
32. PLAN PROFILE SHEET – STA. 510+00 TO STA. 545+48.60

ABBREVIATIONS

M	MARGINAL
R	REPLACE STRUCTURE
R/O	REPLACE (WITH CHINA SLOUGH)/OK (EXISTING)
M/O	MARGINAL (WITH CHINA SLOUGH)/OK (EXISTING)
OK	ACCEPTABLE

LEGEND

┈┈┈┈	WS WITH CHINA SLOUGH
- - - -	WS WITHOUT CHINA SLOUGH
——•——	GROUND
——•——	LEFT BANK
——•——	RIGHT BANK
Q_E	EXISTING CANAL CAPACITY
Q_{A1}	DEMAND FLOW WITH CHINA SLOUGH
Q_{A2}	DEMAND FLOW WITHOUT CHINA SLOUGH

NOTES:

1. HEC–RAS FILE INFORMATION FOR WEST ADAMS CANAL:
   PLAN: WEST ADAMS CANAL DEMAND FLOW
   GEOM: WEST ADAMS CANAL REVISED XS 10–31–02 (.05,.017)
   FLOW: WEST ADAMS CANAL DEMAND FLOW
2. HEC–RAS FILE INFORMATION FOR EAST ADAMS CANAL:
   PLAN: EAST ADAMS CANAL DEMAND FLOW
   GEOM: EAST ADAMS CANAL REVISED 11–01–02 XS (.05,.017)
   FLOW: EAST ADAMS CANAL DEMAND FLOW
3. HEC–RAS FILE INFORMATION FOR ACACIA CANAL:
   PLAN: ACACIA CANAL DEMAND FLOW
   GEOM: YCFCWCD–ACACIA CANAL REVISED XS (.05,.017)
   FLOW: ACACIA CANAL DEMAND FLOW
4. HEC–RAS FILE INFORMATION FOR CHINA SLOUGH:
   PLAN: CHINA SLOUGH DEMAND FLOW (CLEAN)
   GEOM: YCFCWCD–CHINA SLOUGH REVISED XS (0.35 CLEAN)
   FLOW: CHINA SLOUGH DEMAND FLOW w/C.S.
5. DESIGN CAPACITY BASED ON ALBERT J. CLEMMENS,
   CANAL CAPACITIES FOR DEMAND FLOW UNDER SURFACE
   IRRIGATION; JOURNAL OF IRRIGATION AND
   DRAINAGE ENGINEERING, VOL. 112 NO. 4 NOV. 1986

REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ________
DESCRIPTION:
(SEE SHEET 1)

SCALE

YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: LC
DATE ________

DESIGNED BY: ________
R.C.E. ________ DATE ________

CHECKED BY: ________
R.C.E. ________ DATE ________

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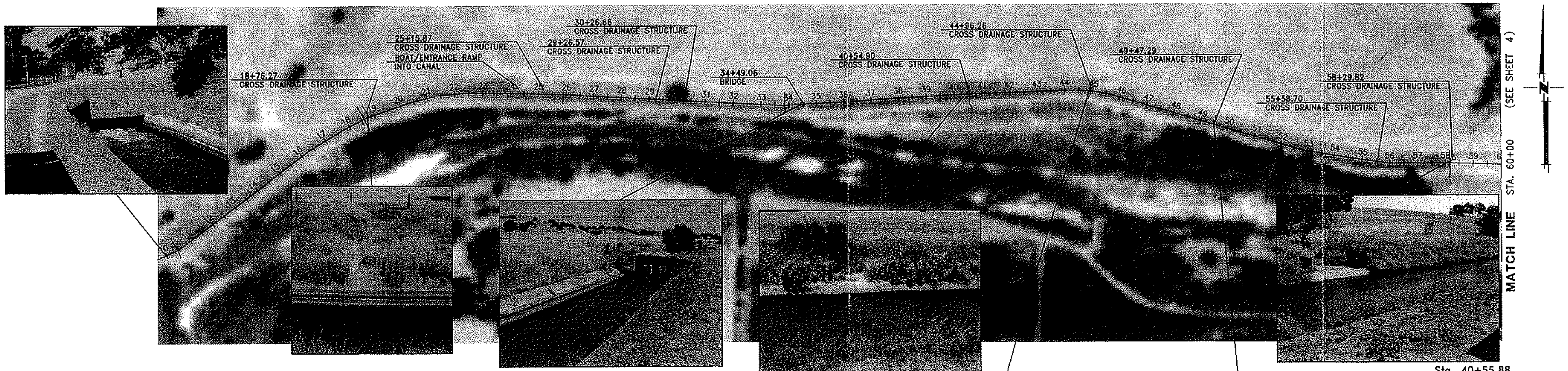
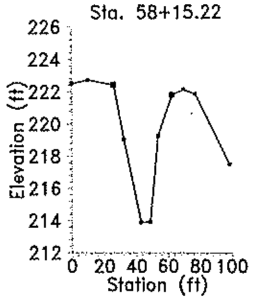
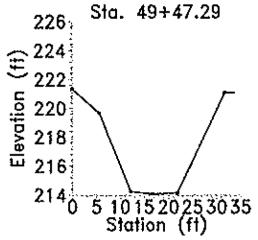
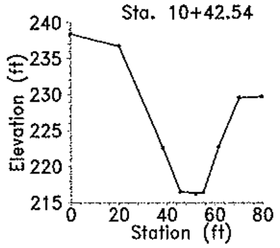
YCFCWCD/YZWD CONJUNCTIVE WATER USE FEASIBILITY STUDY
WEST ADAMS CANAL - DEMAND FLOW
LIST OF DRAWINGS, ABBREVIATIONS
AND LEGEND

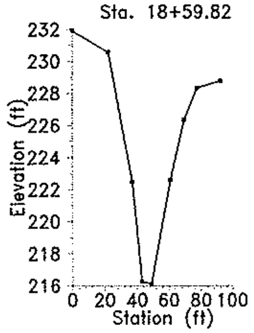
SHEET
2
— OF —
32

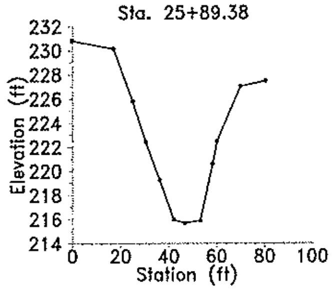


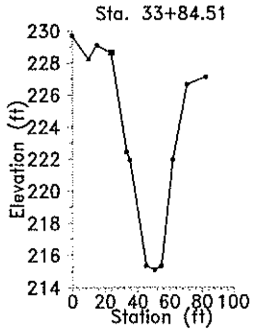


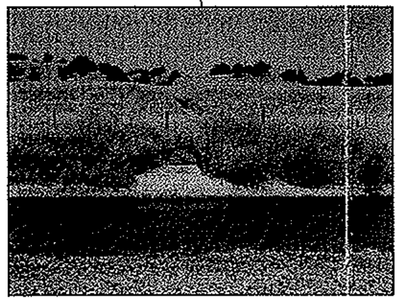


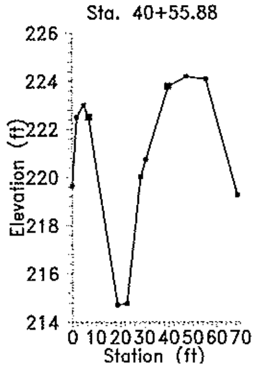


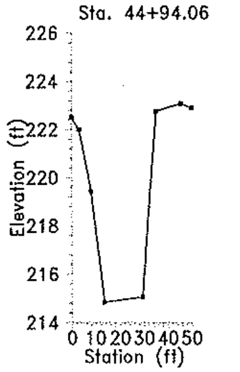


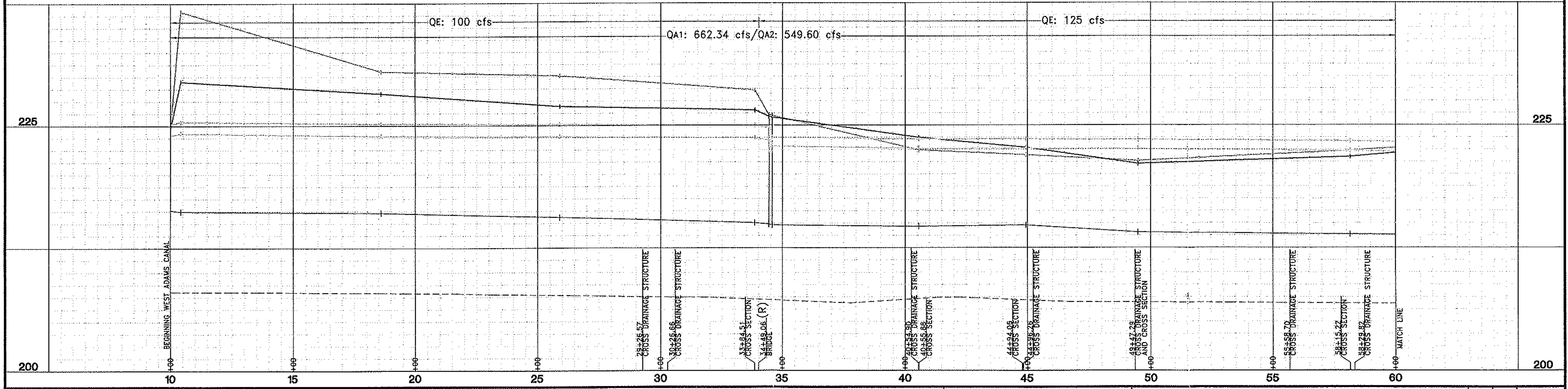












REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ________
DESCRIPTION:
The initial control point used for the Canal Topo was YC-1 of the referenced surey.
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE 8/3/02

DESIGNED BY: FB
R.C.E. ________ DATE ________

CHECKED BY: ________
R.C.E. ________ DATE ________

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YCFCWCD/YZWD CONJUNCTIVE WATER USE FEASIBILITY STUDY
WEST ADAMS CANAL - DEMAND FLOW

PLAN AND PROFILE
STA. 10+00 TO STA. 60+00

SHEET
3
— OF —
32

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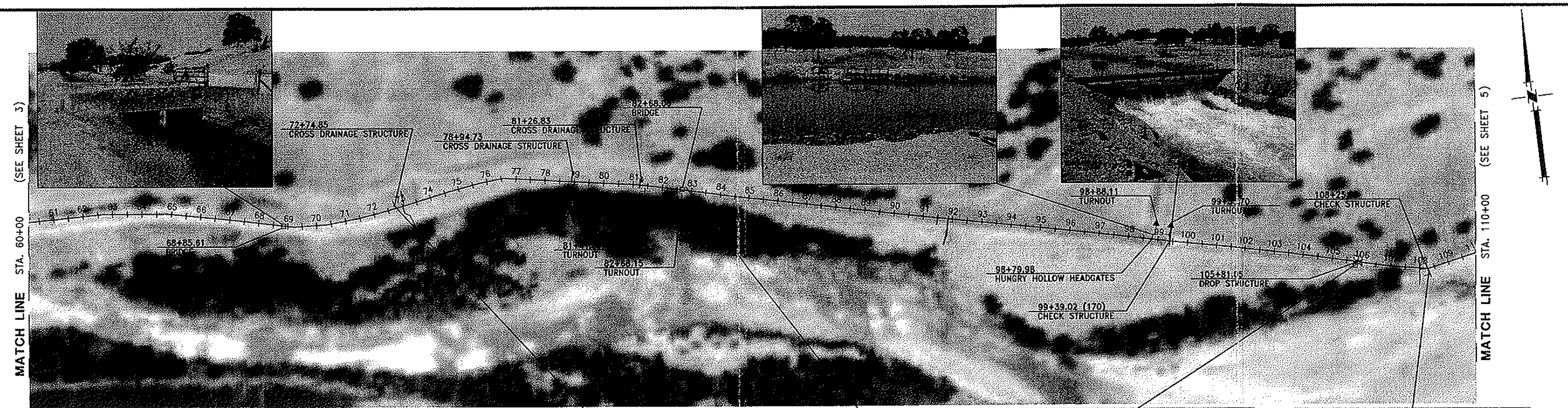

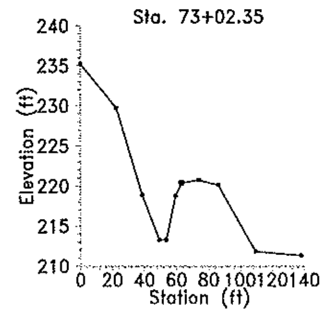
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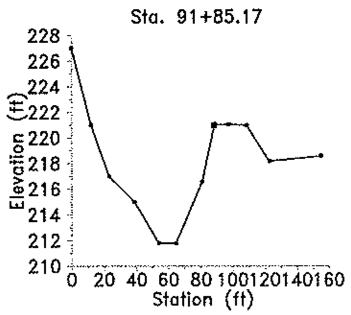
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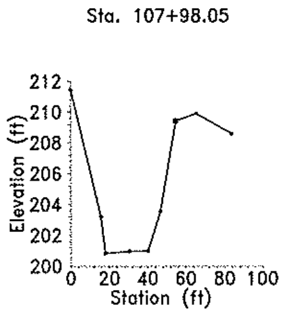
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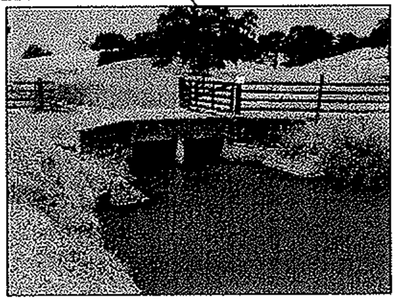

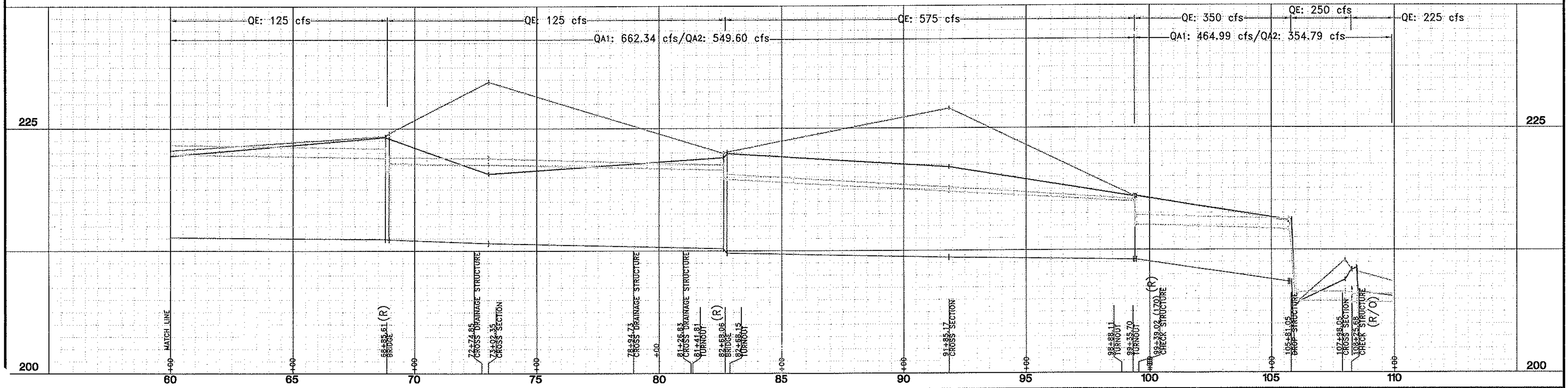

NO.	REVISIONS DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:

SCALE
H: 1"=200'
V: 1"=20'

YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE ______
DESIGNED BY: FB
R.C.E. ______ DATE ______
CHECKED BY: ______
R.C.E. ______ DATE ______

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WEST ADAMS CANAL - DEMAND FLOW
PLAN AND PROFILE
STA. 60+00 TO STA. 110+00

SHEET
4
OF
32

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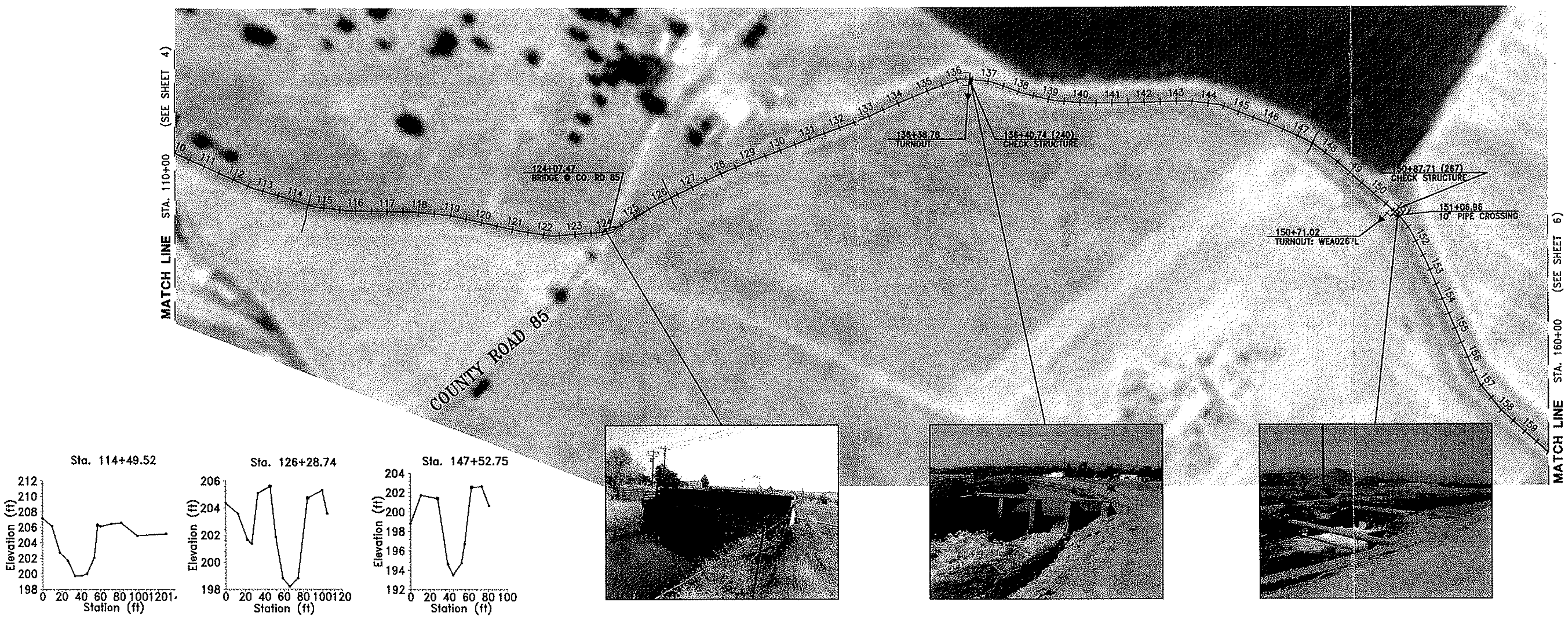

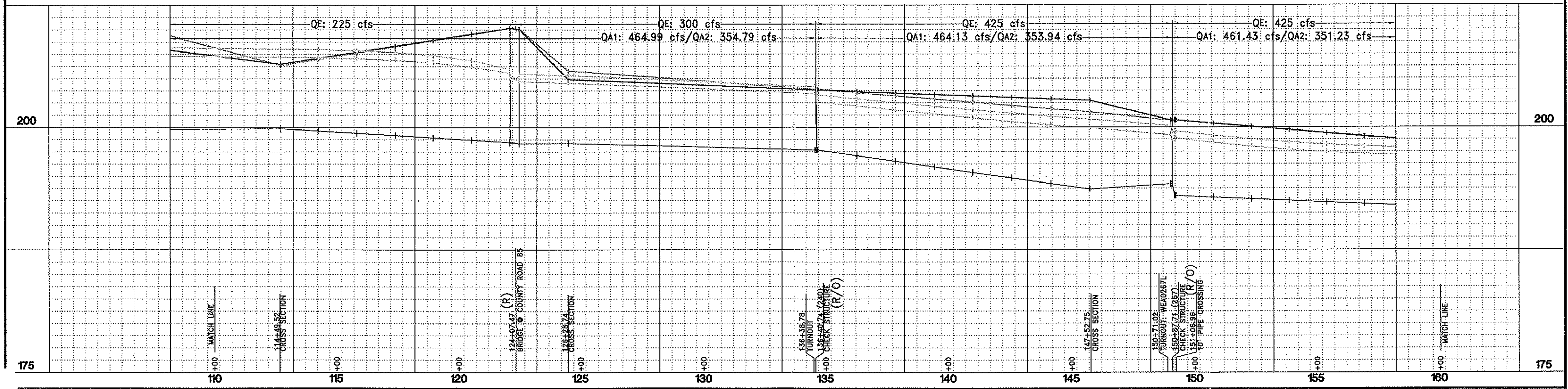

NO.	REVISIONS DESCRIPTION	DATE	BY

BENCHMARK ELEV. ________
DESCRIPTION:

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE ________

DESIGNED BY: ________
R.C.E. ________ DATE ________

CHECKED BY: ________
R.C.E. ________ DATE ________

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WEST ADAMS CANAL - DEMAND FLOW
PLAN AND PROFILE
STA. 110+00 TO STA. 160+00

SHEET
5
OF
32

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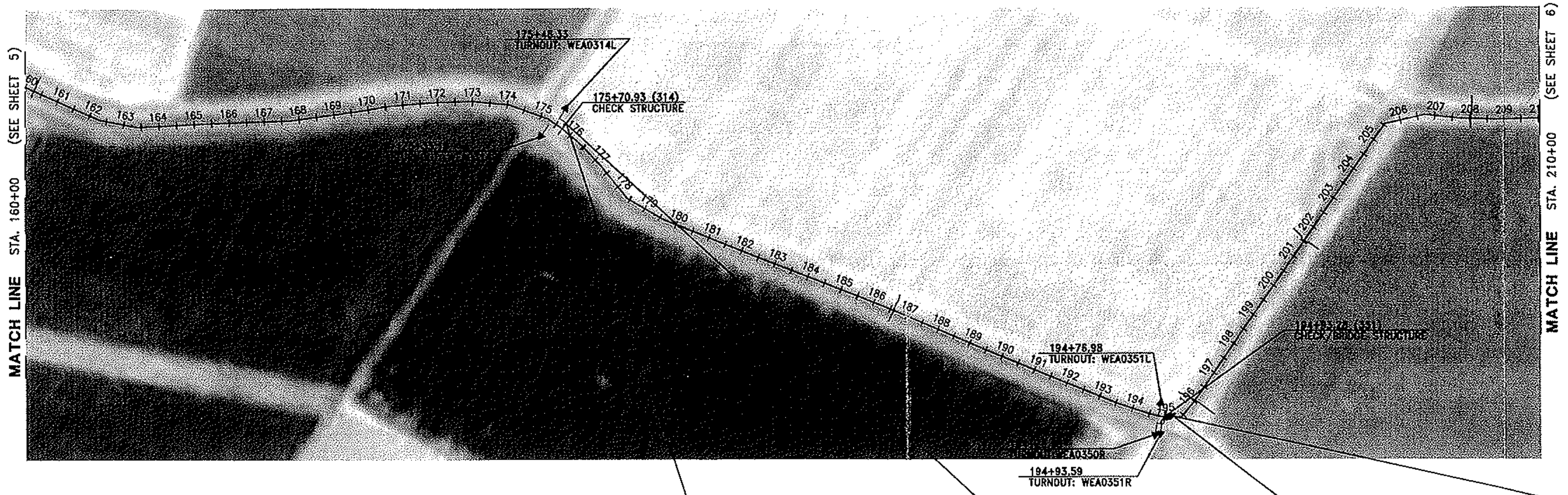

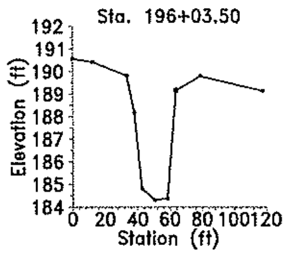

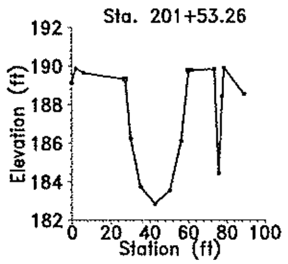

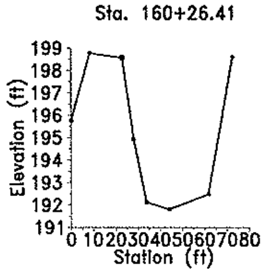

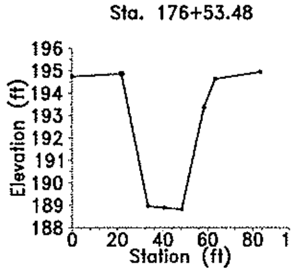

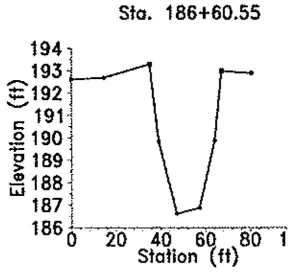

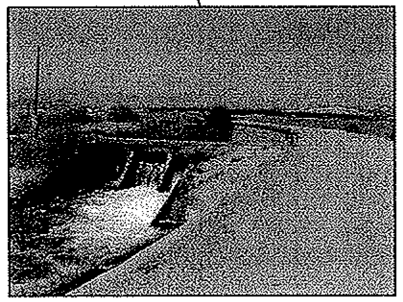

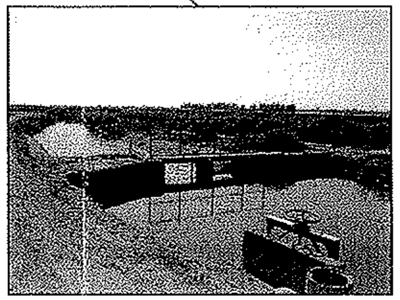

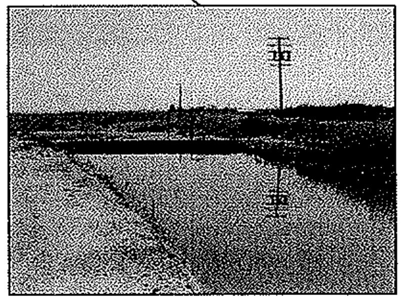

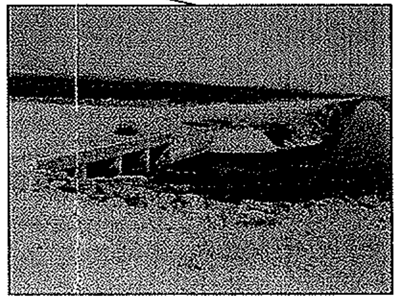

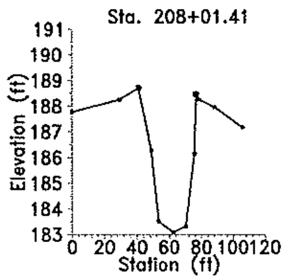

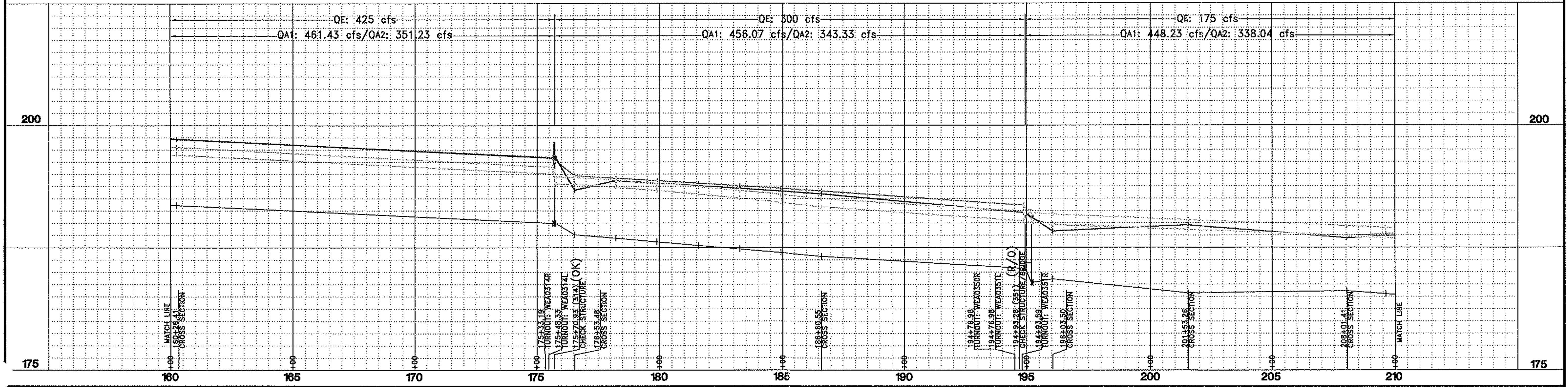

NO.	REVISIONS DESCRIPTION	DATE	BY

BENCHMARK ELEV. ________
DESCRIPTION:

SCALE
H: 1"=200'
V: 1"=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE

DESIGNED BY:
R.C.E. ________ DATE

CHECKED BY:
R.C.E. ________ DATE

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WEST ADAMS CANAL - DEMAND FLOW
PLAN AND PROFILE
STA. 160+00 TO STA. 210+00

SHEET
6
— OF —
32

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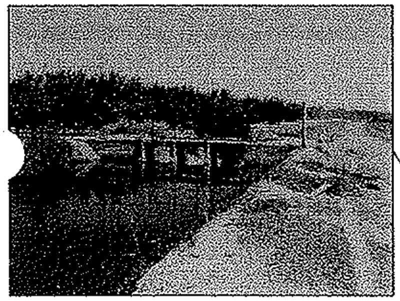

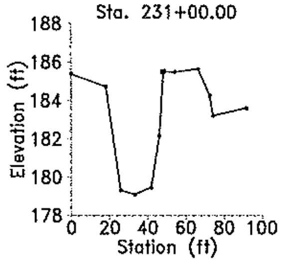

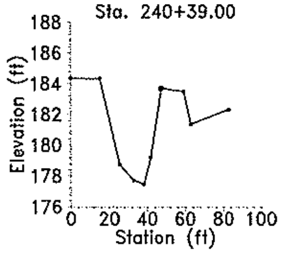

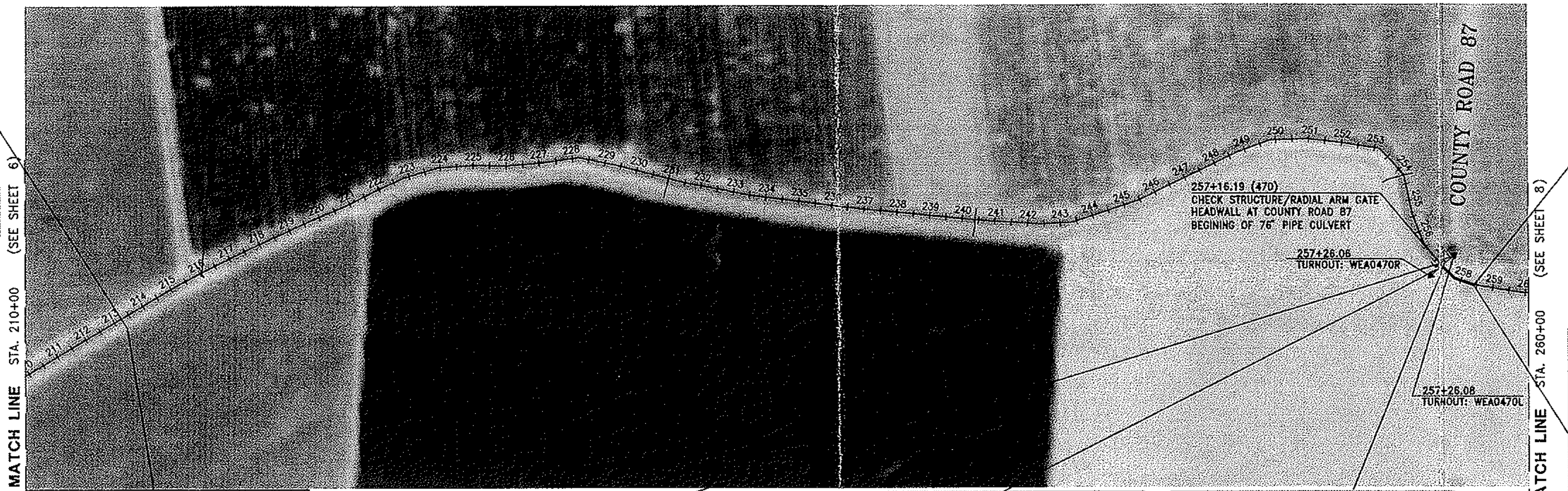

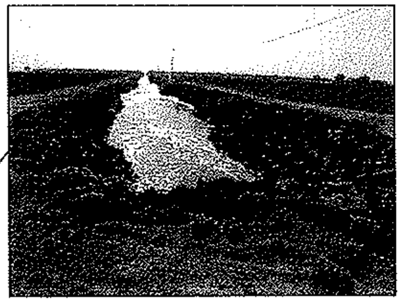

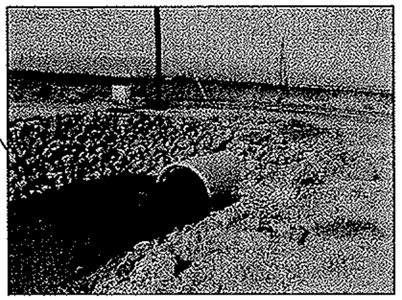

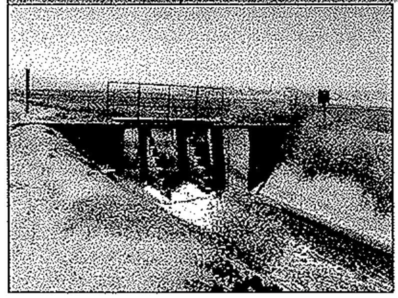

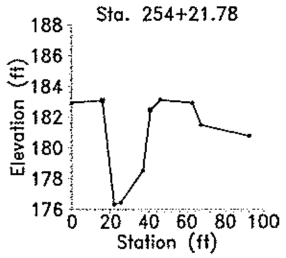

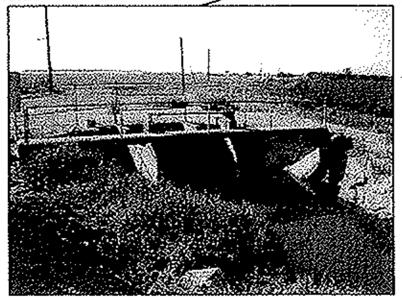

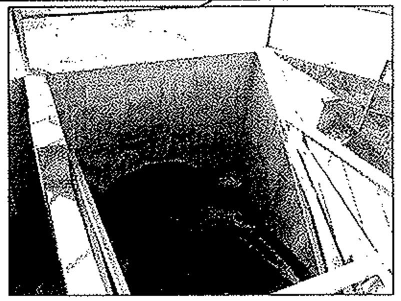

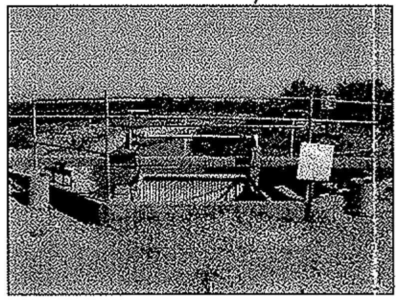

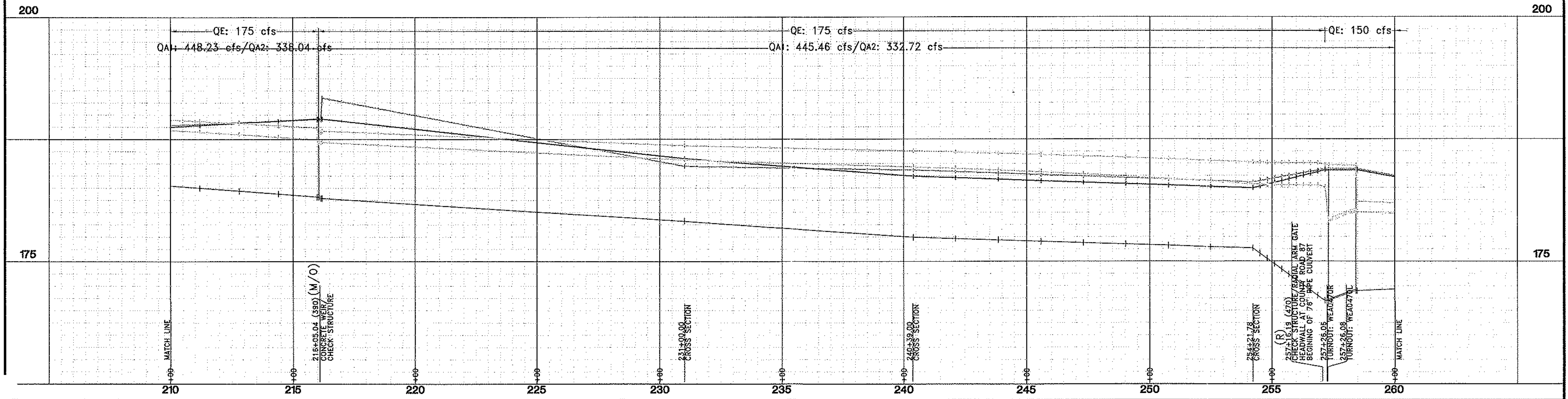

REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ________
DESCRIPTION:

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE ________

DESIGNED BY: ________
R.C.E. ________ DATE ________

CHECKED BY: ________
R.C.E. ________ DATE ________

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YCFCWCD/YZWD CONJUNCTIVE WATER USE FEASIBILITY STUDY
WEST ADAMS CANAL - DEMAND FLOW
PLAN AND PROFILE
STA. 210+00 TO STA. 260+00

SHEET
7
OF
32

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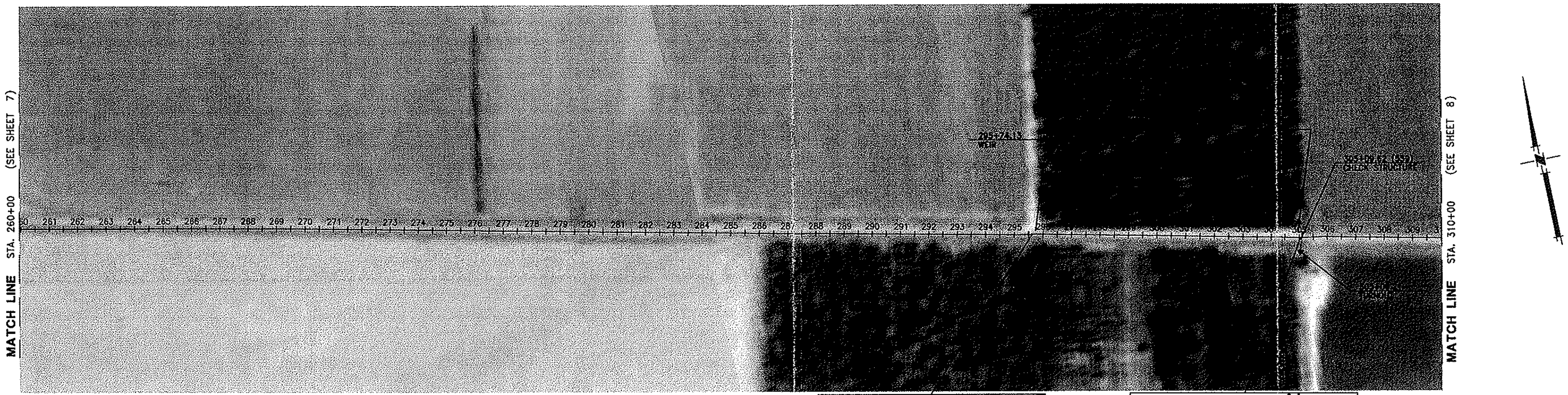

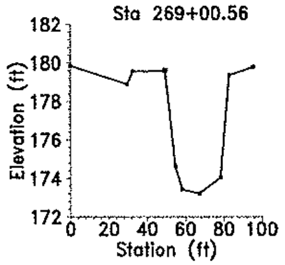

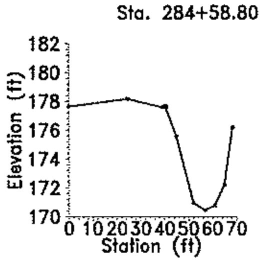

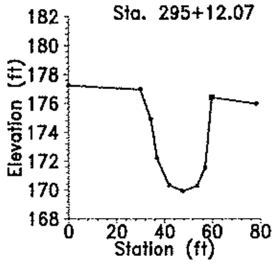

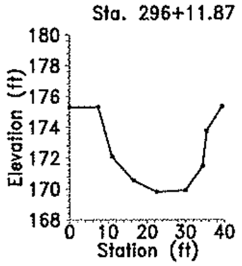

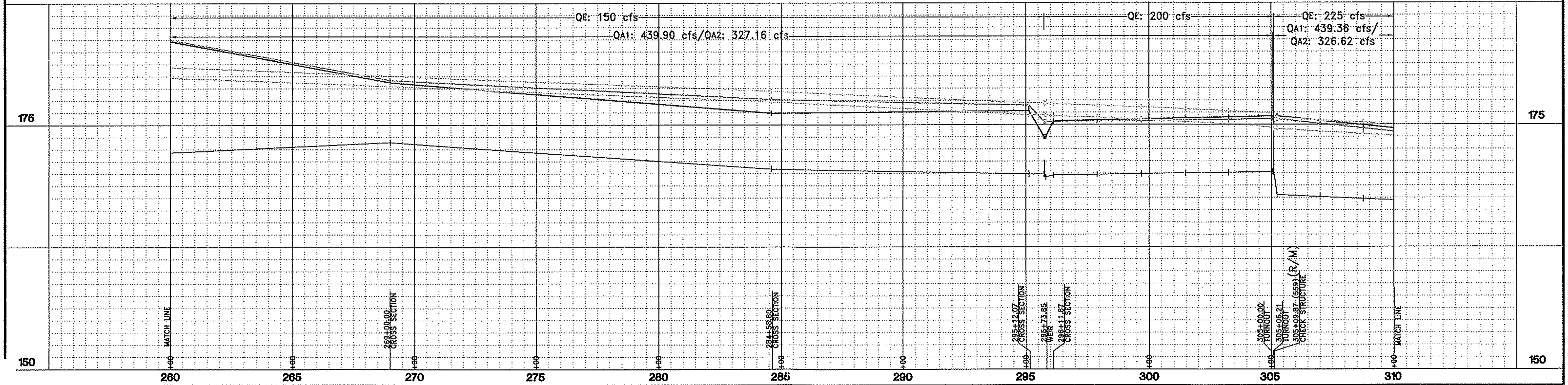

NO.	REVISIONS DESCRIPTION	DATE	BY

BENCHMARK ELEV. ________
DESCRIPTION:

SCALE
H: 1"=200'
V: 1"=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE ________
DESIGNED BY: ________
R.C.E. ________ DATE ________
CHECKED BY: ________
R.C.E. ________ DATE ________

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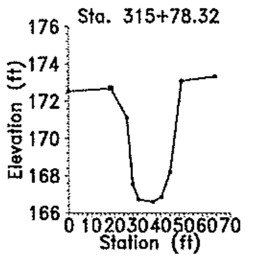
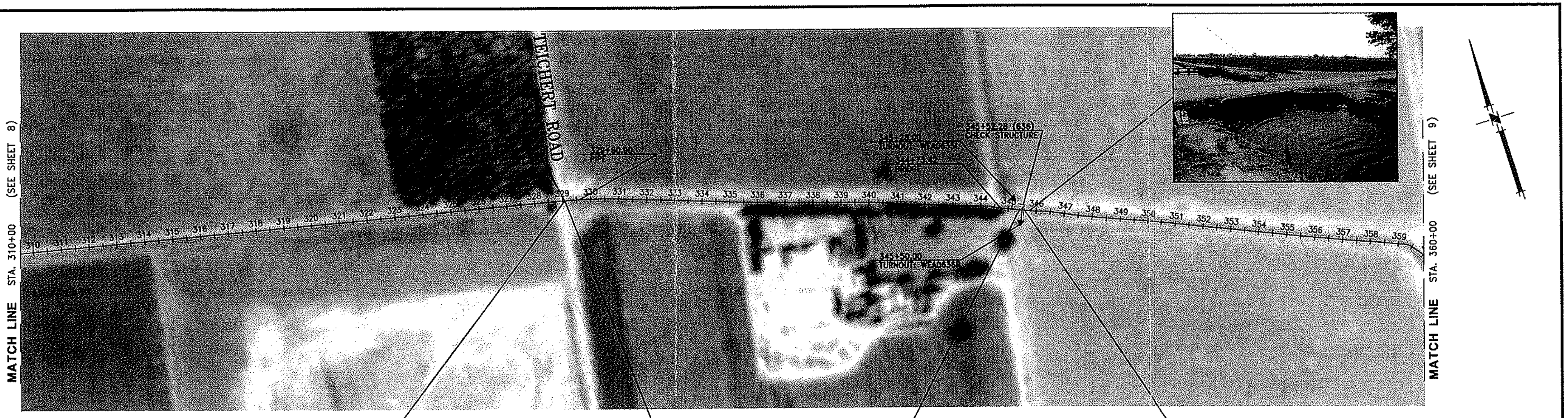
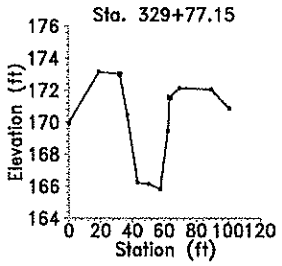
WEST ADAMS CANAL - DEMAND FLOW
PLAN AND PROFILE
STA. 260+00 TO STA. 310+00

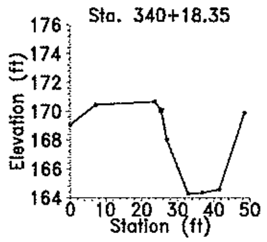
SHEET
8
OF
32

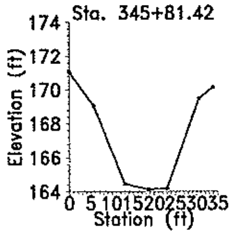
J:\Jobs\8108-YCFC_WCD\W_Adams_Canal\Wood\Civil\Dwg\FDP\FDP_C08-PP08-WAC.dwg 7/17/03 9:22pm lcurd

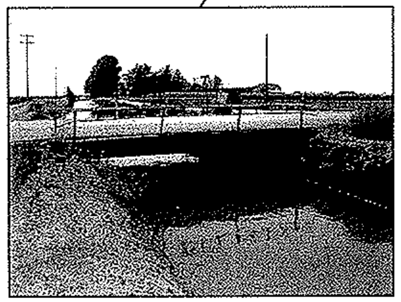


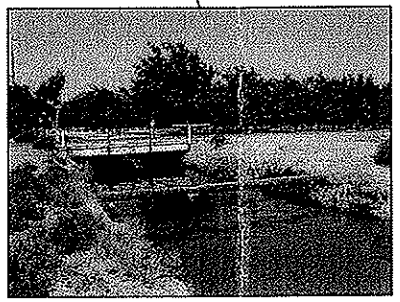


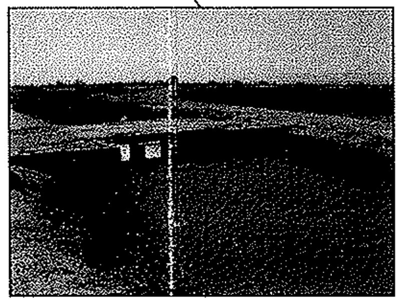


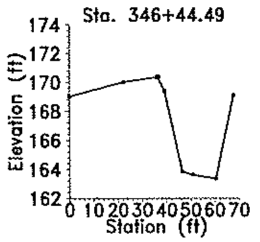


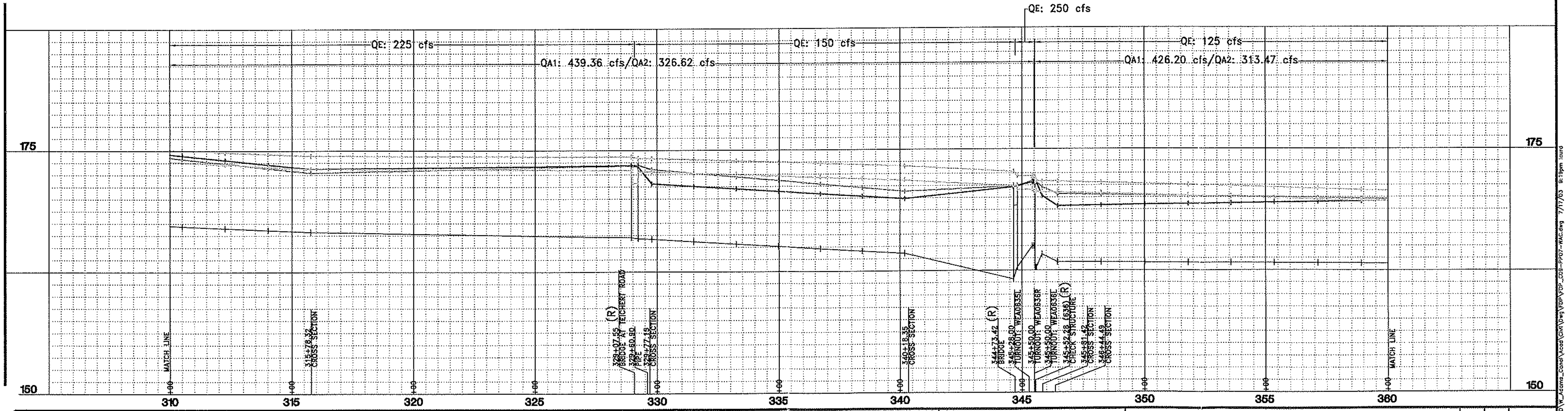












REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: ______
DATE ______

DESIGNED BY: ______
R.C.E. ______ DATE ______

CHECKED BY: ______
R.C.E. ______ DATE ______

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WEST ADAMS CANAL - DEMAND FLOW
PLAN AND PROFILE
STA. 310+00 TO STA. 360+00

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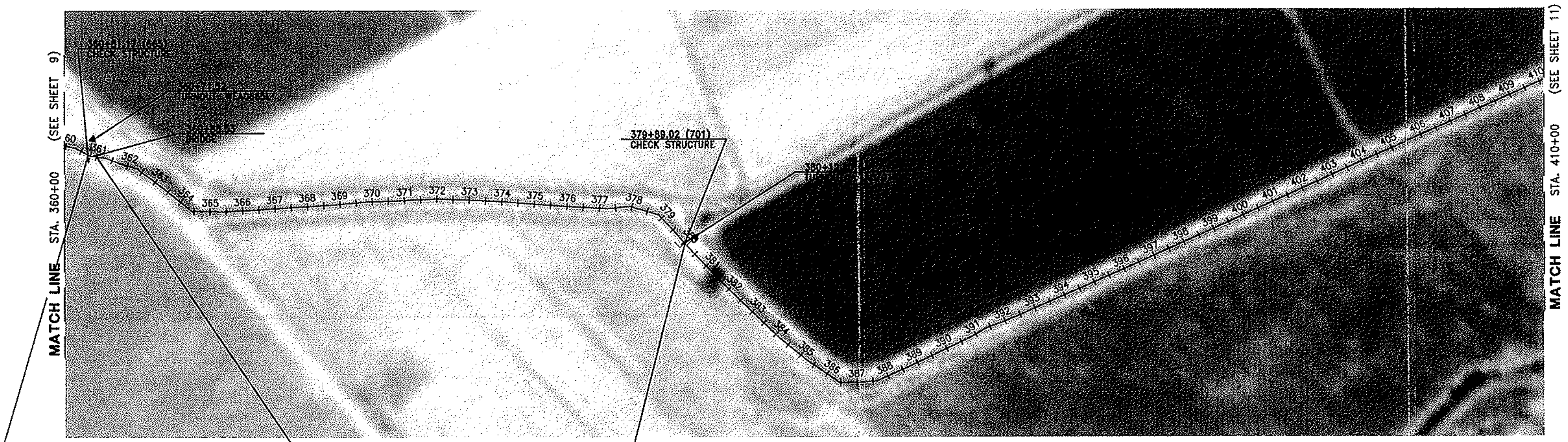

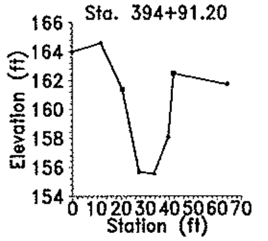

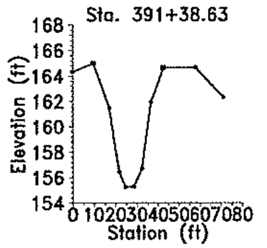

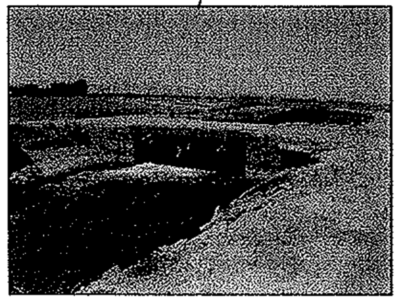

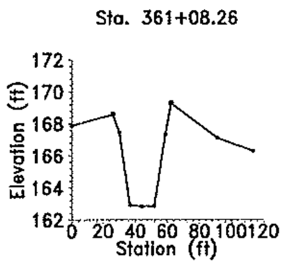

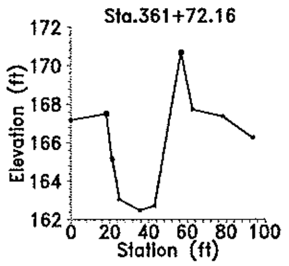

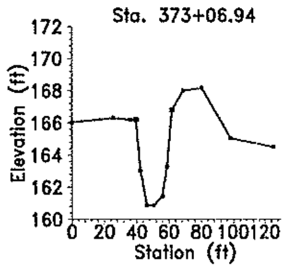

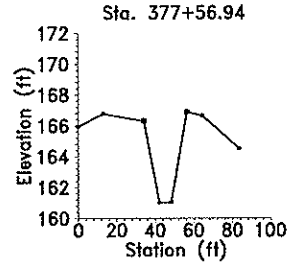

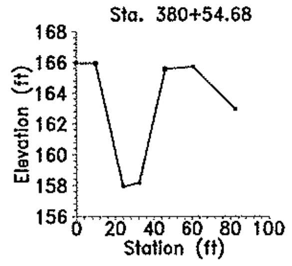

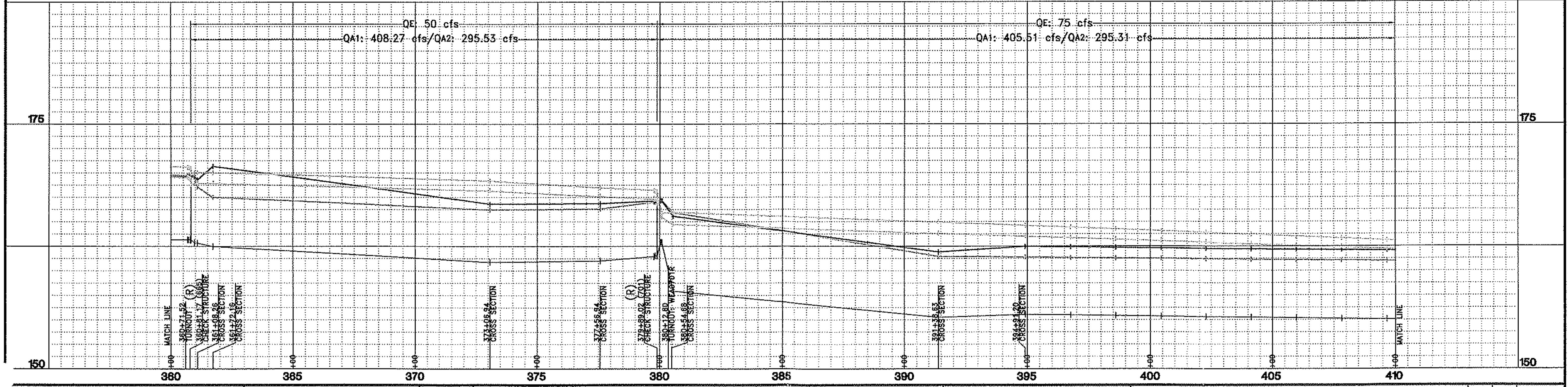

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YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE 9-11-02

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R.C.E. ______ DATE ______

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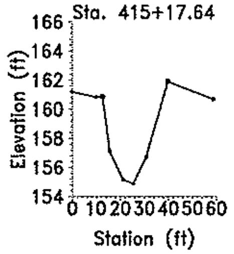

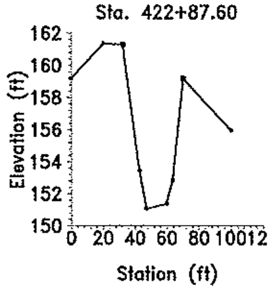

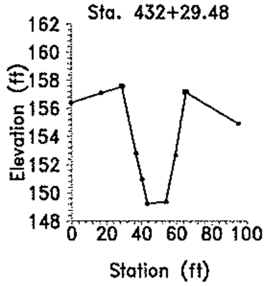

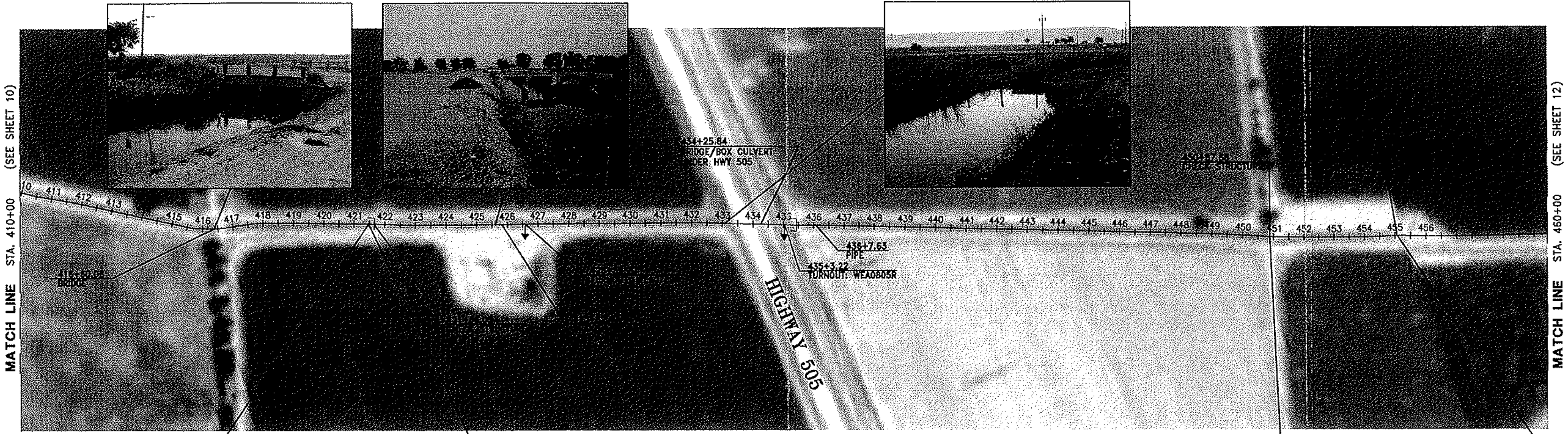

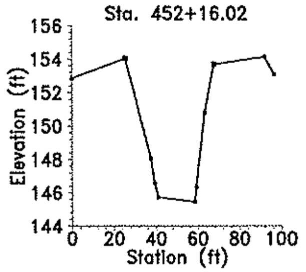

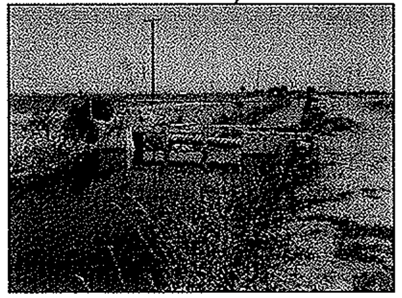

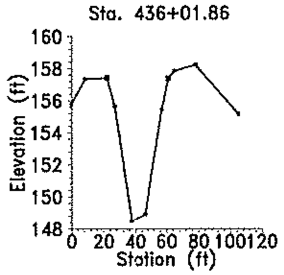

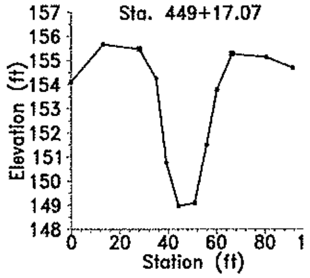

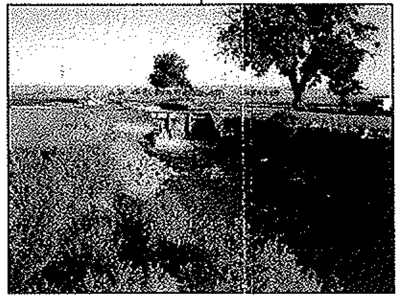

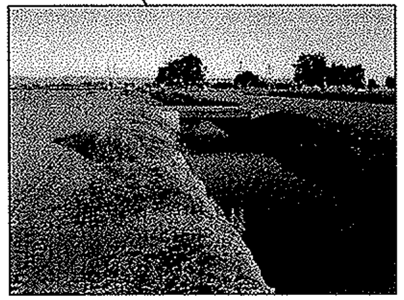

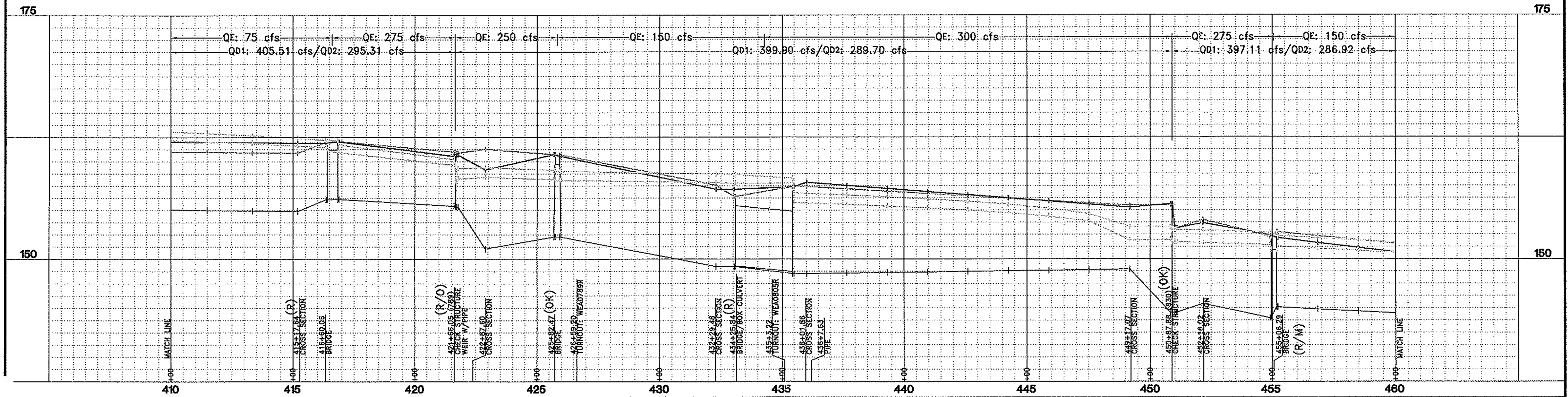

REVISIONS			
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YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE 9-11-02

DESIGNED BY:________
R.C.E. ________ DATE ________

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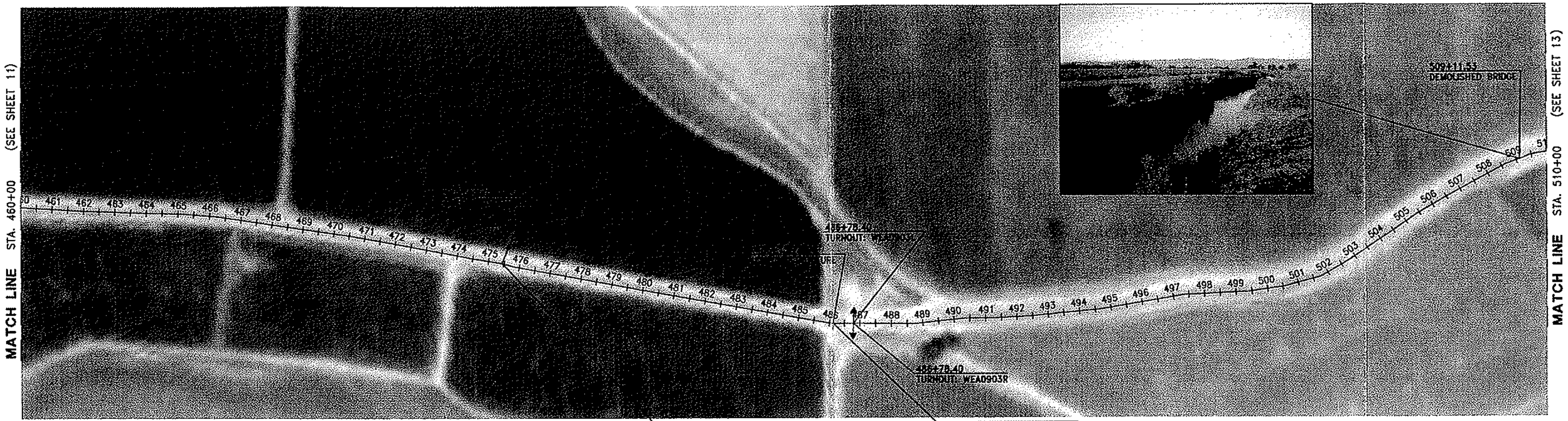

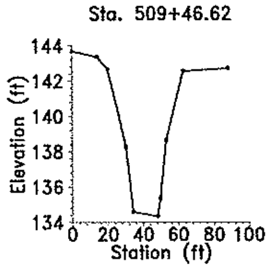

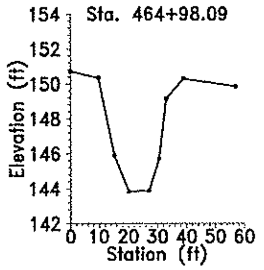

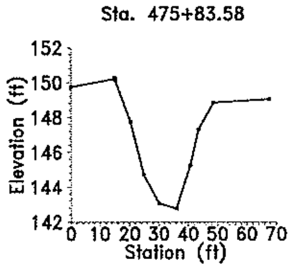

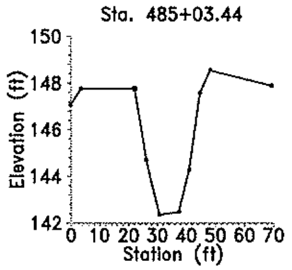

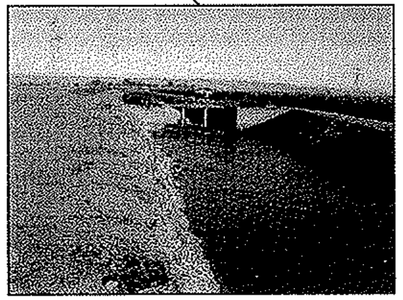

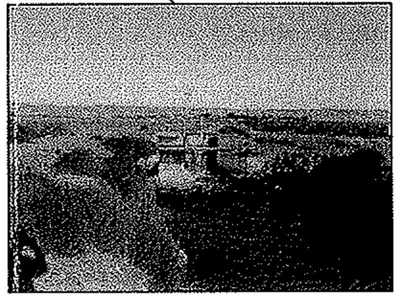

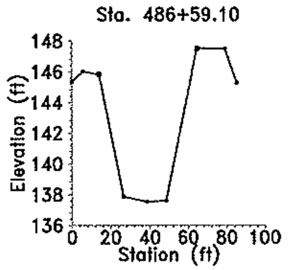

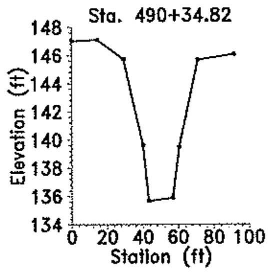

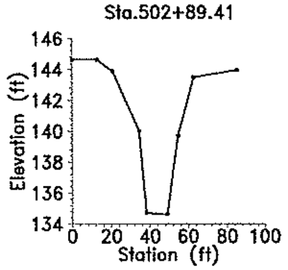

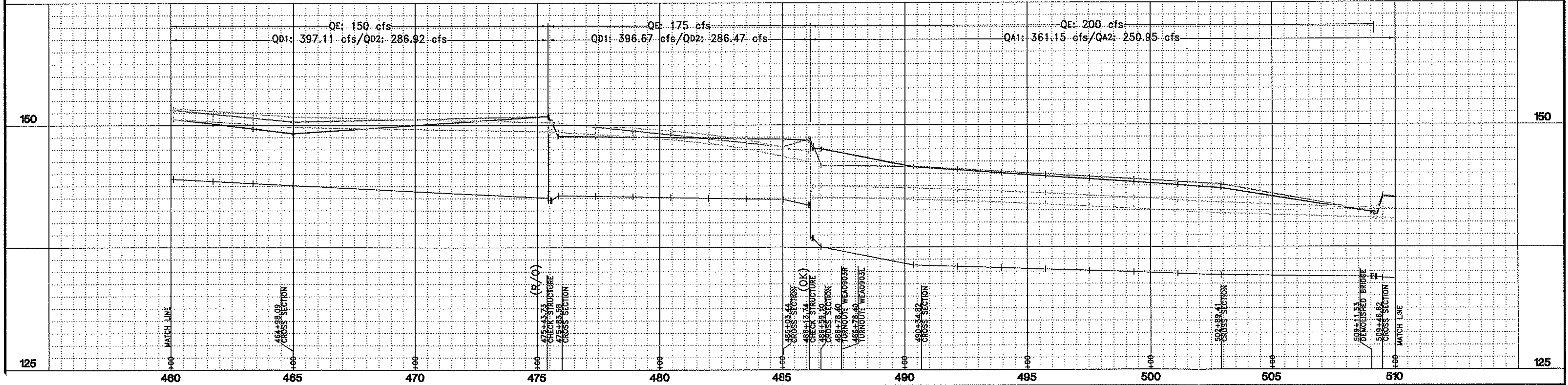

NO.	REVISIONS DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE 9-11-02

DESIGNED BY: ______
R.C.E. ______ DATE ______

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R.C.E. ______ DATE ______

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PLAN AND PROFILE
STA. 460+00 TO STA. 510+00

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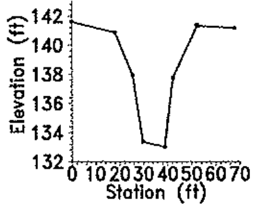

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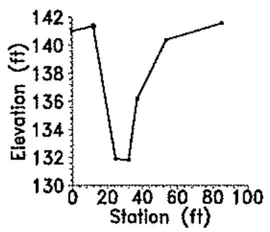

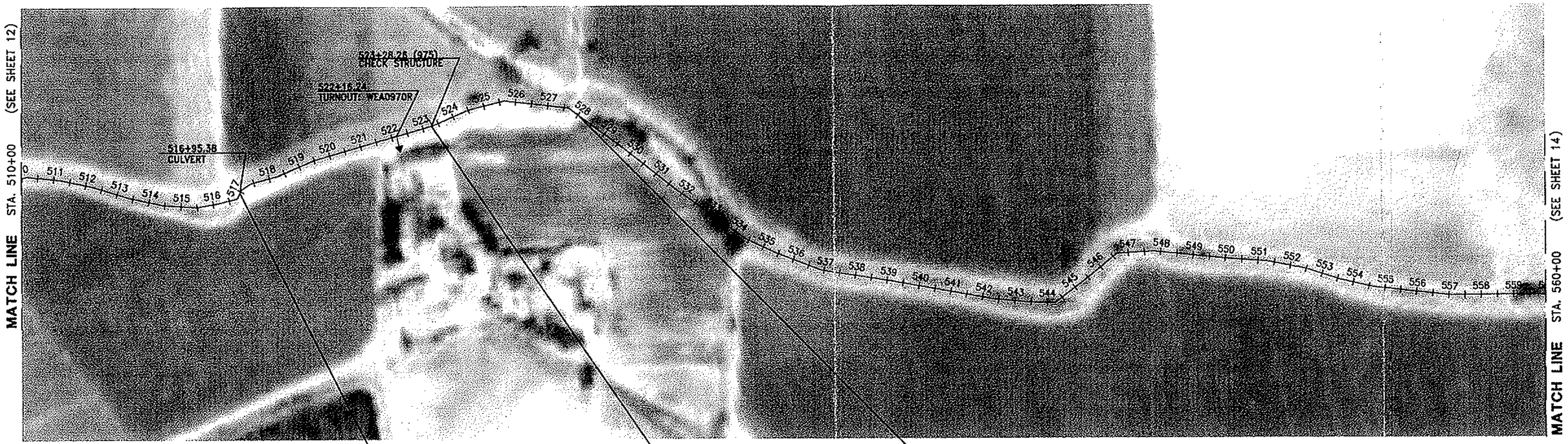

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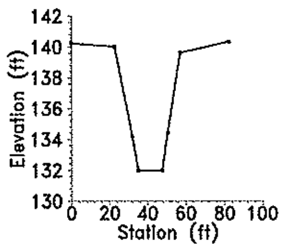

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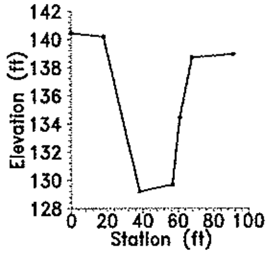

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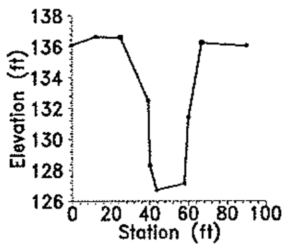

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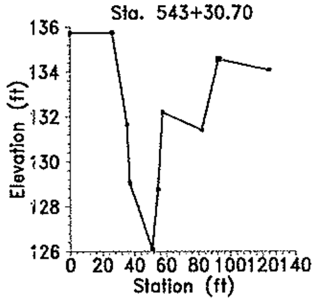

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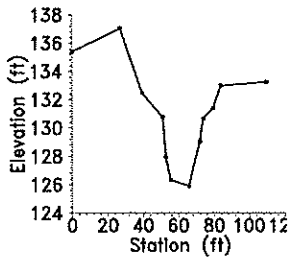

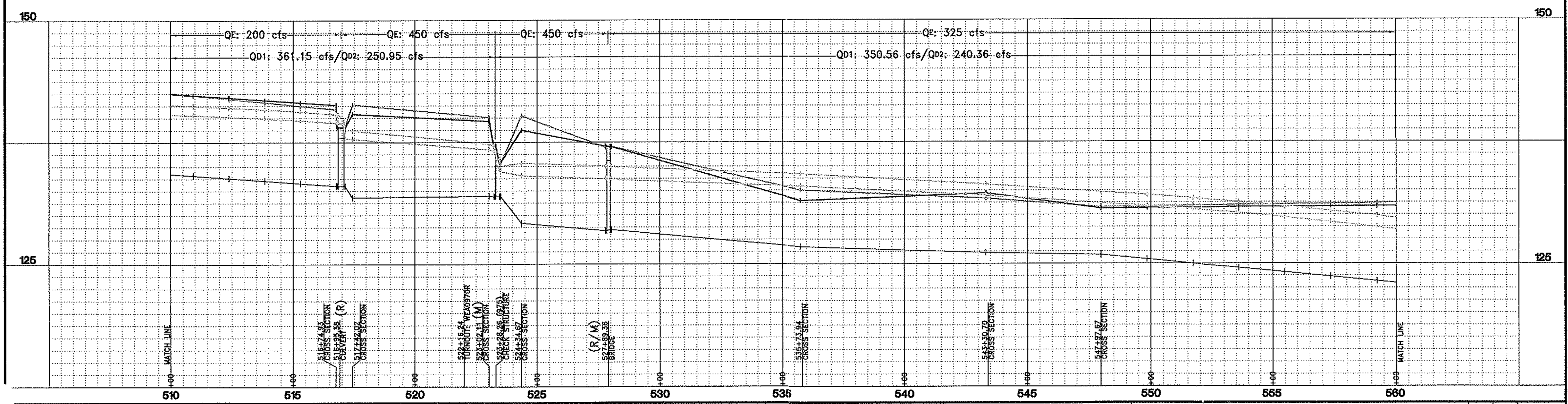

REVISIONS NO.	DESCRIPTION	DATE	BY

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YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
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STA. 510+00 TO STA. 560+00

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32

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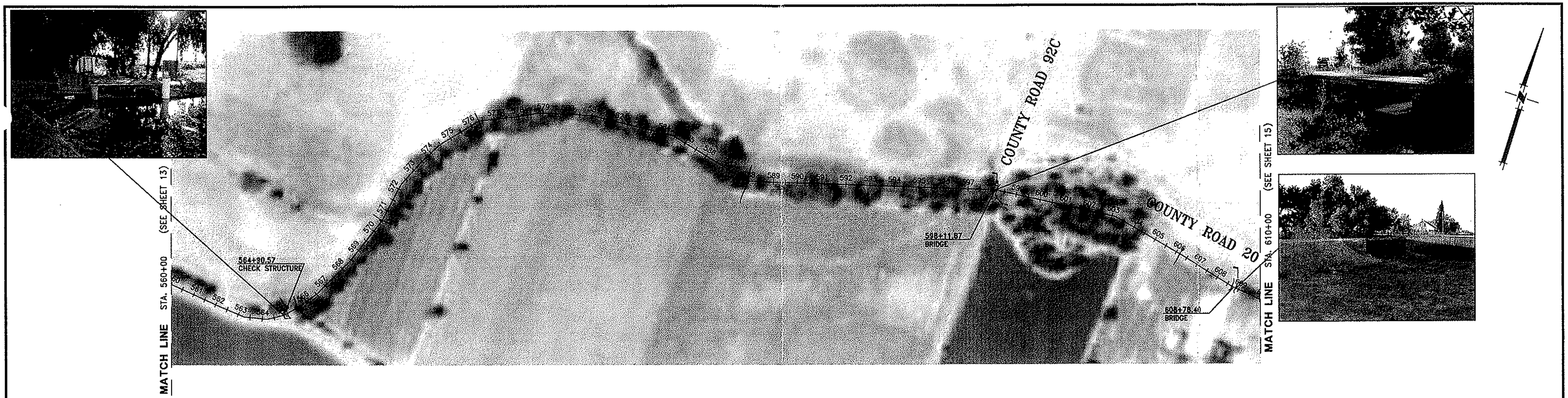

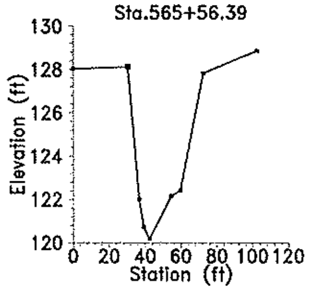

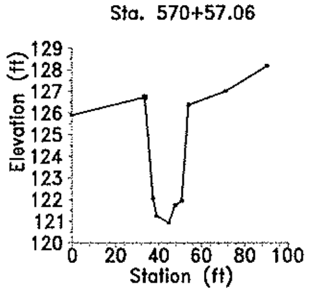

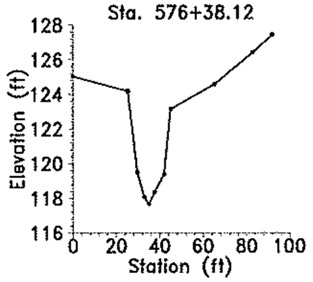

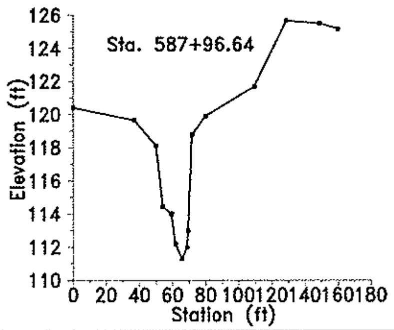

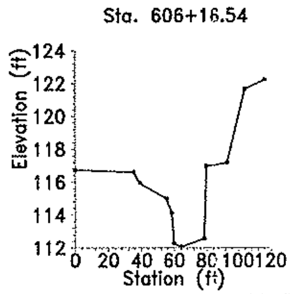

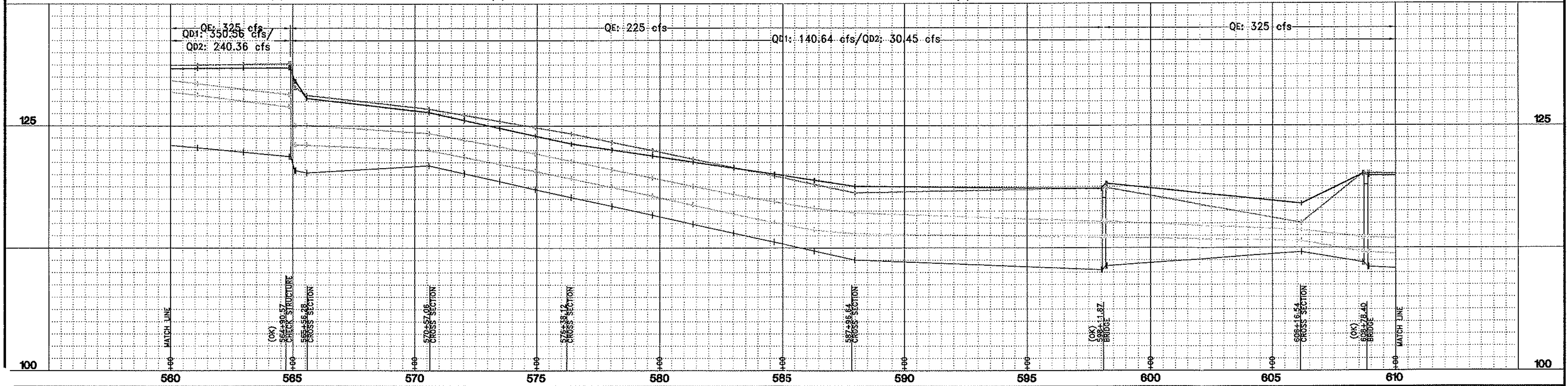

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YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

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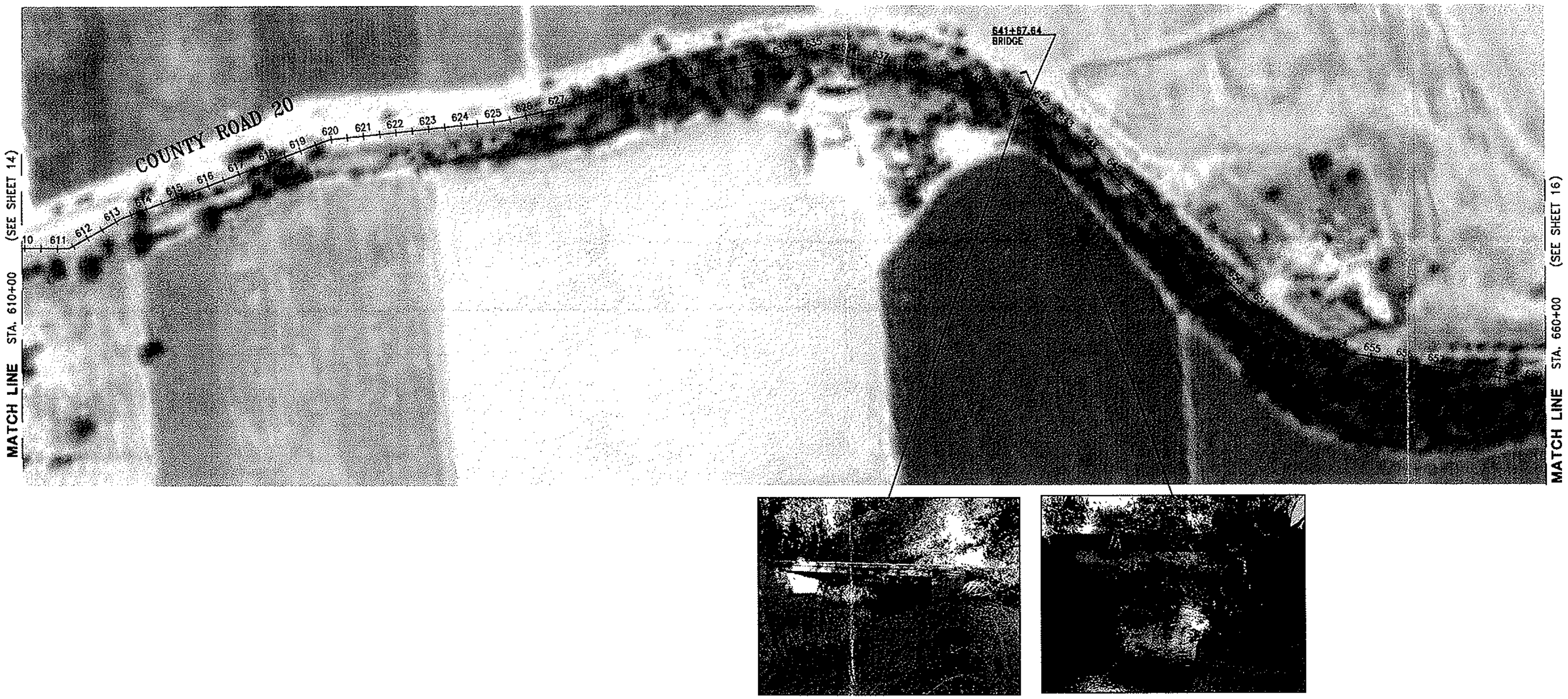

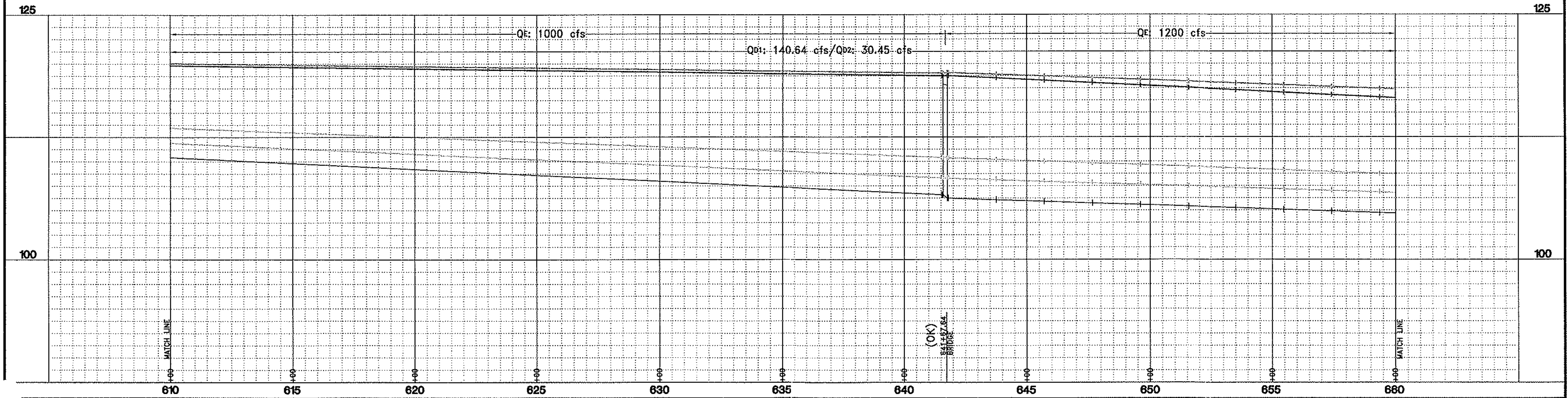

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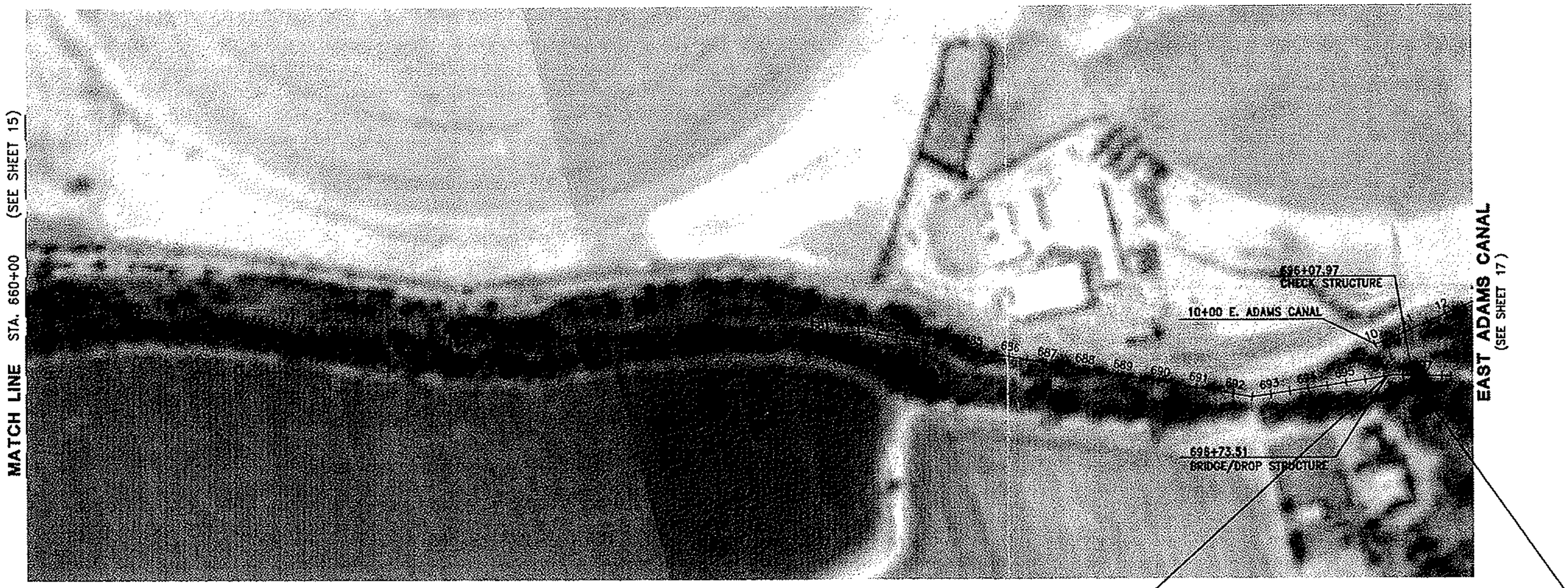
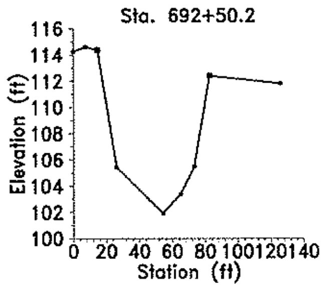
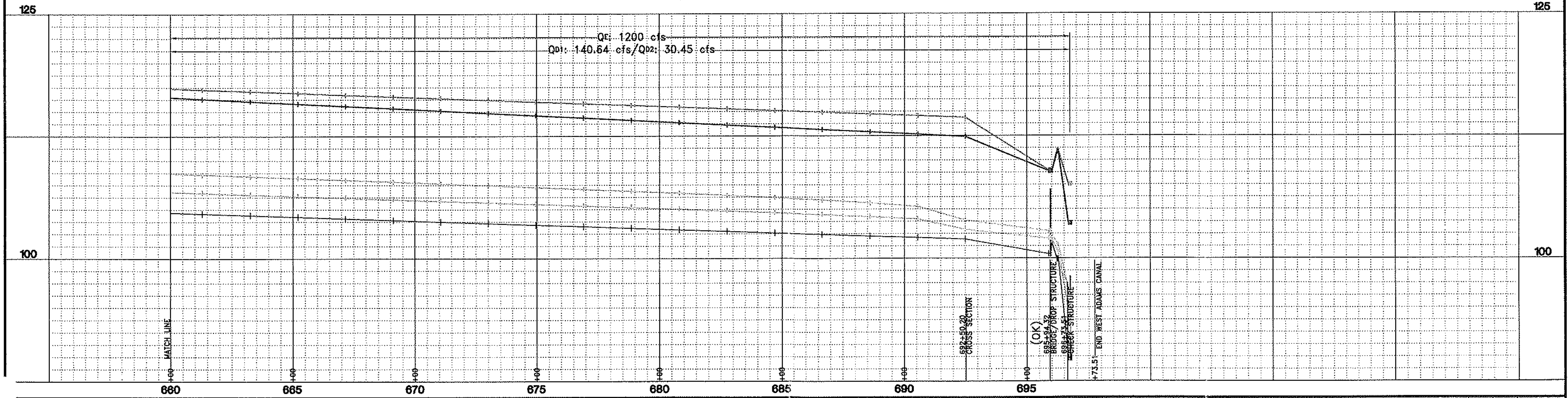
OF
32

J:\Jobs\8108-YCFC_WCD\W_Adams_Canal\Acad\Civil\Dwg\FDP\FDP_C15-PP13-WAC.dwg 7/17/03 9:06pm lcurd







REVISIONS

NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE 9-20-02
DESIGNED BY:
R.C.E. DATE
CHECKED BY:
R.C.E. DATE

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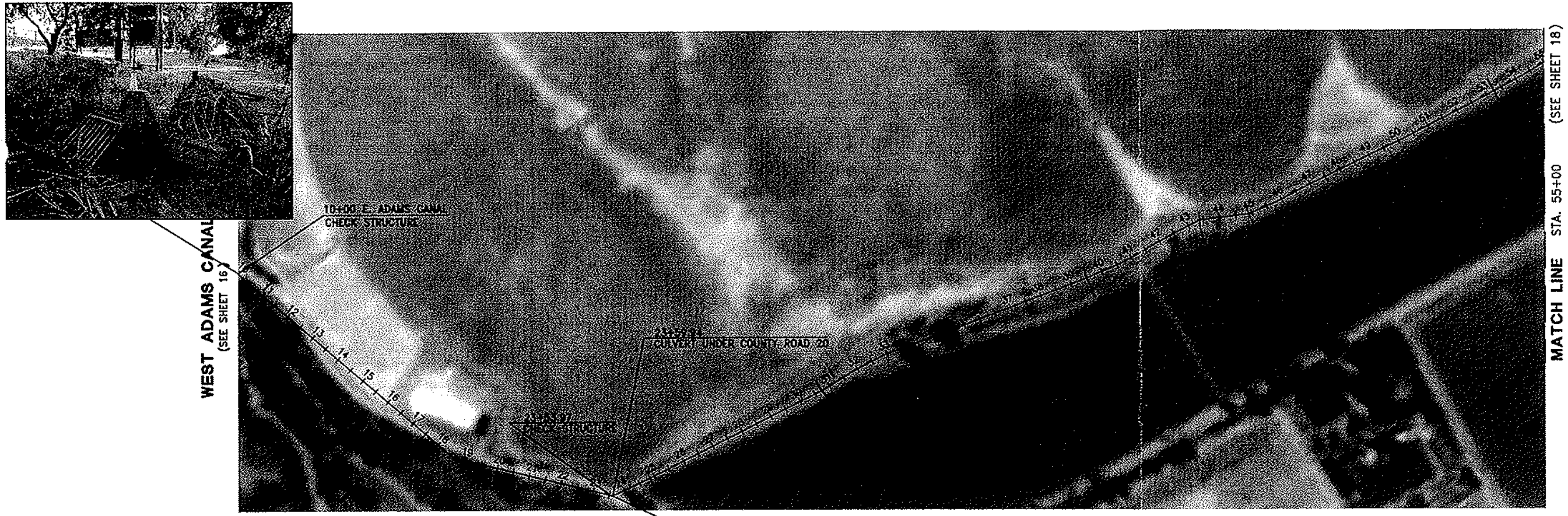
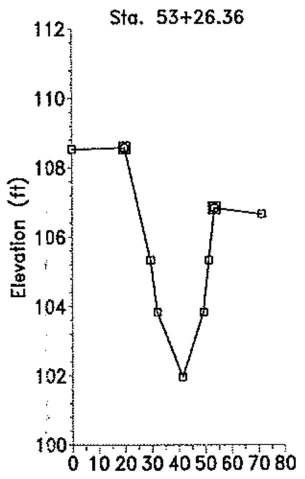
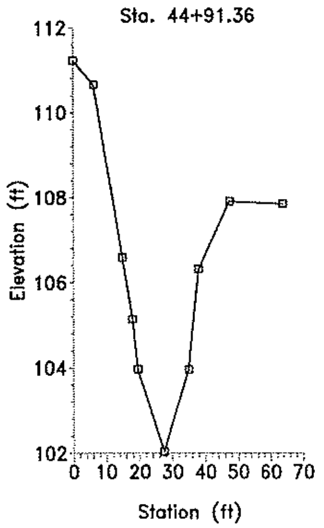
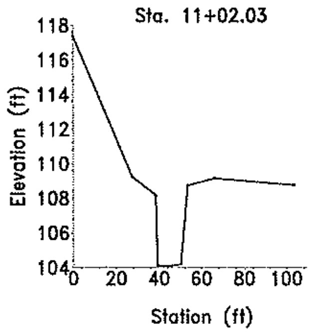
YCFCWCD/YZWD CONJUNCTIVE WATER USE FEASIBILITY STUDY
WEST ADAMS CANAL - DEMAND FLOW
PLAN AND PROFILE
STA. 660+00 TO STA. 697+73.51

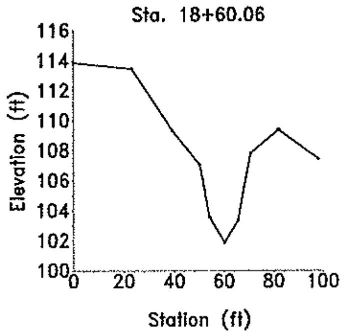
SHEET
16
OF
32

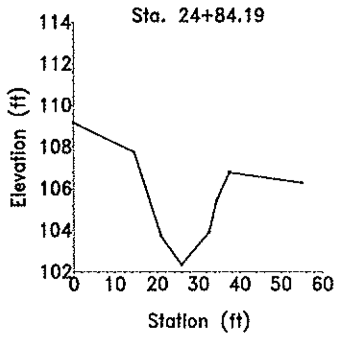


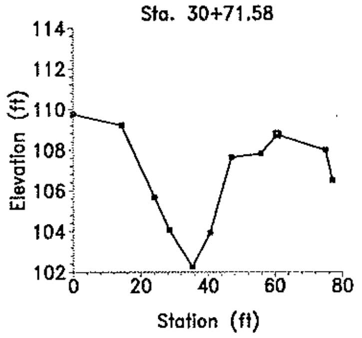


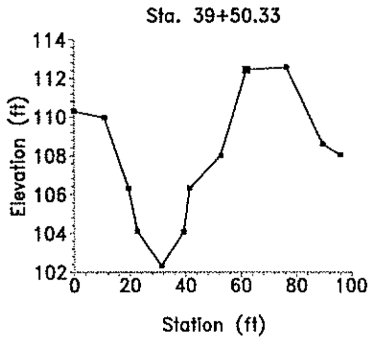


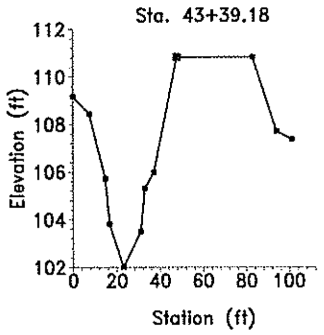


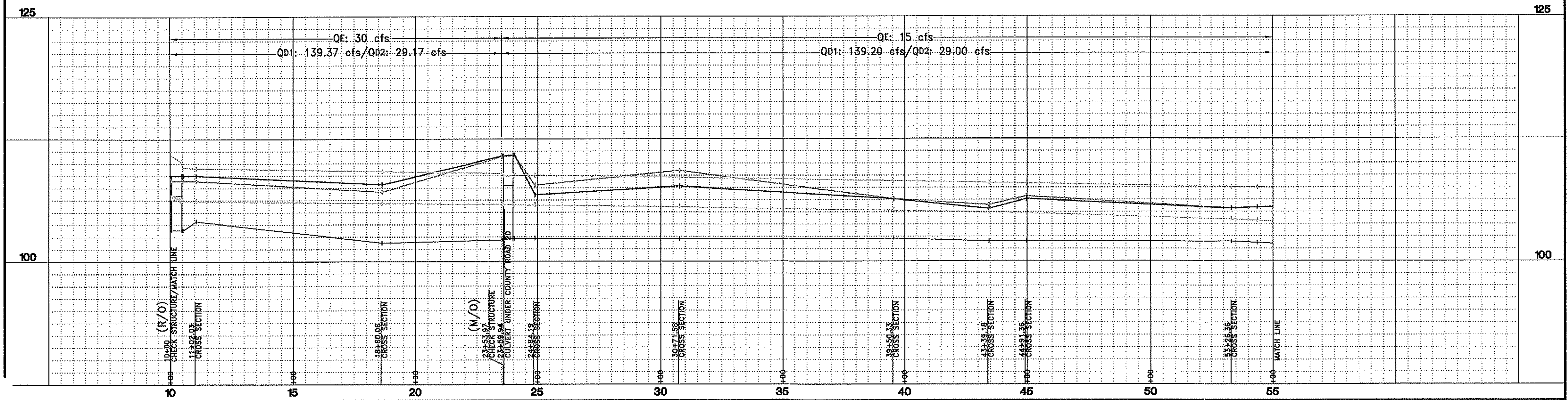












REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1"=10'

YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE 9-25-02 DATE
DESIGNED BY: ______
R.C.E. ______ DATE ______
CHECKED BY: ______
R.C.E. ______ DATE ______

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YCFCWCD/YZWD CONJUNCTIVE WATER USE FEASIBILITY STUDY
EAST ADAMS CANAL - DEMAND FLOW
PLAN AND PROFILE
STA. 10+00 TO STA. 55+00

SHEET
17
— OF —
32

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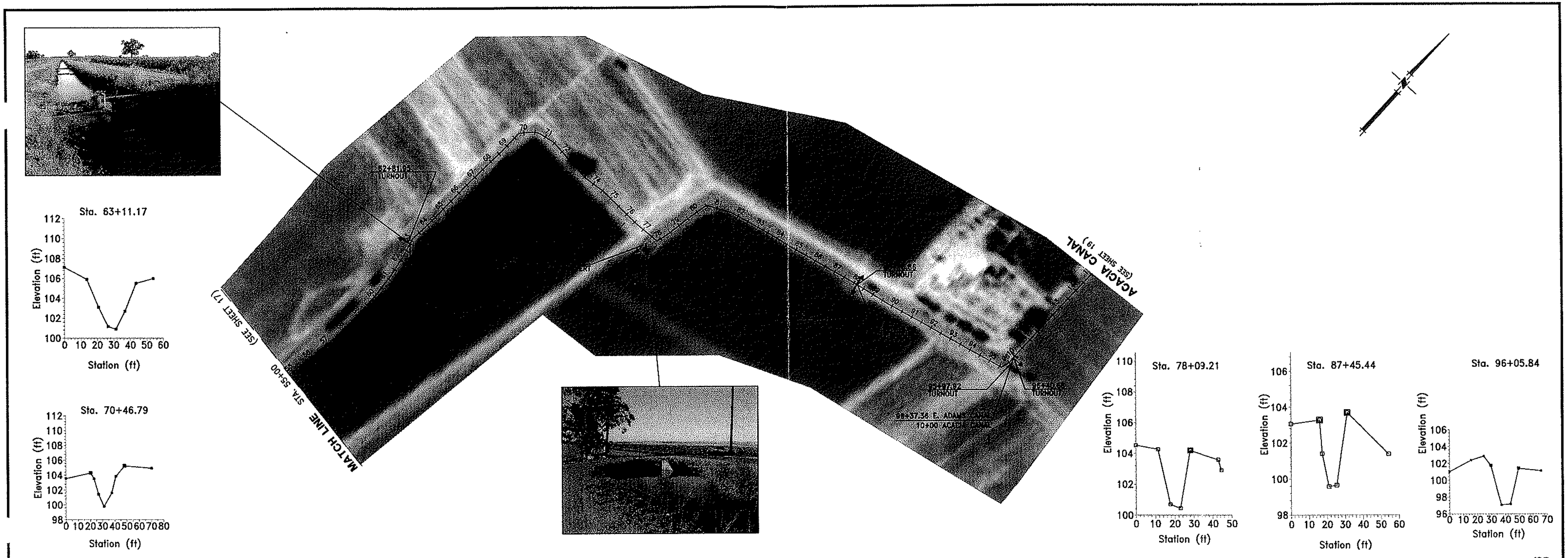

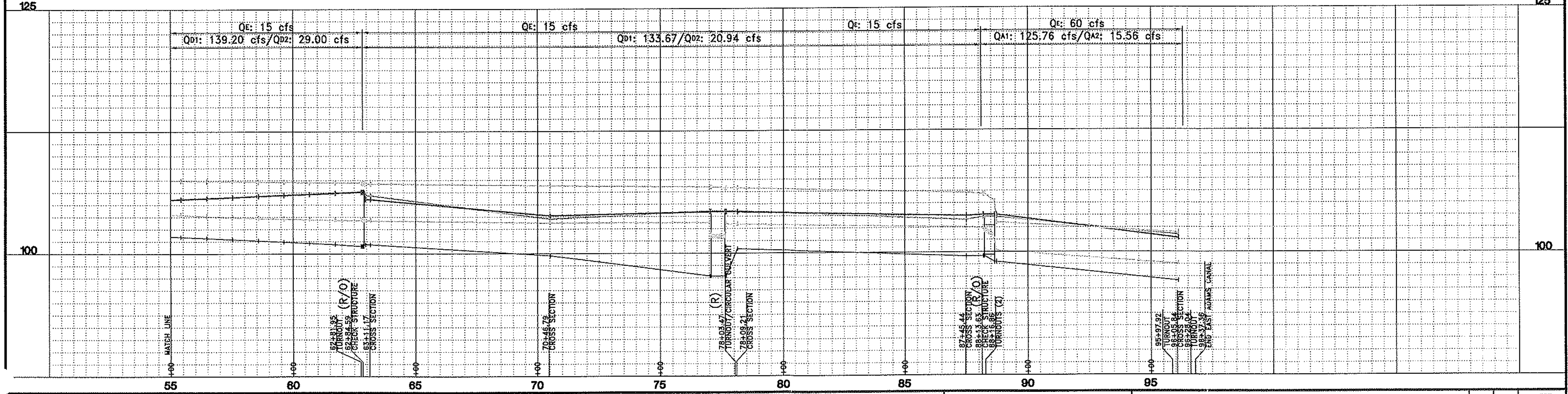

REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC/SF
DATE 9-28-02 DATE
DESIGNED BY: ______
R.C.E. ______ DATE ______
CHECKED BY: ______
R.C.E. ______ DATE ______

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EAST ADAMS CANAL - DEMAND FLOW
PLAN AND PROFILE
STA. 55+00 TO STA. 97+37.36

SHEET
18
OF
32

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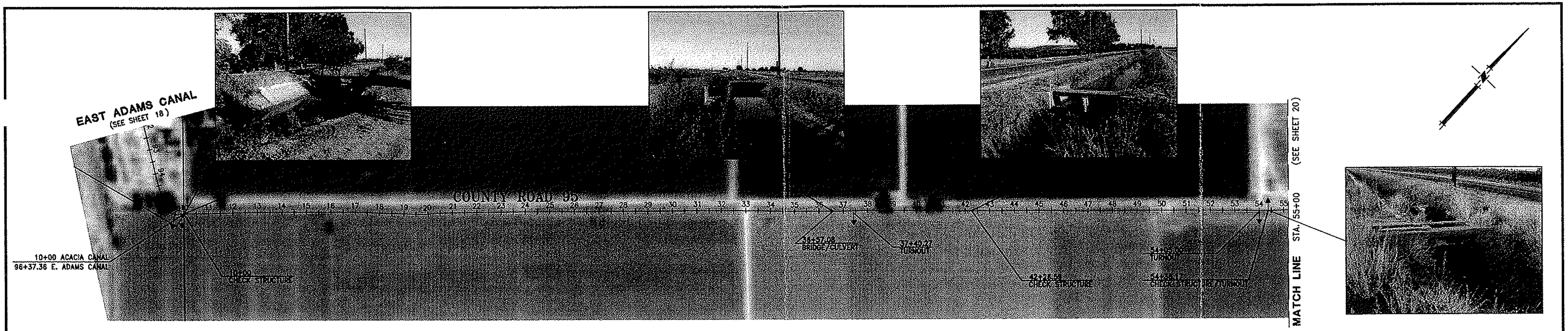

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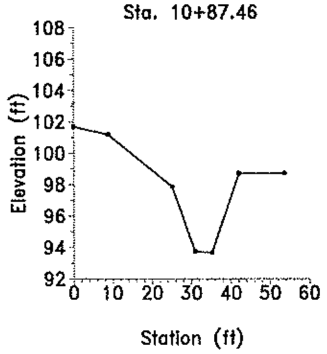

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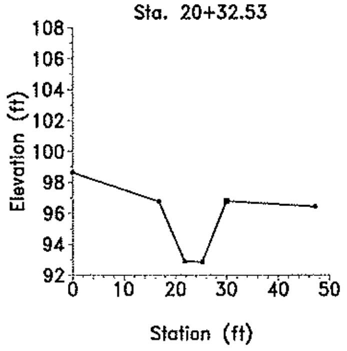

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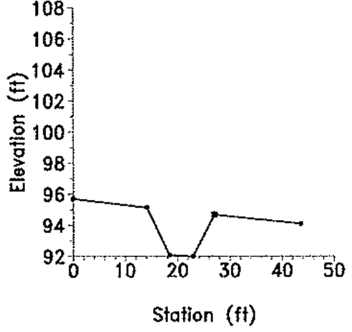

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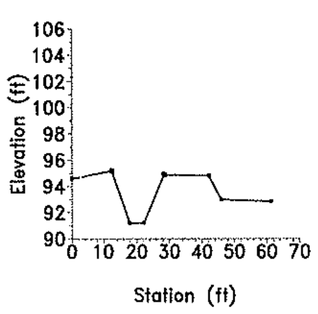

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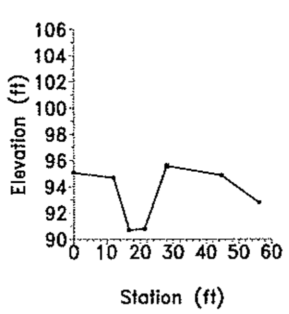

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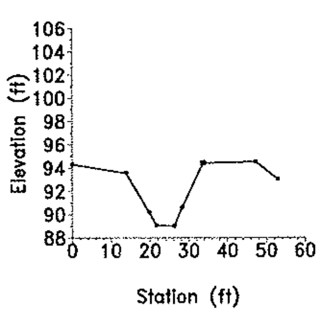

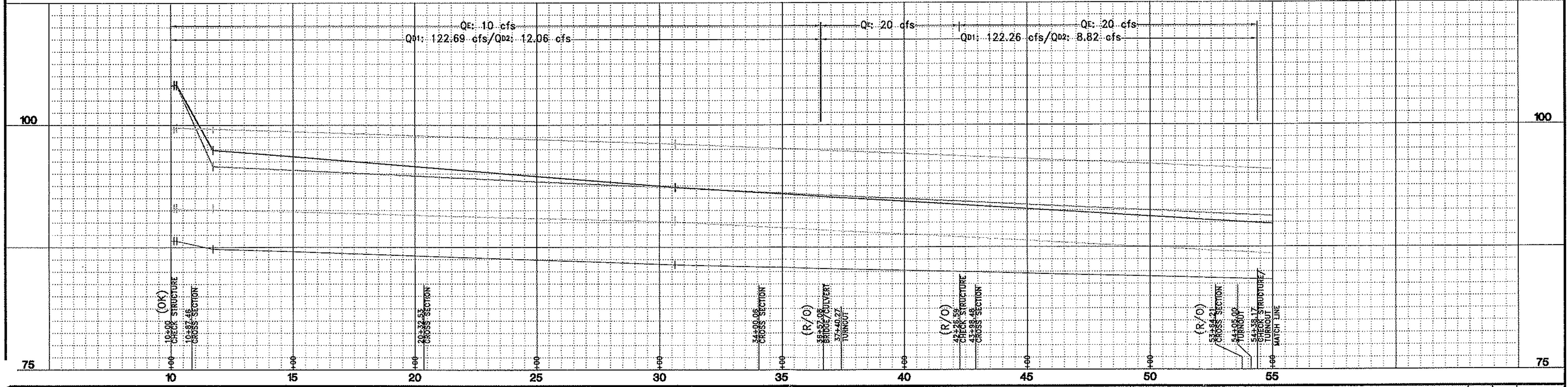

REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ________
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC/SE
DATE 9-25-02 DATE
DESIGNED BY: ________
R.C.E. ________ DATE ________
CHECKED BY: ________
R.C.E. ________ DATE ________

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ACACIA CANAL - DEMAND FLOW
PLAN AND PROFILE
STA. 10+00 TO STA. 55+00

SHEET
19
— OF —
32

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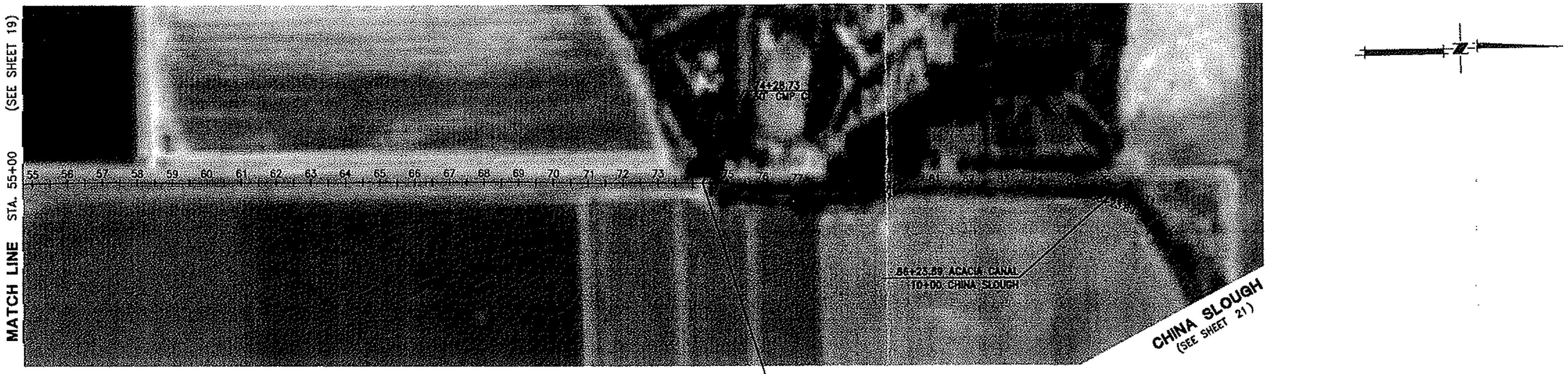

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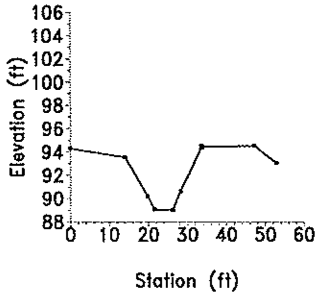

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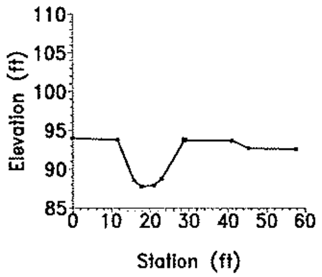

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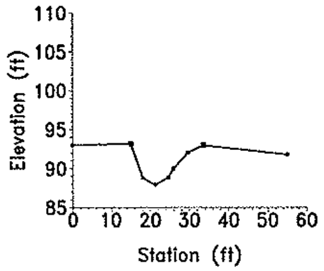

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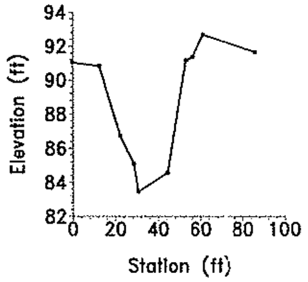

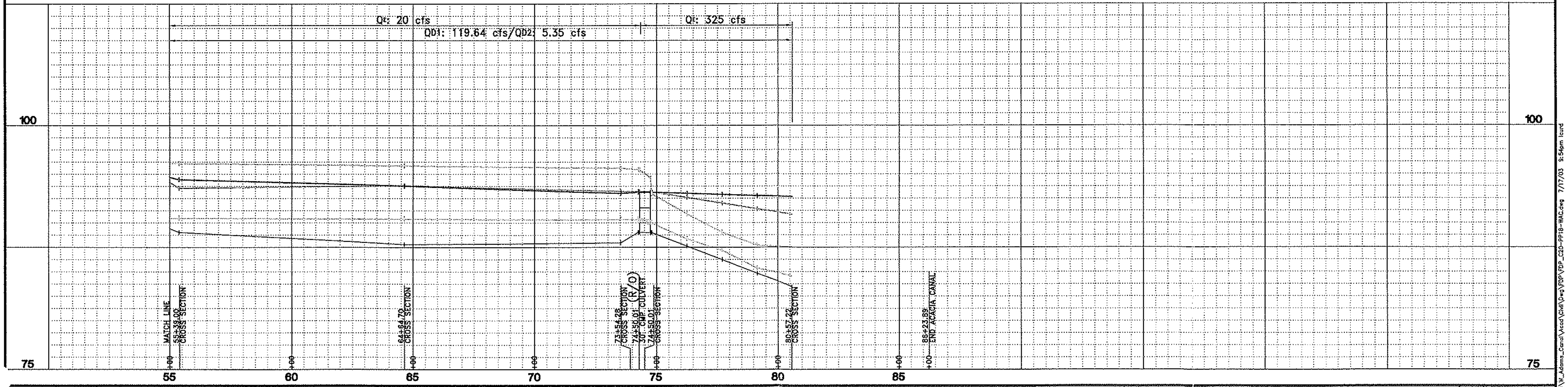

REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1"=10'

YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC/SE
DATE 9-25-02 DATE
DESIGNED BY: ______
R.C.E. ______ DATE ______
CHECKED BY: ______
R.C.E. ______ DATE ______

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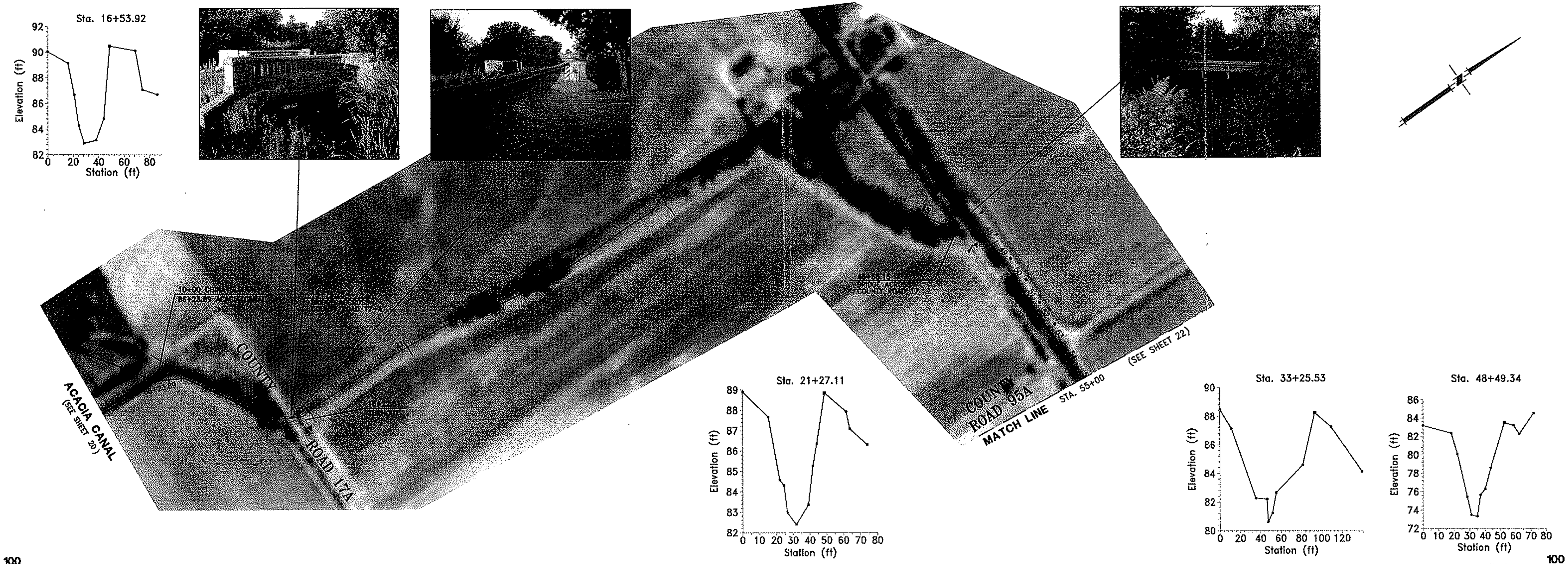
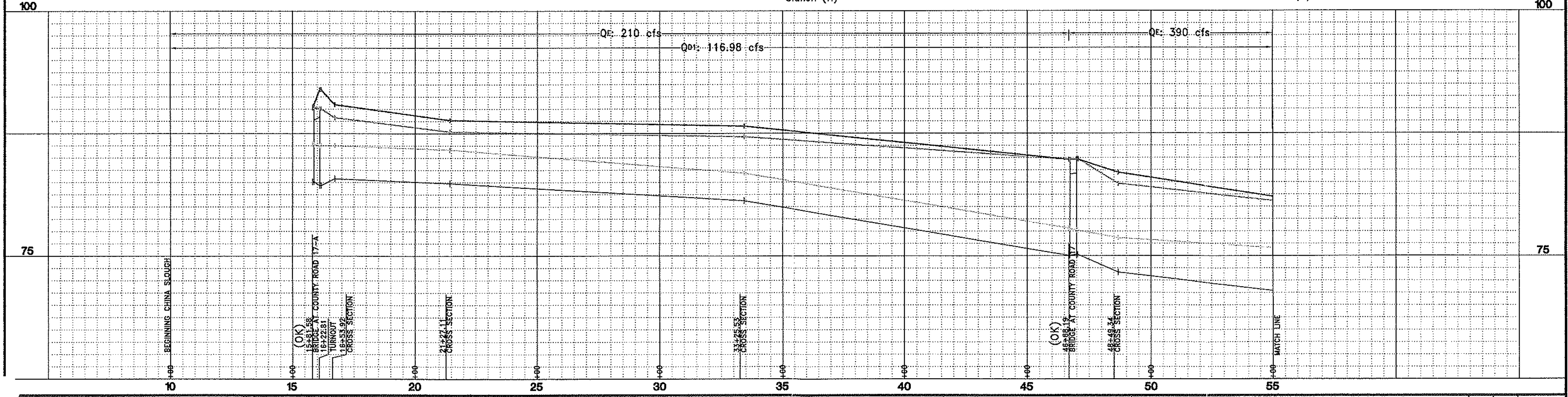
ACACIA CANAL - DEMAND FLOW
PLAN AND PROFILE
STA. 55+00 TO STA. 86+23.89

SHEET
20
OF
32





NO.	REVISIONS DESCRIPTION	DATE	BY

BENCHMARK ELEV. ________
DESCRIPTION:

(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC/SE
DATE 9-25-02 DATE

DESIGNED BY: ________
R.C.E. ________ DATE ________

CHECKED BY: ________
R.C.E. ________ DATE ________

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CHINA SLOUGH - DEMAND FLOW
STA. 10+00 TO STA. 55+00

SHEET
21
OF
32

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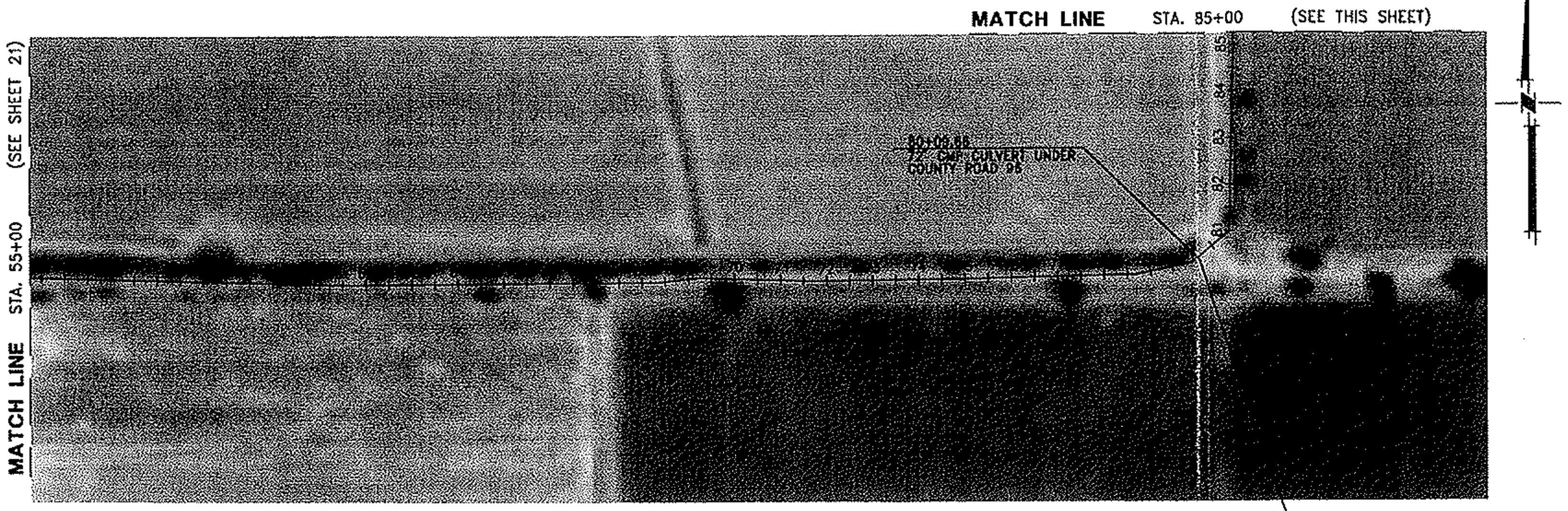

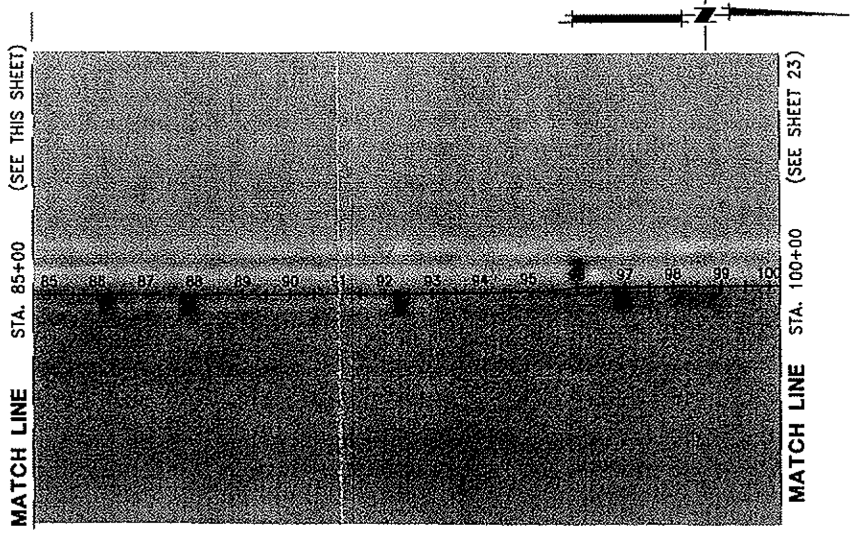

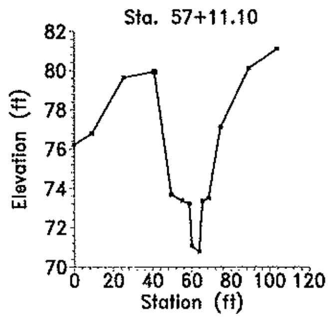

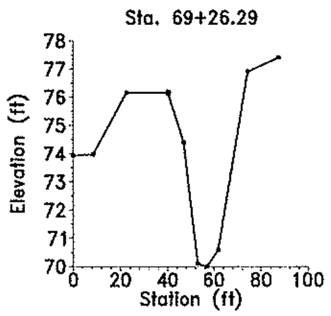

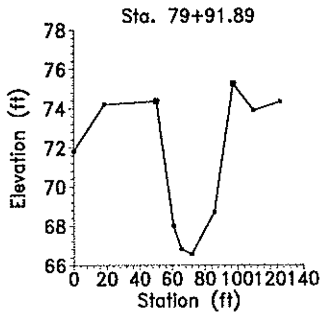

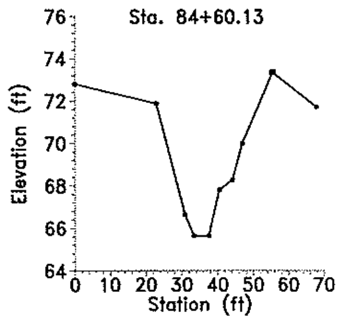

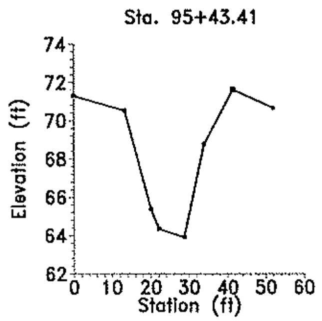

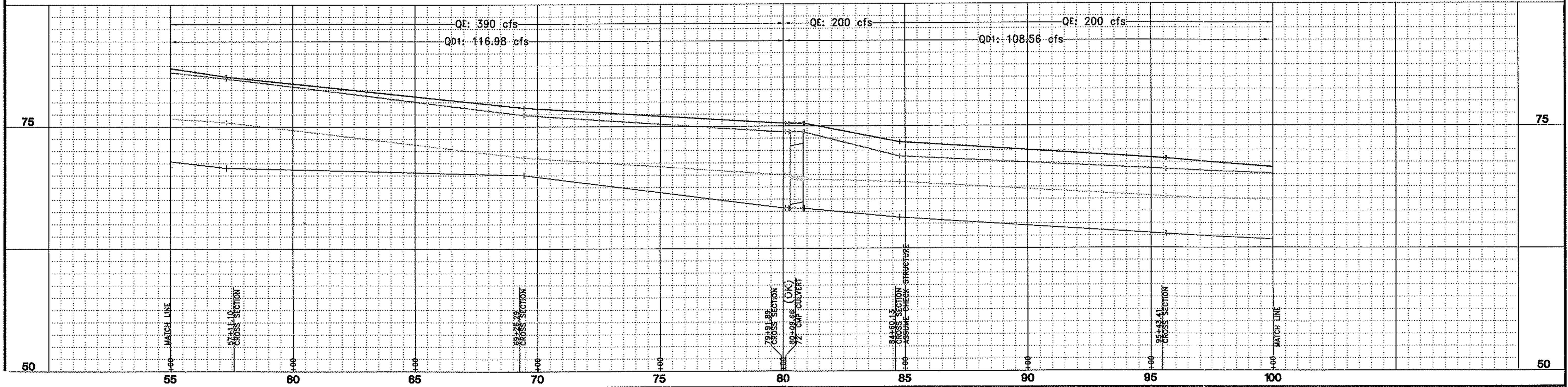

REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
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YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC/SE
DATE 9-25-02 DATE

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CHECKED BY:
R.C.E. ______ DATE ______

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CHINA SLOUGH - DEMAND FLOW
PLAN AND PROFILE
STA. 55+00 TO STA. 100+00

SHEET
22
— OF —
32

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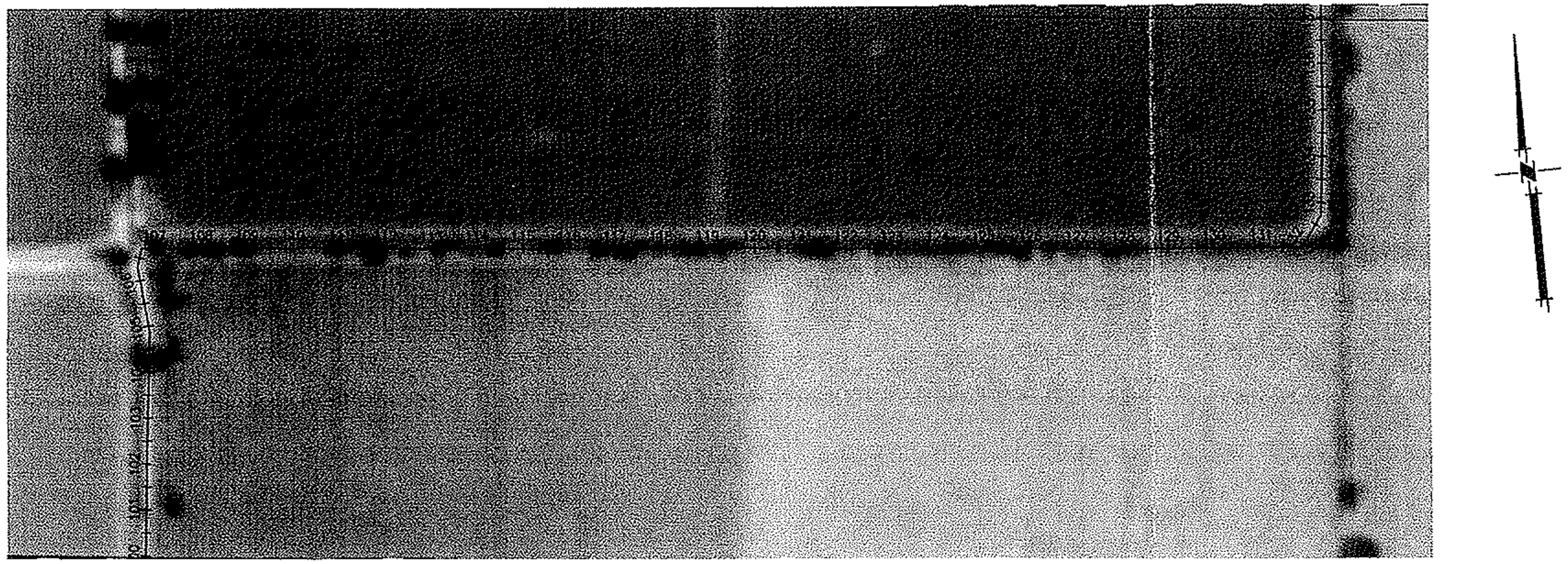
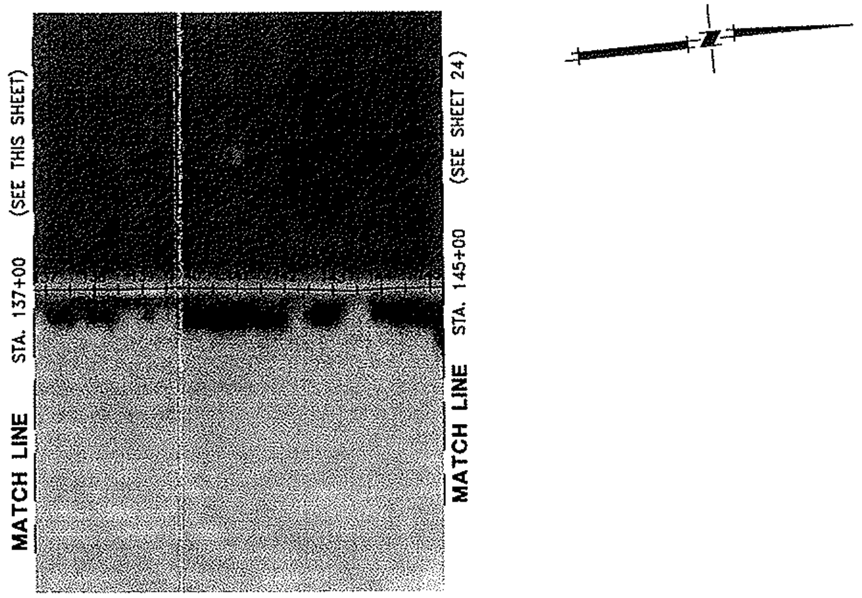
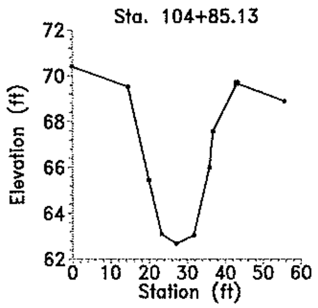
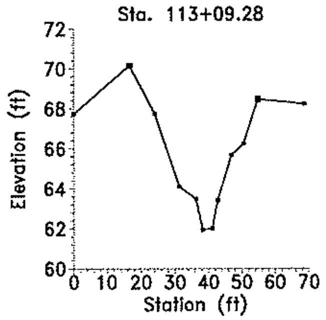
MATCH LINE STA. 137+00 (SEE THIS SHEET)

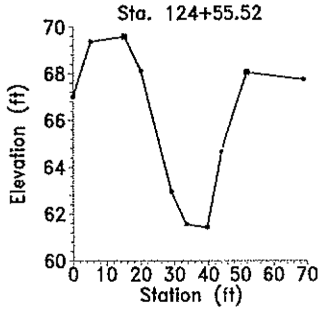


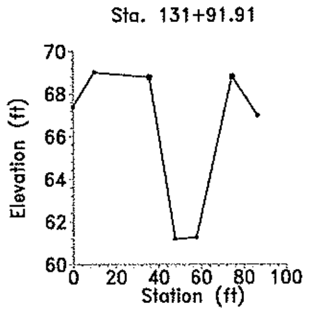
MATCH LINE STA. 100+00 (SEE SHEET 22)

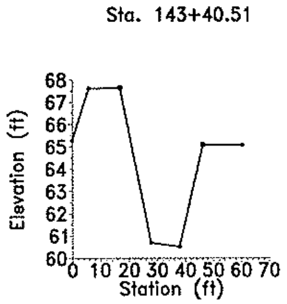


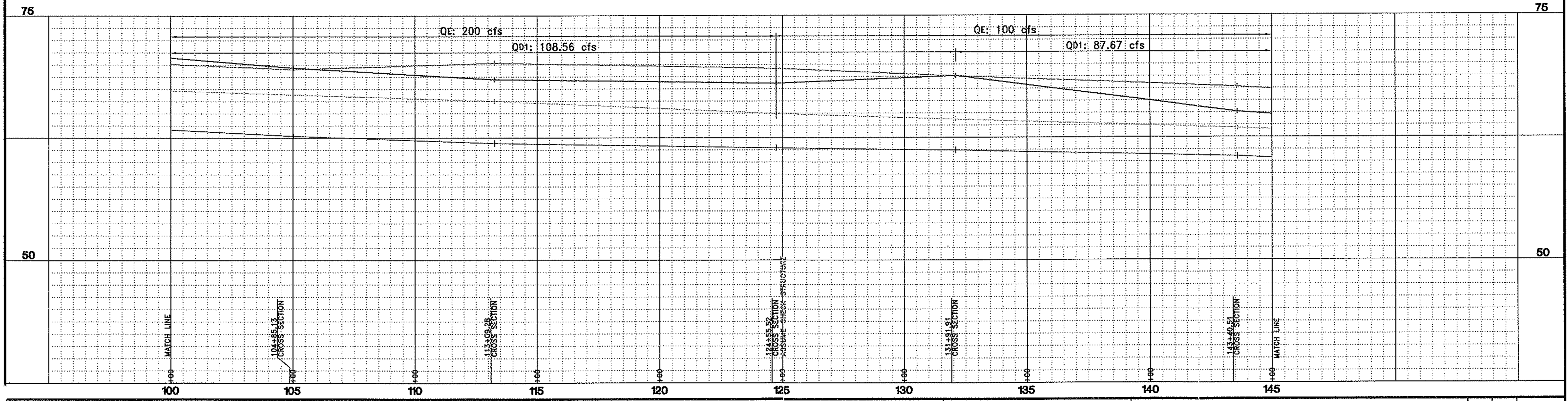












NO.	REVISIONS DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC/SE
DATE 9-25-02 DATE

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CHINA SLOUGH - DEMAND FLOW
PLAN AND PROFILE
STA. 100+00 TO STA. 145+00

SHEET
23
OF
32

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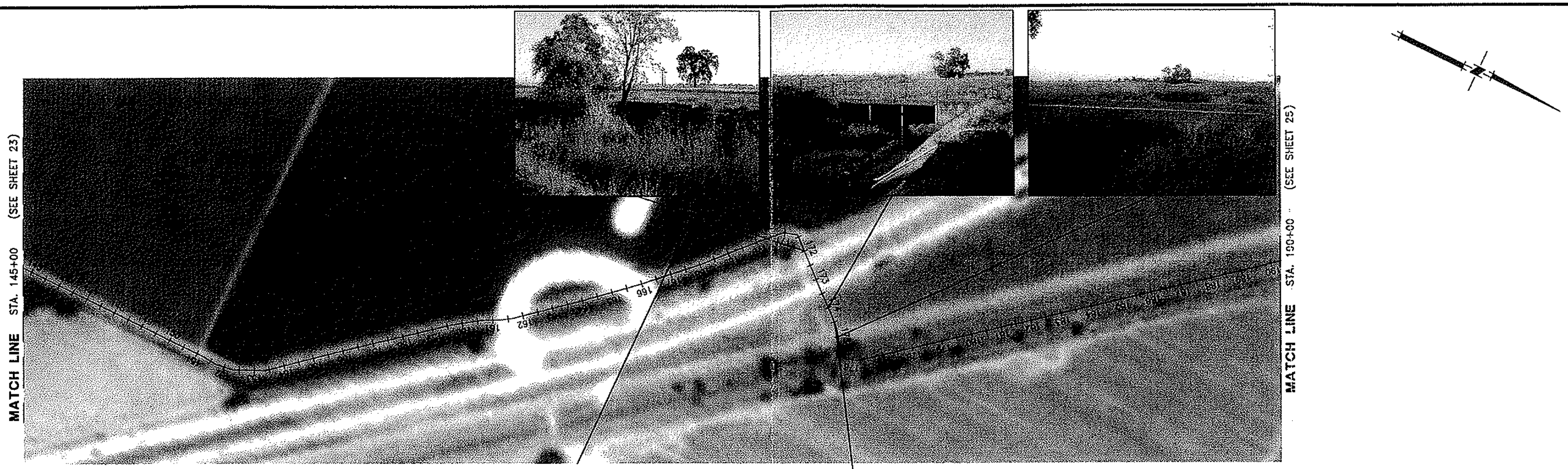

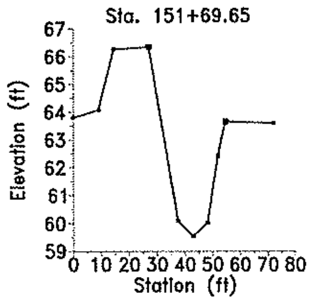

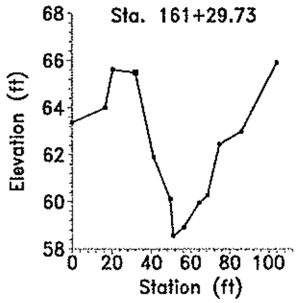

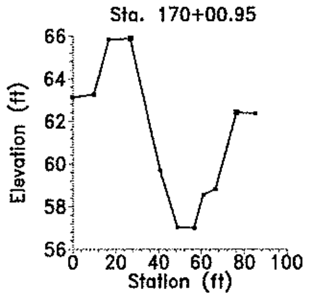

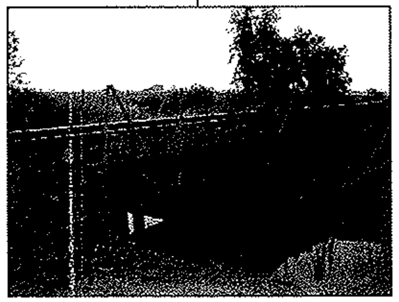

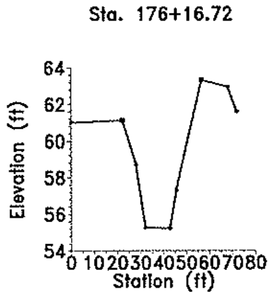

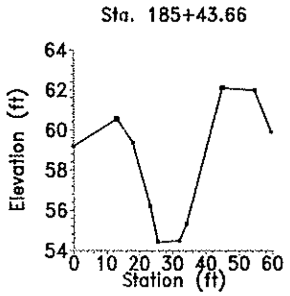

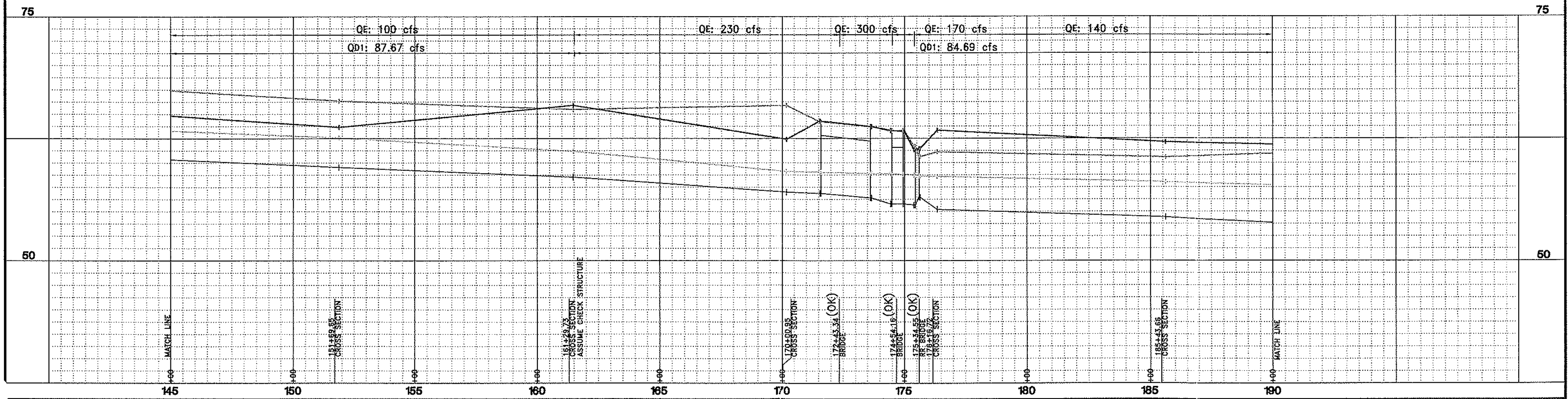

NO.	REVISIONS DESCRIPTION	DATE	BY

BENCHMARK ELEV. ________
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC/SE
DATE 9-25-02 DATE
DESIGNED BY: ________
R.C.E. ________ DATE ________
CHECKED BY: ________
R.C.E. ________ DATE ________

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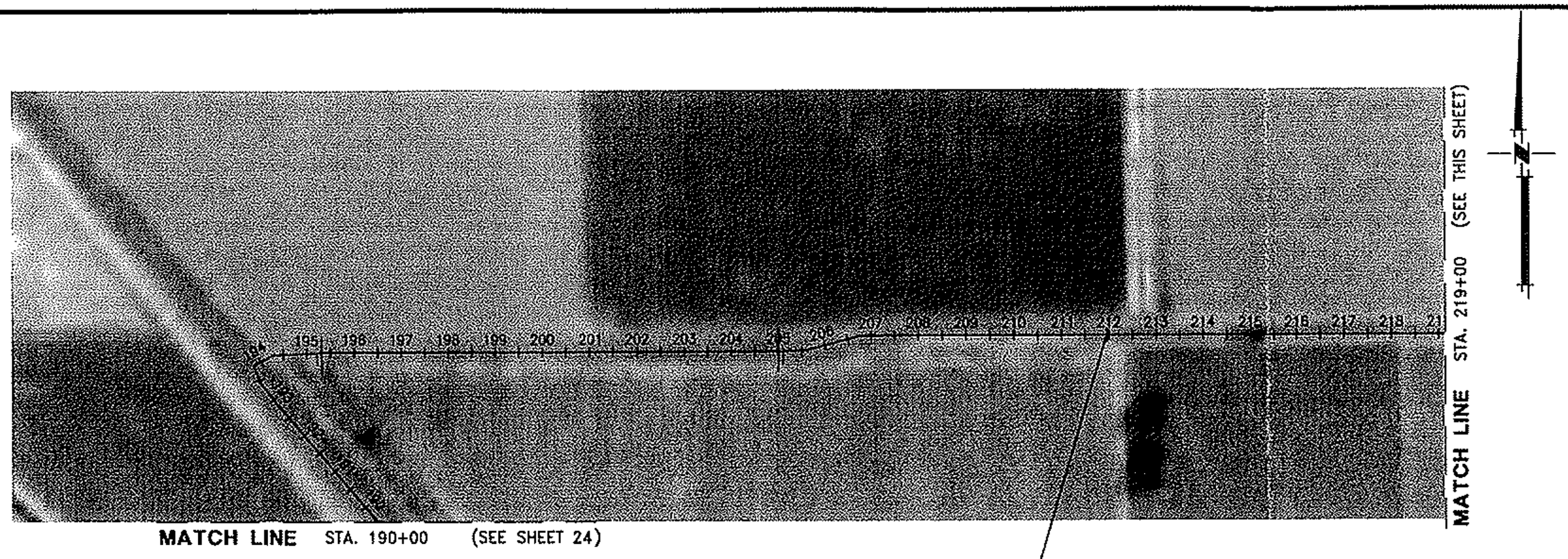
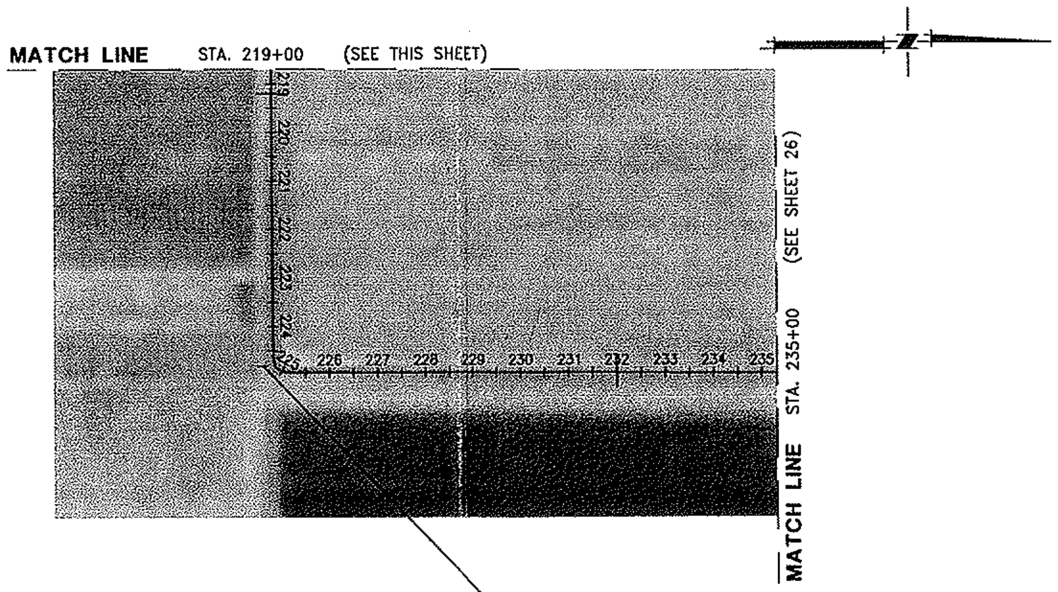
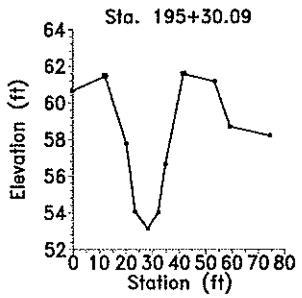
CHINA SLOUGH - DEMAND FLOW
PLAN AND PROFILE
STA. 145+00 TO STA. 190+00

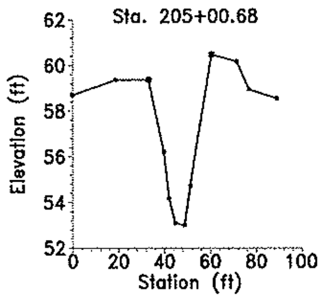
SHEET
24
— OF —
32

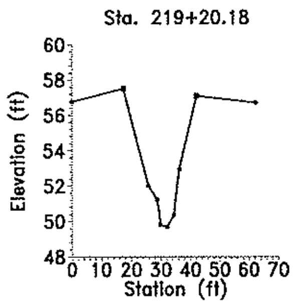
J:\Jobs\8108-YCFC_WCD\W_Adams_Canal\Acad\Civil\Dwg\FDP\FDP_C24-PP21-WAC.dwg 7/17/03 8:21pm lcurd

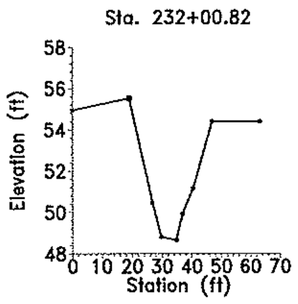


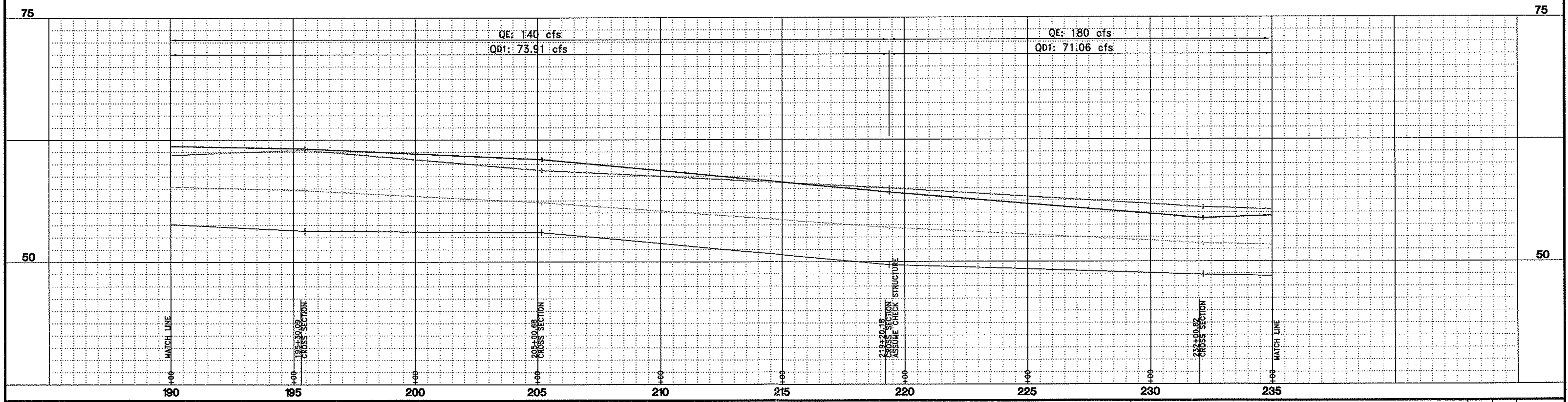












NO.	REVISIONS DESCRIPTION	DATE	BY

BENCHMARK ELEV. ________

DESCRIPTION:

(SEE SHEET NO. 1)

SCALE
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V: 1"=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

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CHINA SLOUGH - DEMAND FLOW
PLAN AND PROFILE
STA. 190+00 TO STA. 235+00

SHEET
25
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32

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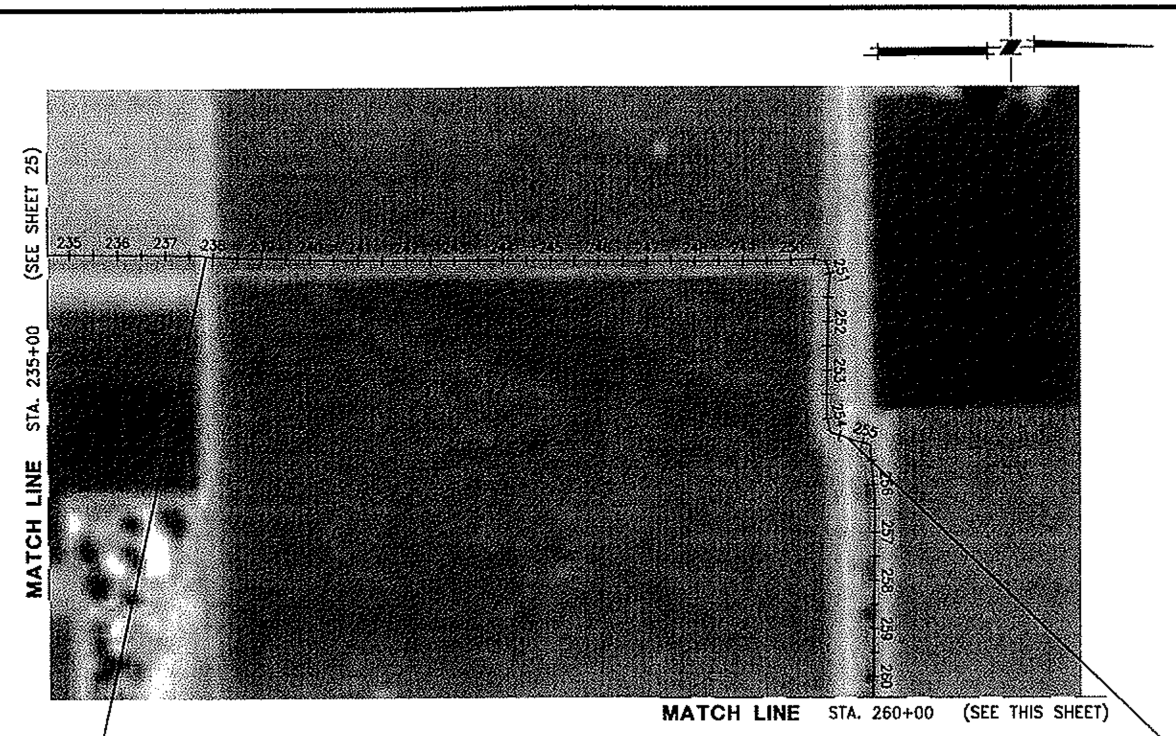

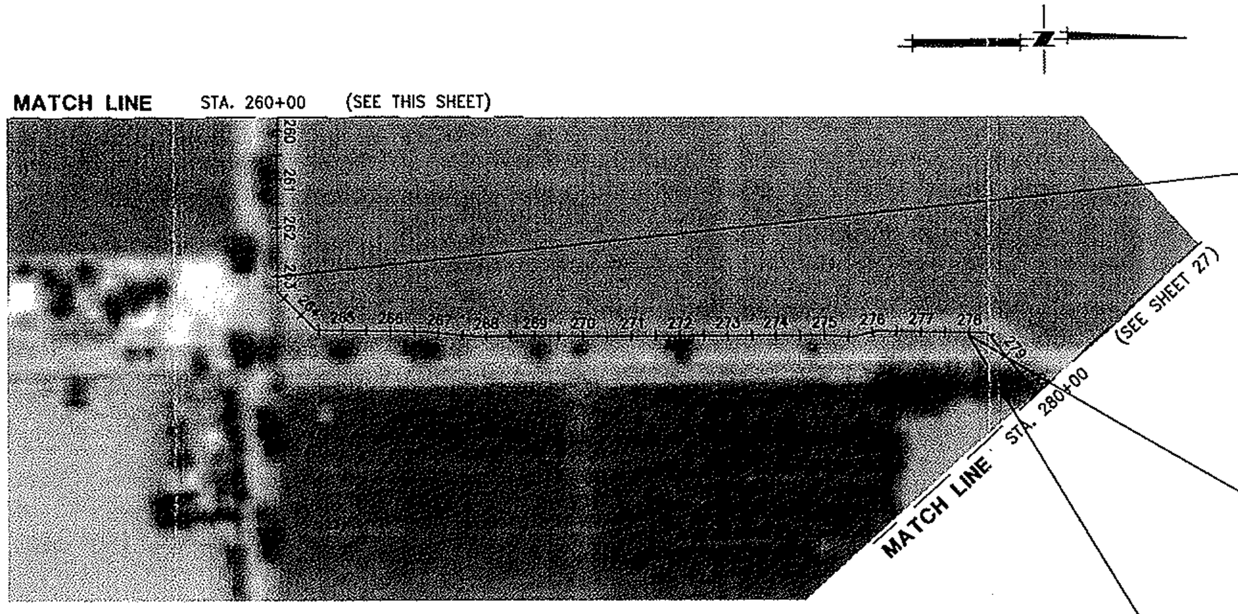

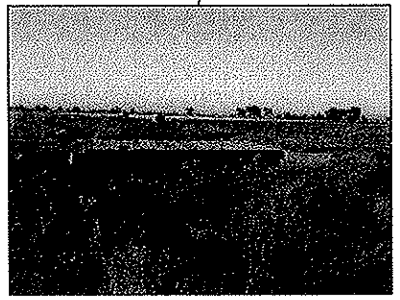

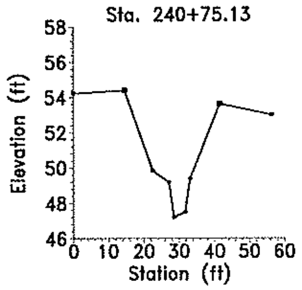

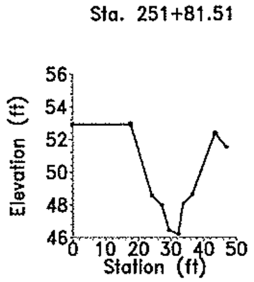

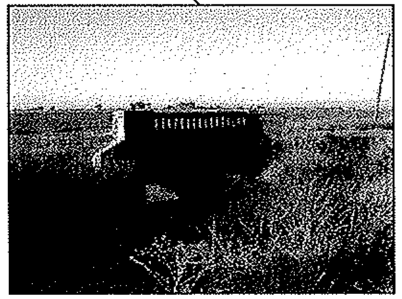

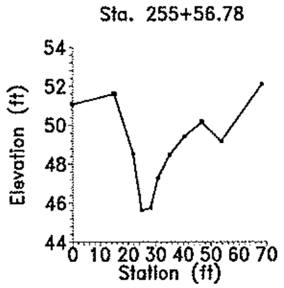

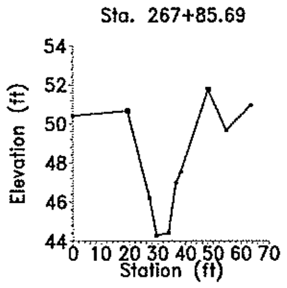

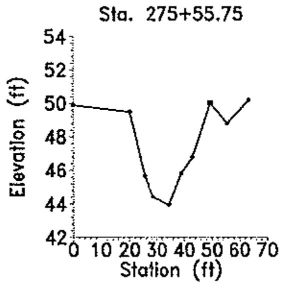

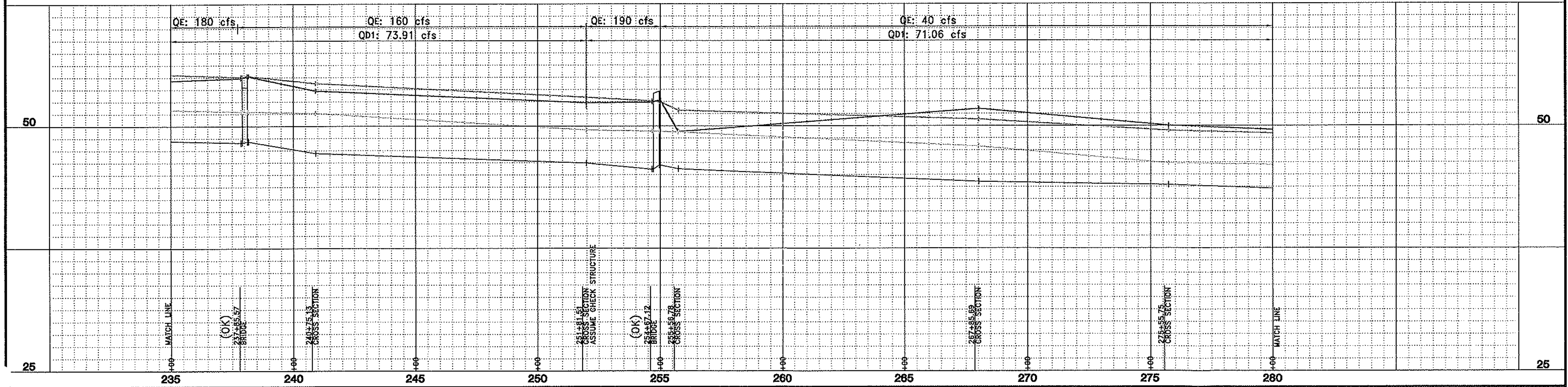

REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC/SE
DATE 9-25-02 DATE

DESIGNED BY: ______
R.C.E. ______ DATE ______

CHECKED BY: ______
R.C.E. ______ DATE ______

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CHINA SLOUGH - DEMAND FLOW
PLAN AND PROFILE
STA. 235+00 TO 280+00

SHEET
26
— OF —
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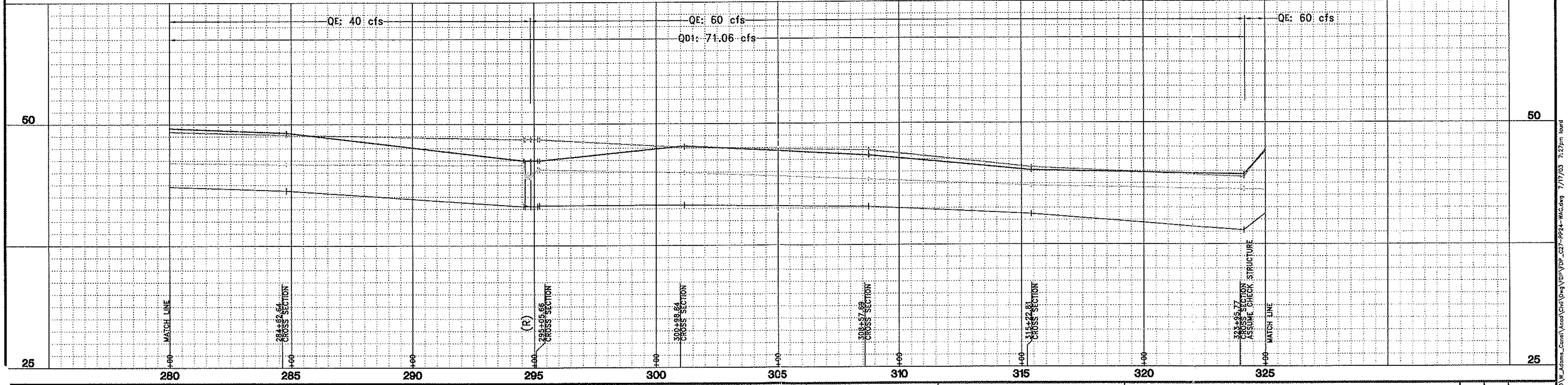

NO.	REVISIONS DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
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YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

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CHINA SLOUGH - DEMAND FLOW
PLAN AND PROFILE
STA. 280+00 TO STA. 325+00

SHEET
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OF
32

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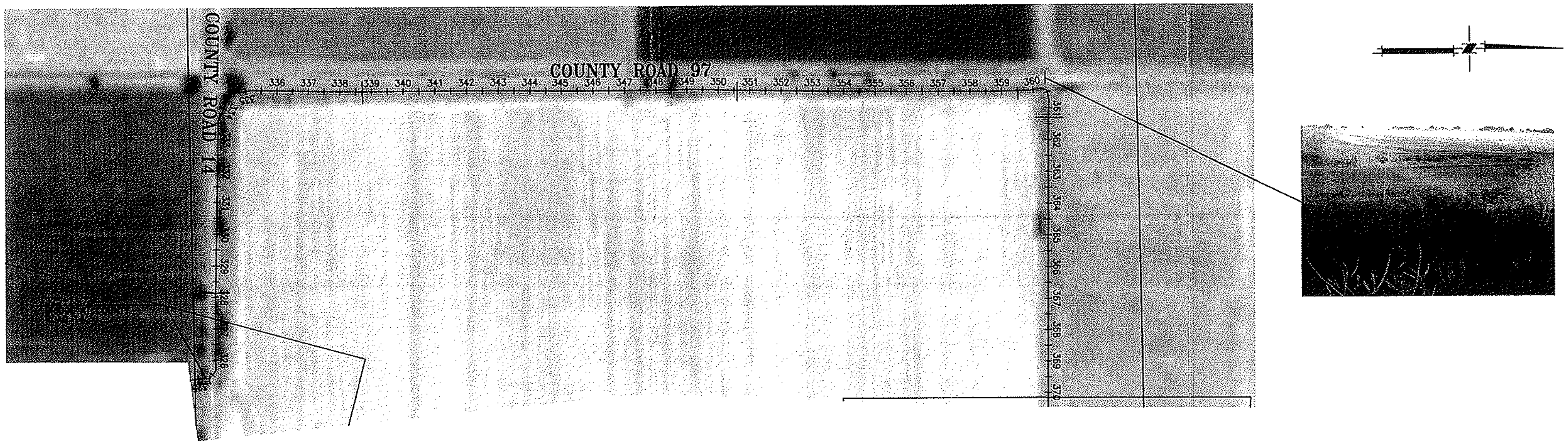

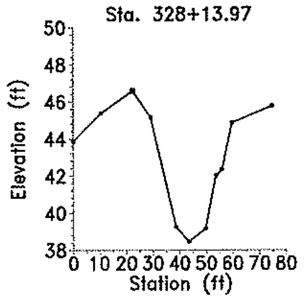
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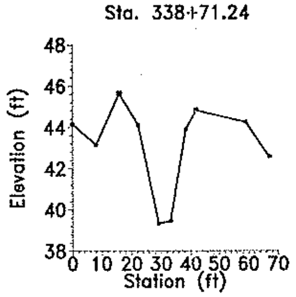
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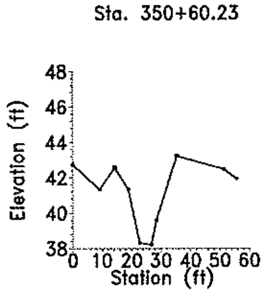
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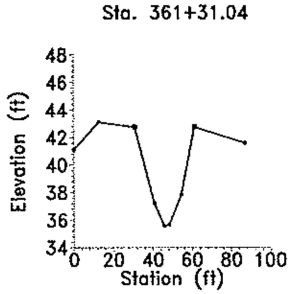
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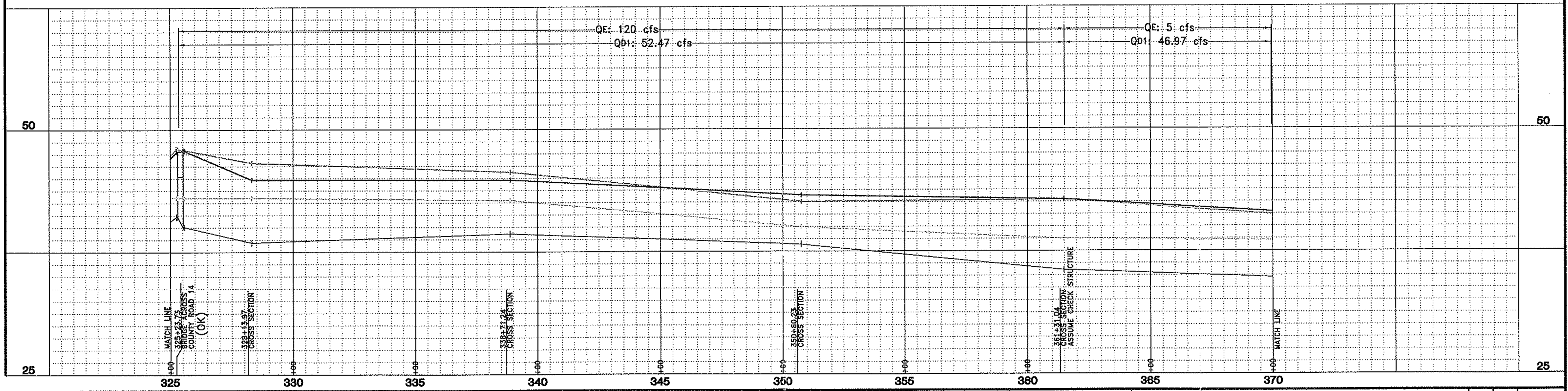

NO.	REVISIONS DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1"=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC/SE
DATE 9-25-02 DATE ______
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CHINA SLOUGH - DEMAND FLOW
PLAN AND PROFILE
STA. 325+00 TO STA. 370+00

SHEET
28
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32

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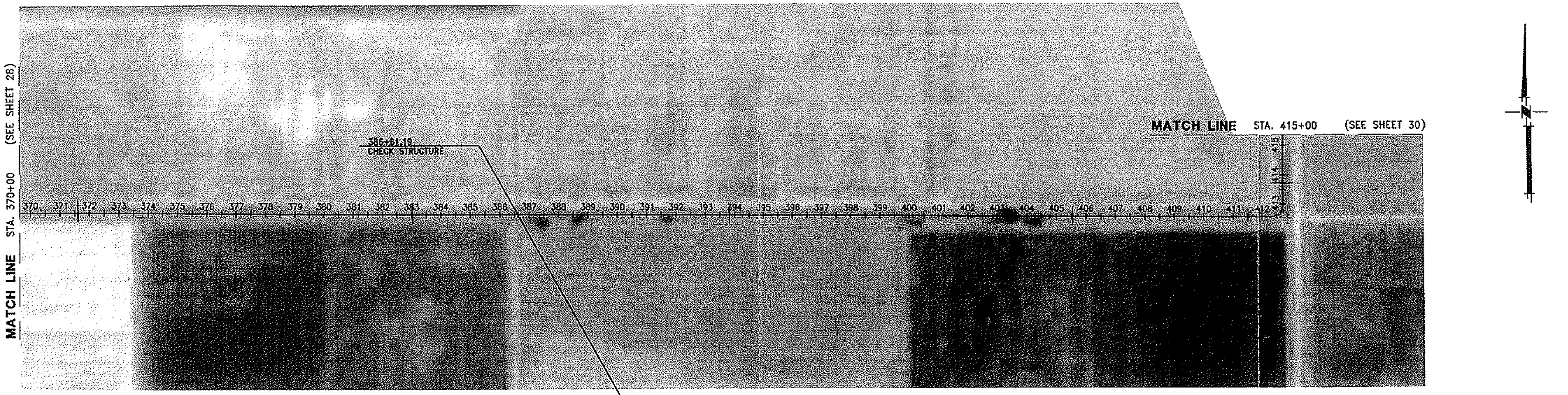

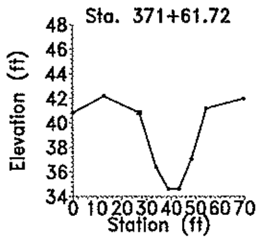

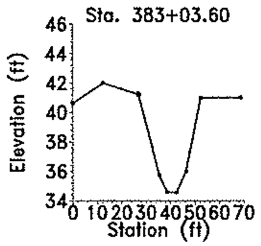

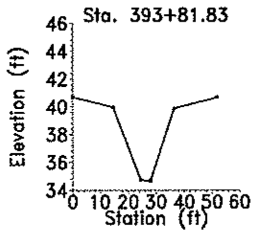

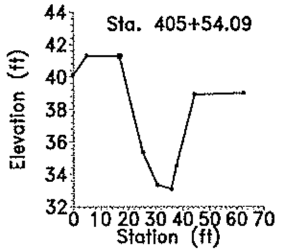

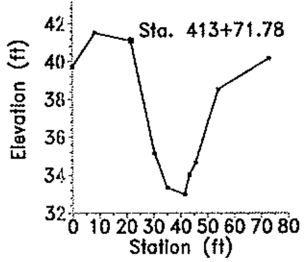

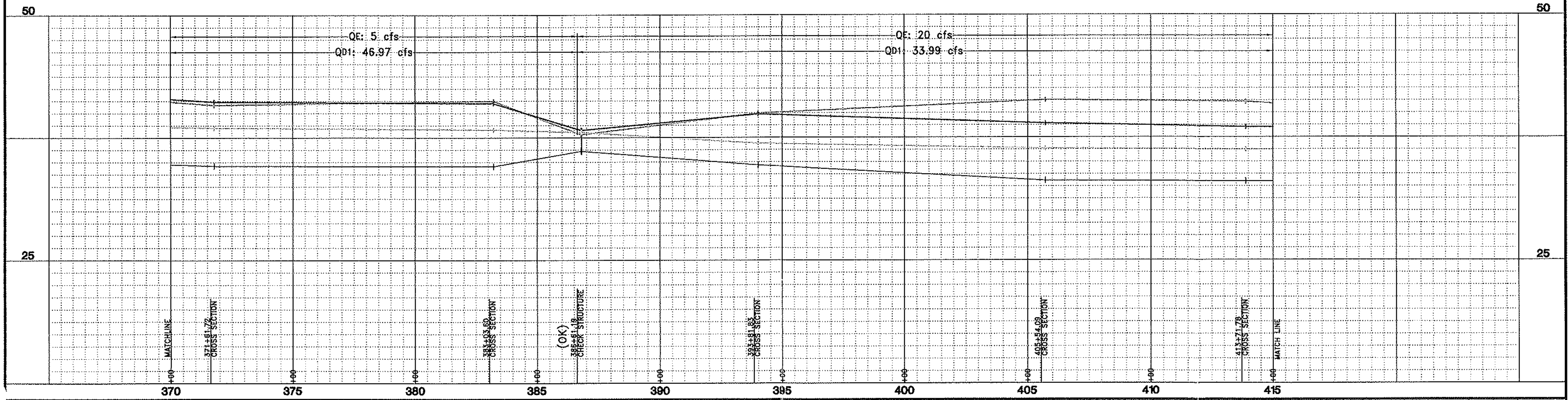

REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ________
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

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CHINA SLOUGH - DEMAND FLOW
PLAN AND PROFILE
STA. 370+00 TO STA. 415+00

SHEET
29
— OF —
32

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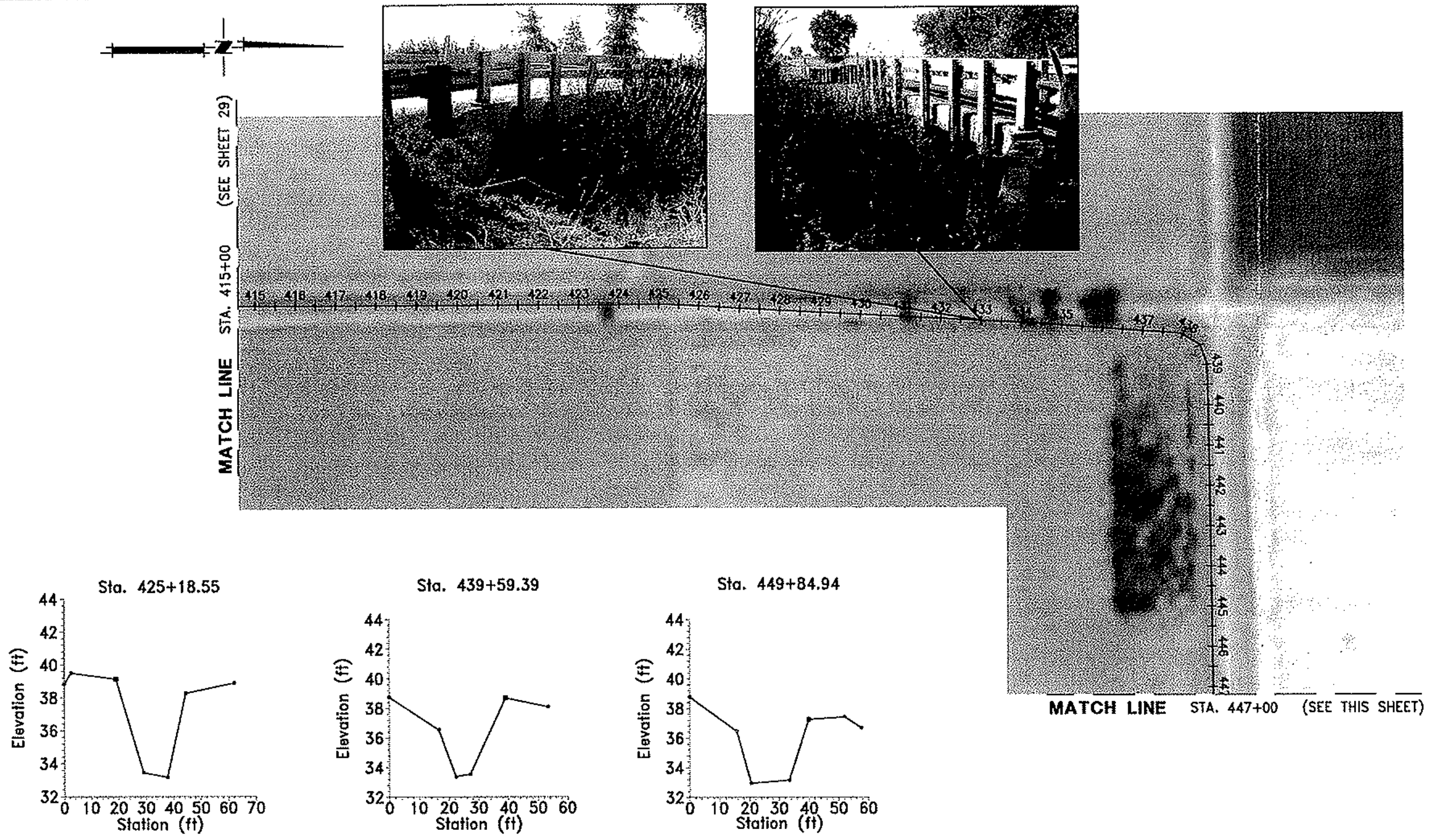

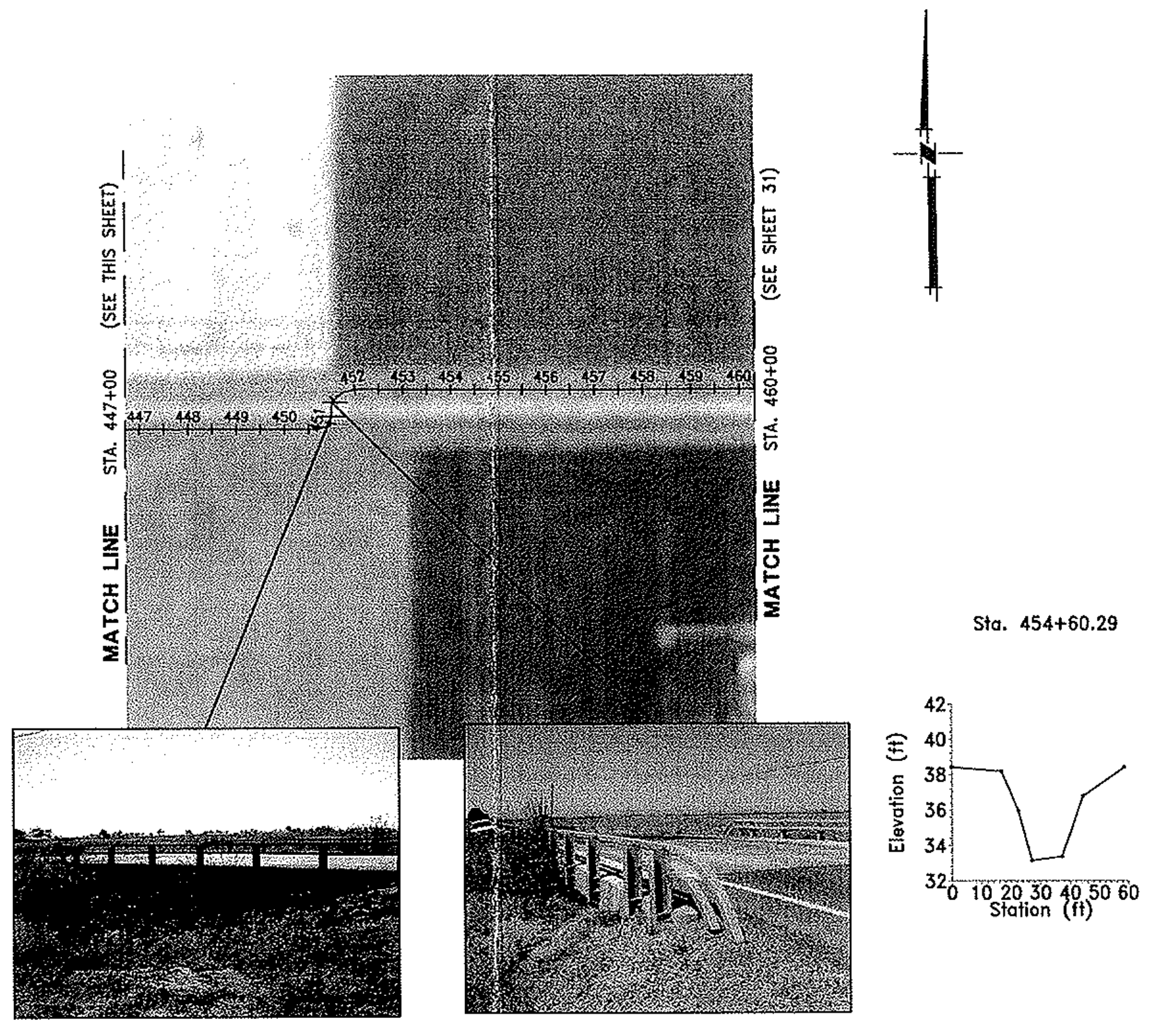

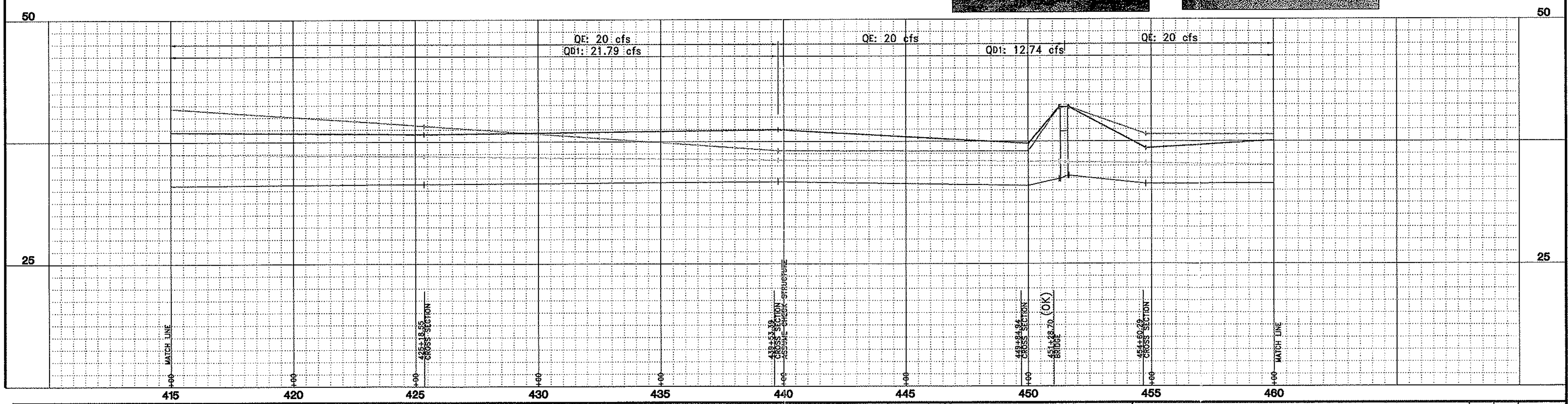

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BENCHMARK ELEV. ________
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YOLO COUNTY FLOOD CONTROL
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CHINA SLOUGH - DEMAND FLOW
PLAN AND PROFILE
STA. 415+00 TO 460+00

SHEET
30
OF
32

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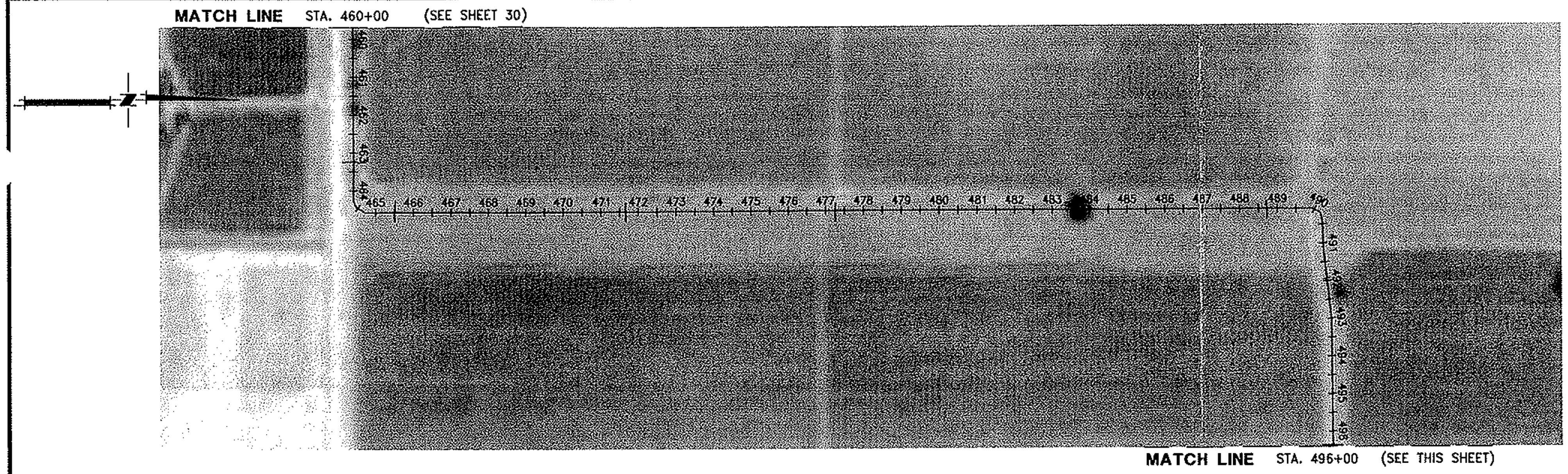

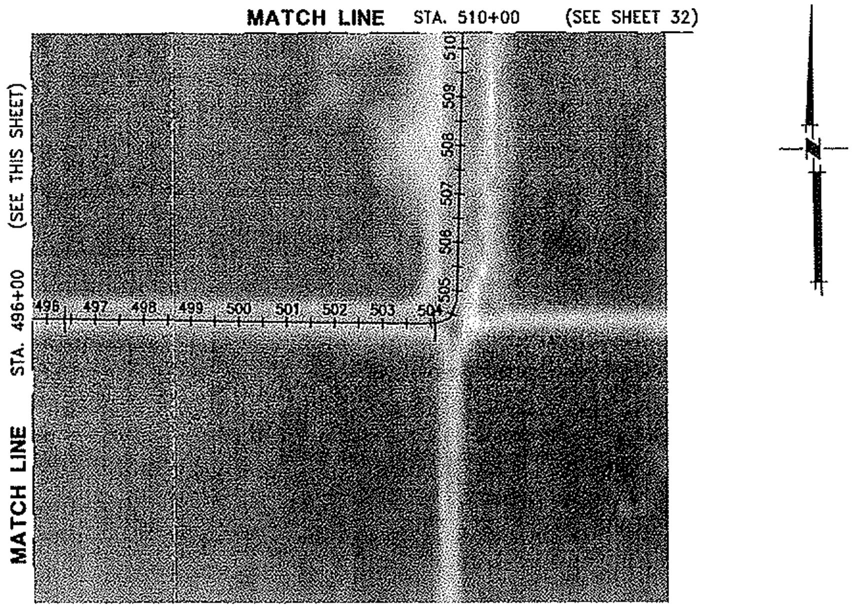

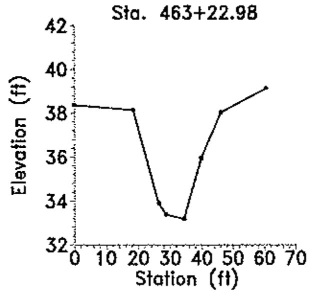
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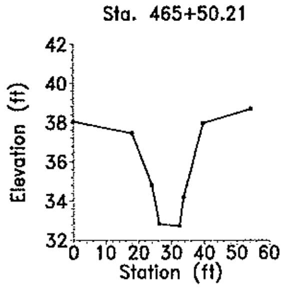
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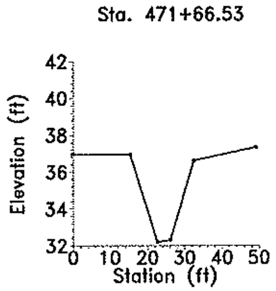
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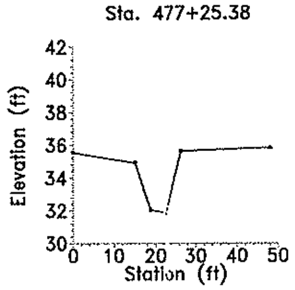
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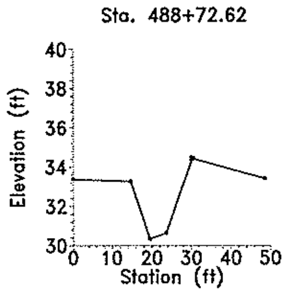
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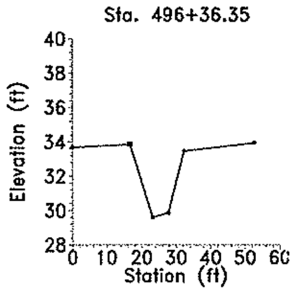
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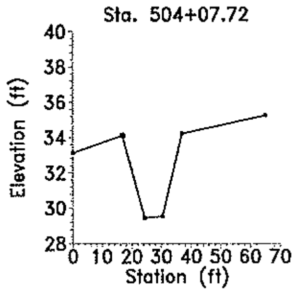
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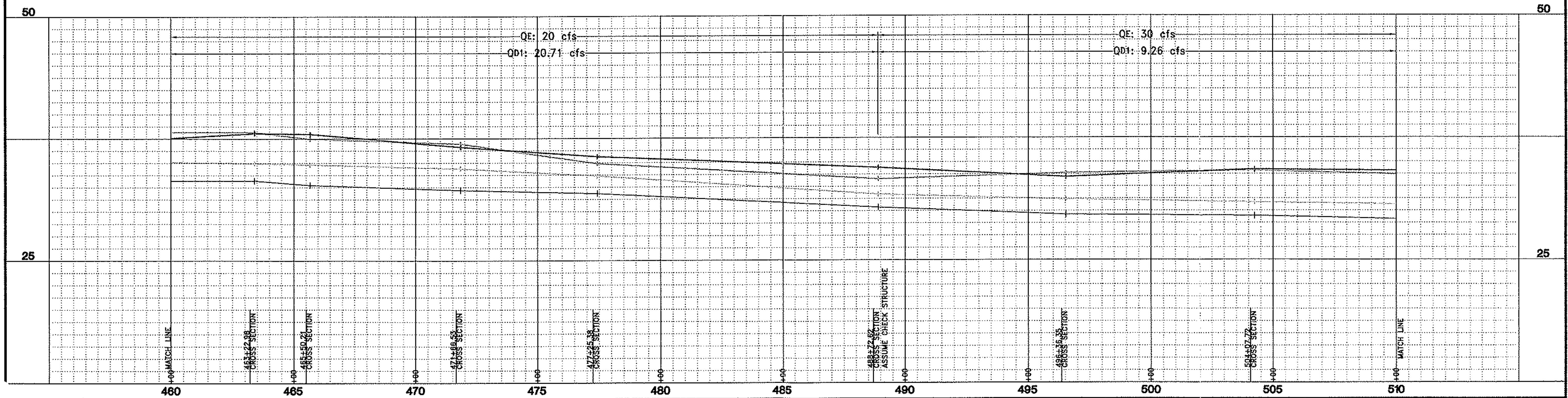

REVISIONS
NO. DESCRIPTION DATE BY

BENCHMARK ELEV. ______
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SCALE
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V: 1'=10'

YOLO COUNTY FLOOD CONTROL
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STA. 460+00 TO STA. 510+00

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OF
32

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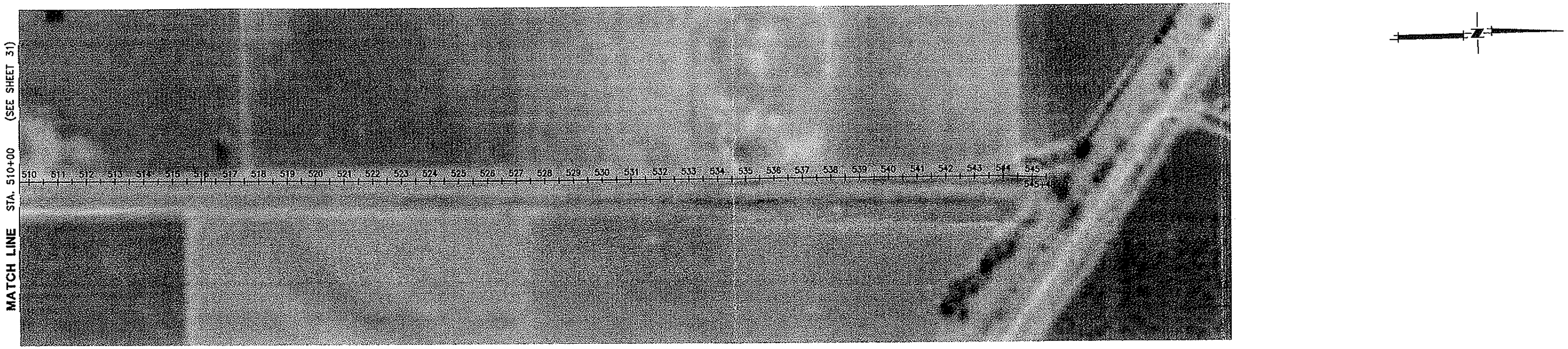

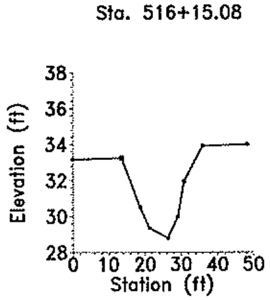

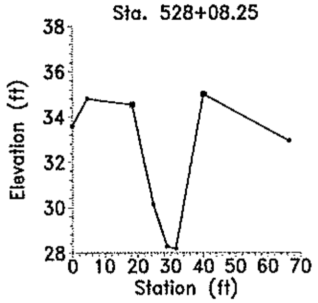

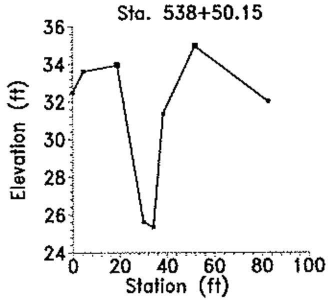

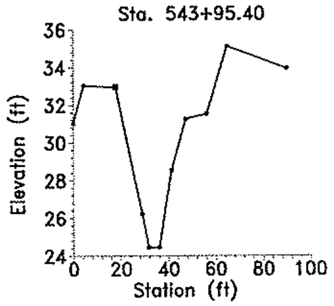

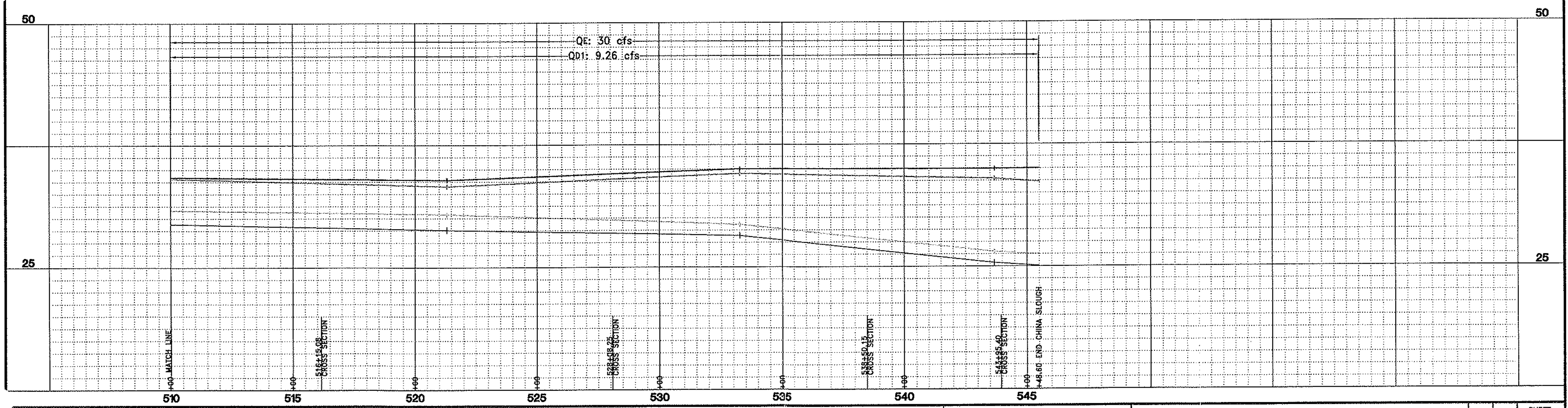

REVISIONS
NO. DESCRIPTION DATE BY

BENCHMARK ELEV. ________
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC/SE
DATE 9-25-02 DATE
DESIGNED BY: ________
R.C.E. ________ DATE ________
CHECKED BY: ________
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YCFCWCD/YZWD CONJUNCTIVE WATER USE FEASIBILITY STUDY
CHINA SLOUGH - DEMAND FLOW
PLAN AND PROFILE
STA. 510+00 TO 545-48.60

SHEET
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OF
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Plan & Profile Drawings-Arranged Flow

Appendix E

EVALUATION/IMPROVEMENT PLANS FOR

WEST ADAMS CANAL - ARRANGED FLOW

YCFCWCD/YZWD CONJUCTIVE WATER USE FEASIBILITY STUDY

SCALE: 1" = 100'

ENGINEER

WOOD-RODGERS INC.
3301 C STREET, SUITE 100B
SACRAMENTO, CA 95816
PHONE: (916) 341-7760

NOTE:

UNDER THE "ARRANGED" SYSTEM THE WATER USER COORDINATES THE OPENING AND CLOSING OF THE SYSTEM WITH THE DISTRICT.

SITE PLAN

SHEET LAYOUT

DRAFT

REVISIONS

NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ________

DESCRIPTION: Survey Datum – The coordinates shown on the drawing are based on the Cache Creek Record of Survey (March–April 2002). Elevations are based on the North American Vertical Datum of 1988 (NAVD 1988) Yolo County GPS Subsidence Survey. Horizontal Coordinates are based on the North American Datum of 1983 (NAD 83). California State Plane Coordinates Zone 2.

SCALE

YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: JB
DATE ________

DESIGNED BY: ________
R.C.E. ________ DATE ________

CHECKED BY: ________
R.C.E. ________ DATE ________

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YCFCWCD/YZWD CONJUNCTIVE WATER USE FEASIBILITY STUDY
WEST ADAMS CANAL - ARRANGED FLOW
TITLE SHEET

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OF
32

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LIST OF DRAWINGS

1. TITLE SHEET
2. LIST OF DRAWING AND ABBREVIATIONS
3. PLAN PROFILE SHEET – STA. 10+00 TO STA. 60+00
4. PLAN PROFILE SHEET – STA. 60+00 TO STA. 110+00
5. PLAN PROFILE SHEET – STA. 110+00 TO STA. 160+00
6. PLAN PROFILE SHEET – STA. 160+00 TO STA. 210+00
7. PLAN PROFILE SHEET – STA. 210+00 TO STA. 260+00
8. PLAN PROFILE SHEET – STA. 260+00 TO STA. 310+00
9. PLAN PROFILE SHEET – STA. 310+00 TO STA. 360+00
10. PLAN PROFILE SHEET – STA. 360+00 TO STA. 410+00
11. PLAN PROFILE SHEET – STA. 410+00 TO STA. 460+00
12. PLAN PROFILE SHEET – STA. 460+00 TO STA. 510+00
13. PLAN PROFILE SHEET – STA. 510+00 TO STA. 560+00
14. PLAN PROFILE SHEET – STA. 560+00 TO STA. 610+00
15. PLAN PROFILE SHEET – STA. 610+00 TO STA. 660+00
16. PLAN PROFILE SHEET – STA. 660+00 TO STA. 697+73.51
17. PLAN PROFILE SHEET – STA. 10+00 TO STA. 55+00
18. PLAN PROFILE SHEET – STA. 55+00 TO STA. 97+37.36
19. PLAN PROFILE SHEET – STA. 10+00 TO STA. 55+00
20. PLAN PROFILE SHEET – STA. 55+00 TO STA. 86+23.89
21. PLAN PROFILE SHEET – STA. 10+00 TO STA. 50+00
22. PLAN PROFILE SHEET – STA. 50+00 TO STA. 100+00
23. PLAN PROFILE SHEET – STA. 100+00 TO STA. 145+00
24. PLAN PROFILE SHEET – STA. 145+00 TO STA. 190+00
25. PLAN PROFILE SHEET – STA. 190+00 TO STA. 235+00
26. PLAN PROFILE SHEET – STA. 235+00 TO STA. 280+00
27. PLAN PROFILE SHEET – STA. 280+00 TO STA. 325+00
28. PLAN PROFILE SHEET – STA. 325+00 TO STA. 370+00
29. PLAN PROFILE SHEET – STA. 370+00 TO STA. 415+00
30. PLAN PROFILE SHEET – STA. 415+00 TO STA. 460+00
31. PLAN PROFILE SHEET – STA. 460+00 TO STA. 510+00
32. PLAN PROFILE SHEET – STA. 510+00 TO STA. 545+48.60

ABBREVIATIONS

M	MARGINAL
R	REPLACE STRUCTURE
R/O	REPLACE (WITH CHINA SLOUGH)/OK (EXISTING)
M/O	MARGINAL (WITH CHINA SLOUGH)/OK (EXISTING)
OK	ACCEPTABLE

LEGEND

┄┄┄┄	WS WITH CHINA SLOUGH
┄┄┄┄	WS WITHOUT CHINA SLOUGH
——•——	GROUND
——•——	LEFT BANK
——•——	RIGHT BANK
Q_E	EXISTING CANAL CAPACITY
Q_{A1}	ARRANGED FLOW WITH CHINA SLOUGH
Q_{A2}	ARRANGED FLOW WITHOUT CHINA SLOUGH

NOTES:

1. HEC–RAS FILE INFORMATION FOR WEST ADAMS CANAL:
   PLAN: WEST ADAMS CANAL ARRANGED FLOW
   GEOM: WEST ADAMS CANAL REVISED XS 10–31–02 (.05,.017)
   FLOW: WEST ADAMS CANAL ARRANGED FLOW
2. HEC–RAS FILE INFORMATION FOR EAST ADAMS CANAL:
   PLAN: EAST ADAMS CANAL ARRANGED FLOW
   GEOM: EAST ADAMS CANAL REVISED 11–01–02 XS (.05,.017)
   FLOW: EAST ADAMS CANAL ARRANGED FLOW
3. HEC–RAS FILE INFORMATION FOR ACACIA CANAL:
   PLAN: ACACIA CANAL ARRANGED FLOW
   GEOM: YCFCWCD–ACACIA CANAL REVISED XS (.05,.017)
   FLOW: ACACIA CANAL ARRANGED FLOW
4. HEC–RAS FILE INFORMATION FOR CHINA SLOUGH:
   PLAN: CHINA SLOUGH ARRANGED FLOW (CLEAN)
   GEOM: YCFCWCD–CHINA SLOUGH REVISED XS (0.35 CLEAN)
   FLOW: CHINA SLOUGH ARRANGED FLOW w/C.S.
5. DESIGN CAPACITY BASED ON ALBERT J. CLEMMENS, CANAL CAPACITIES FOR ARRANGED FLOW UNDER SURFACE IRRIGATION; JOURNAL OF IRRIGATION AND DRAINAGE ENGINEERING, VOL. 112 NO. 4 NOV. 1986

REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE

YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: LC
DATE ______
DESIGNED BY: ______
R.C.E. ______ DATE ______
CHECKED BY: ______
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YCFCWCD/YZWD CONJUNCTIVE WATER USE FEASIBILITY STUDY
WEST ADAMS CANAL – ARRANGED FLOW
LIST OF DRAWINGS, ABBREVIATIONS
AND LEGEND

SHEET
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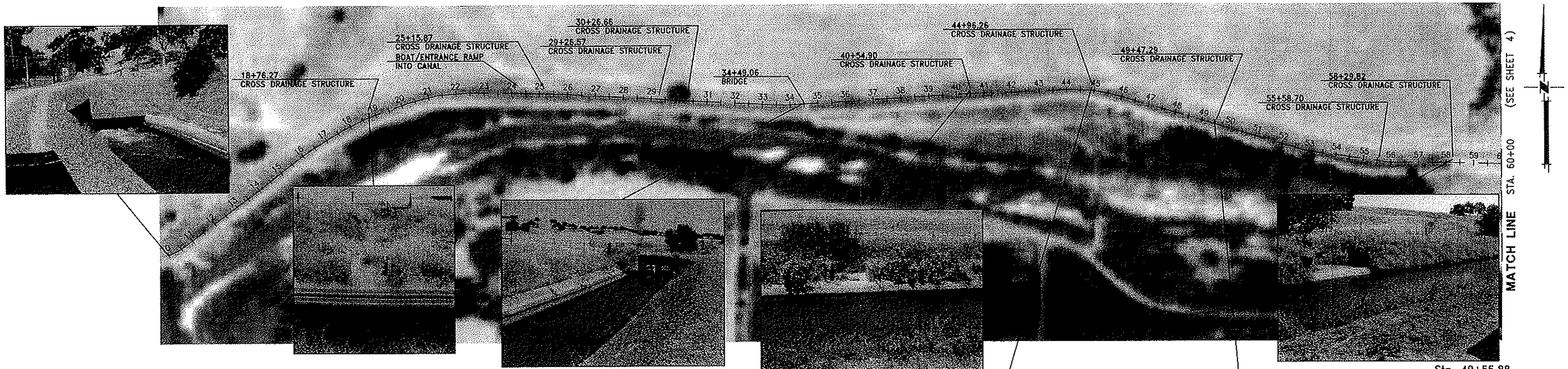

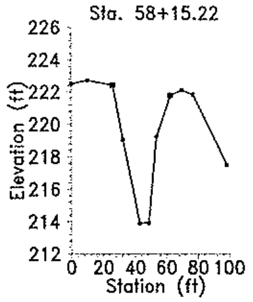

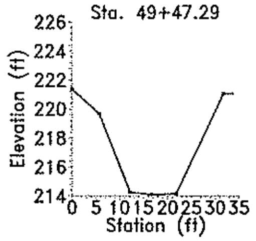

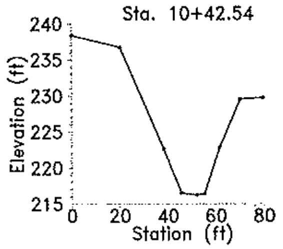

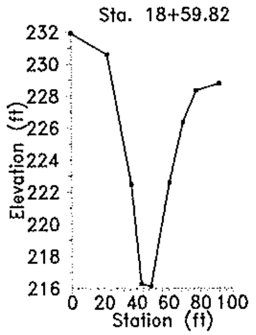

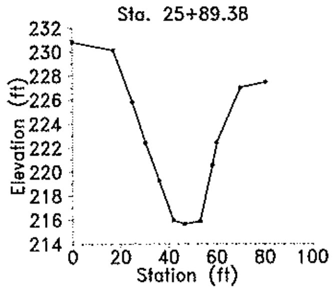

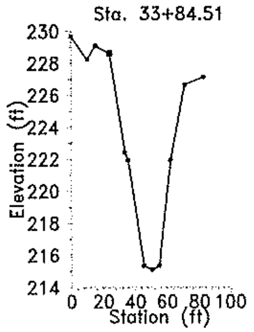

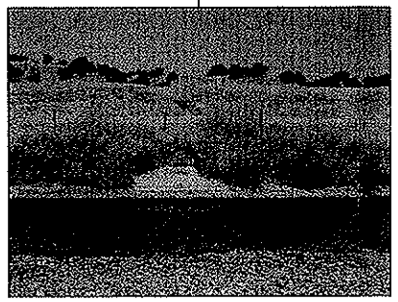

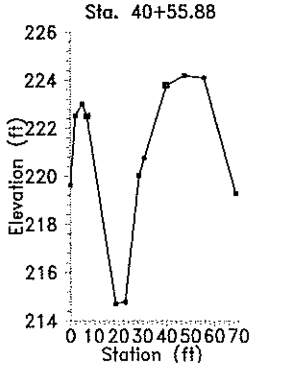

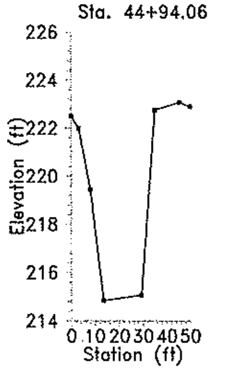

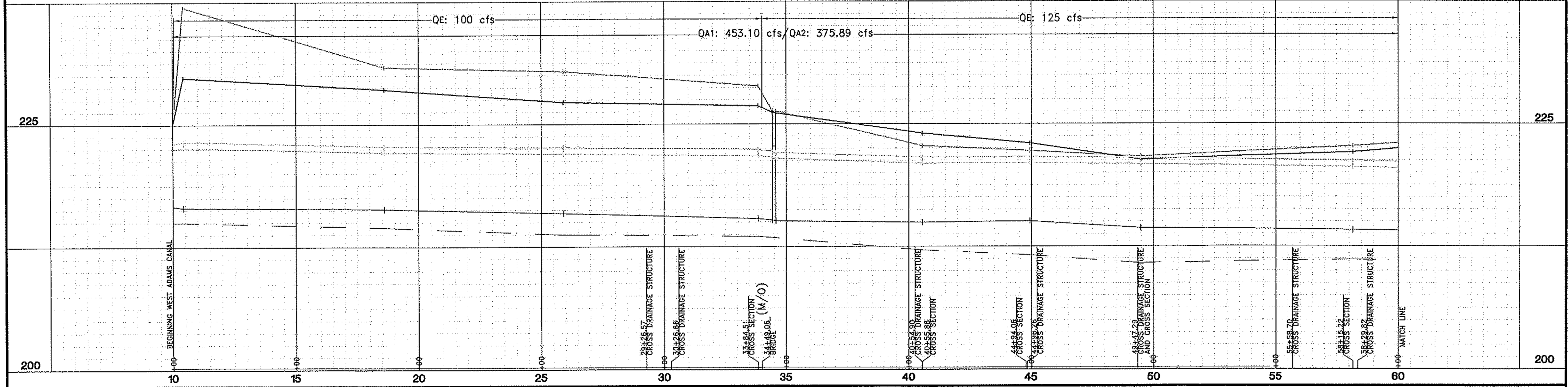

NO.	REVISIONS DESCRIPTION	DATE	BY

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The initial control point used for the Canal Topo was YC-1 of the referenced surey.
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE 8/3/02

DESIGNED BY: FB
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WEST ADAMS CANAL - ARRANGED FLOW

PLAN AND PROFILE
STA. 10+00 TO STA. 60+00

SHEET
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OF
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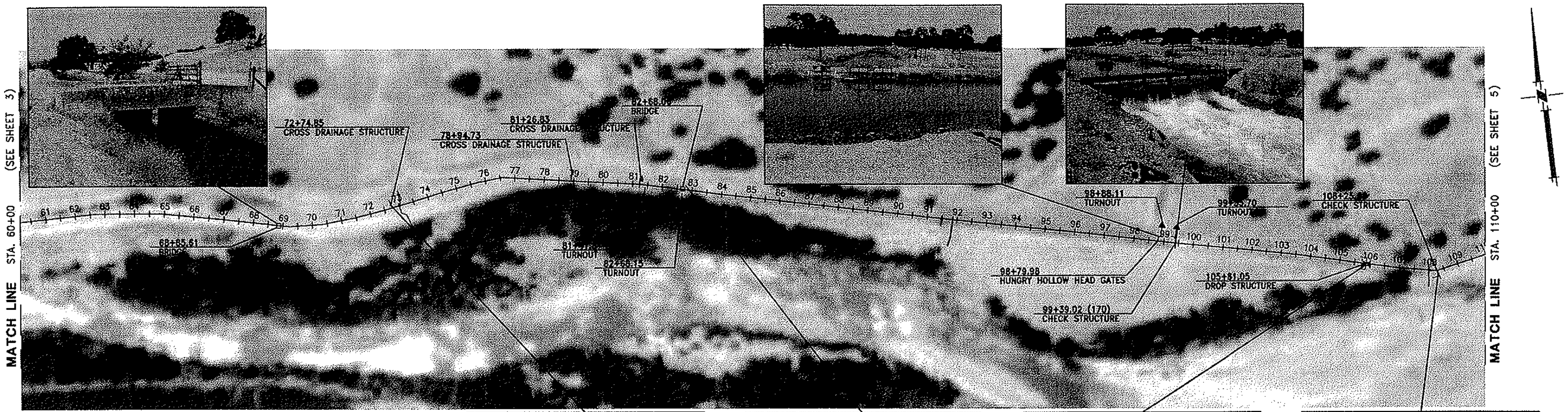

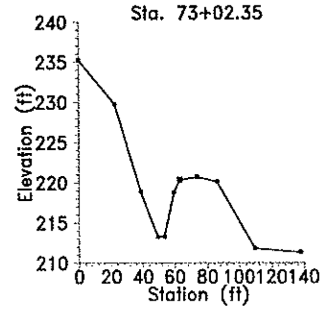

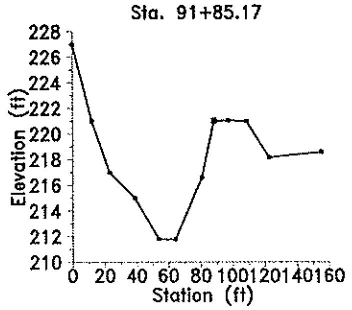

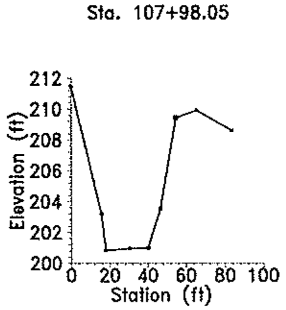

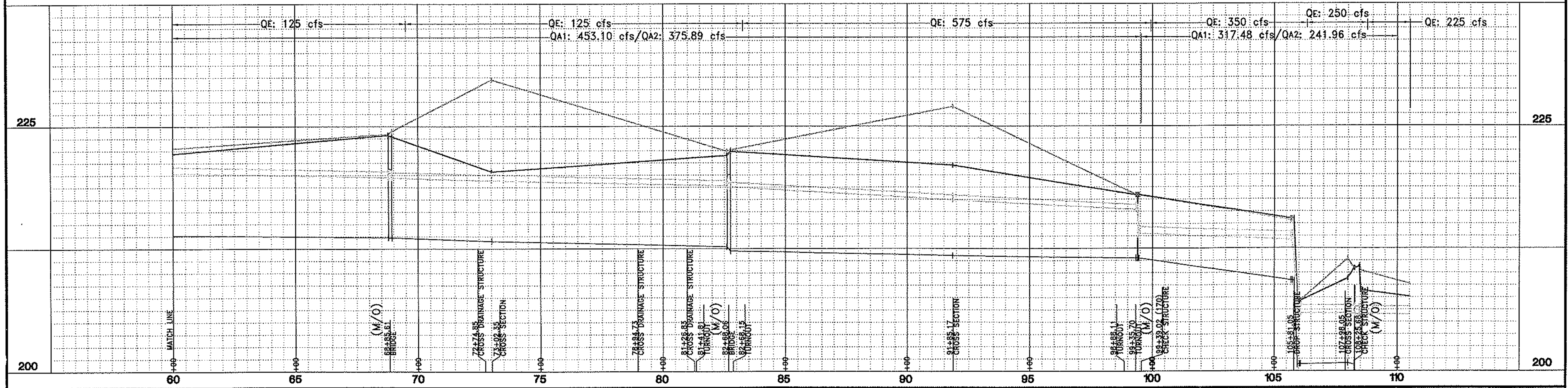

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NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
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V: 1'=20'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

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DATE ______
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WEST ADAMS CANAL - ARRANGED FLOW
PLAN AND PROFILE
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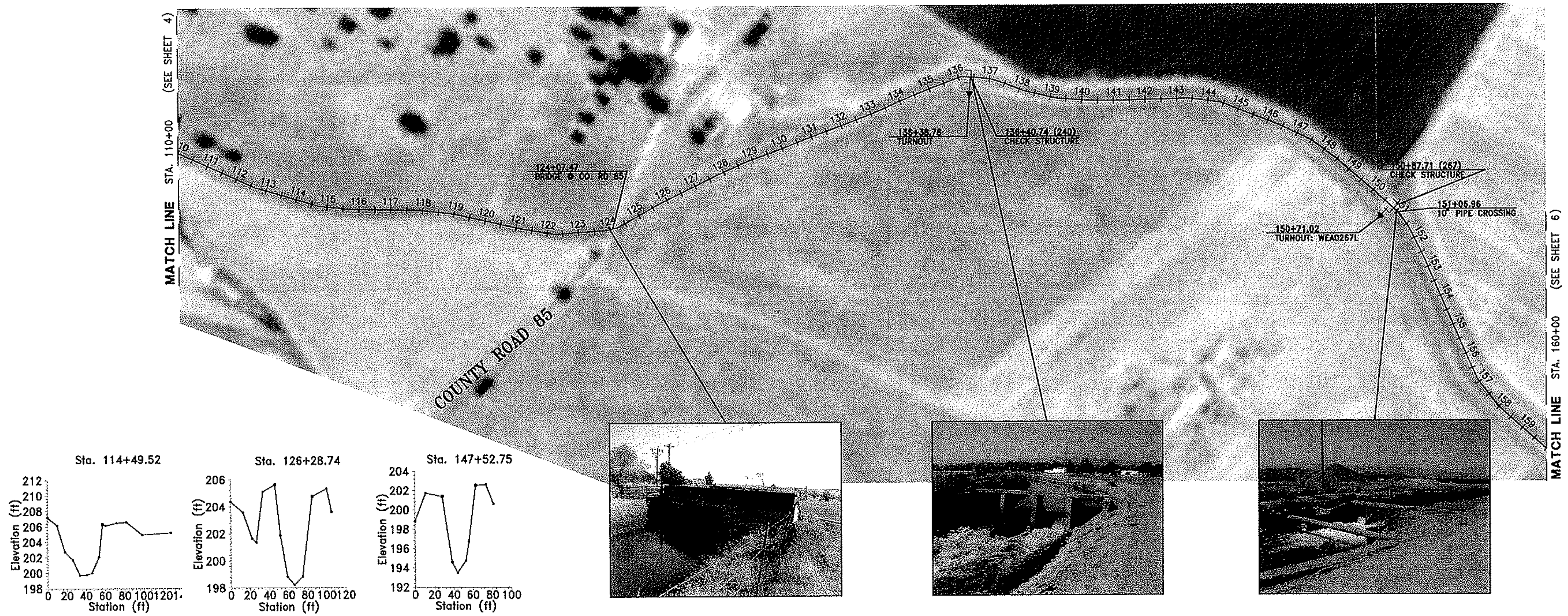

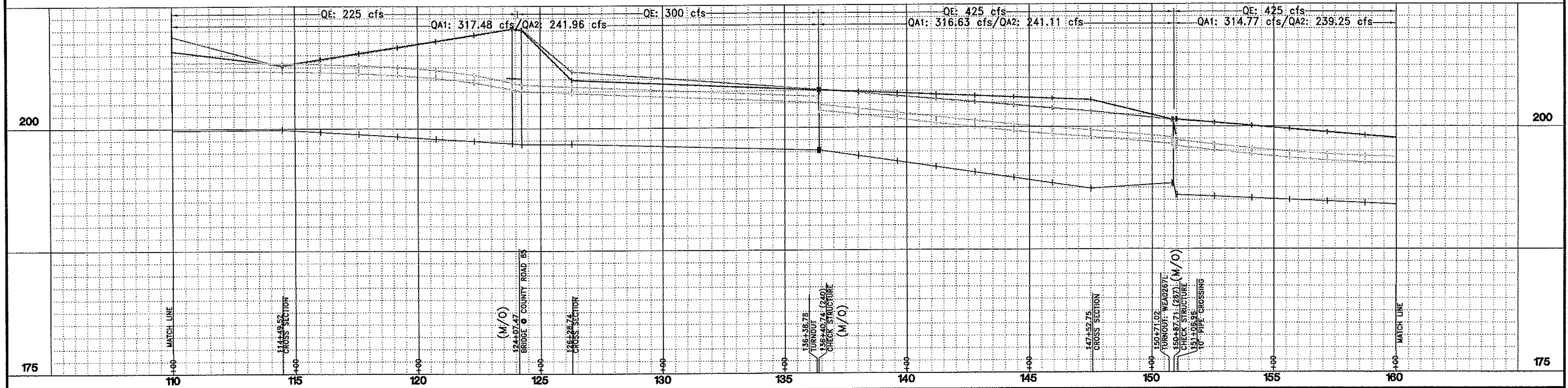

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NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
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V: 1"=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

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PLAN AND PROFILE
STA. 110+00 TO STA. 160+00

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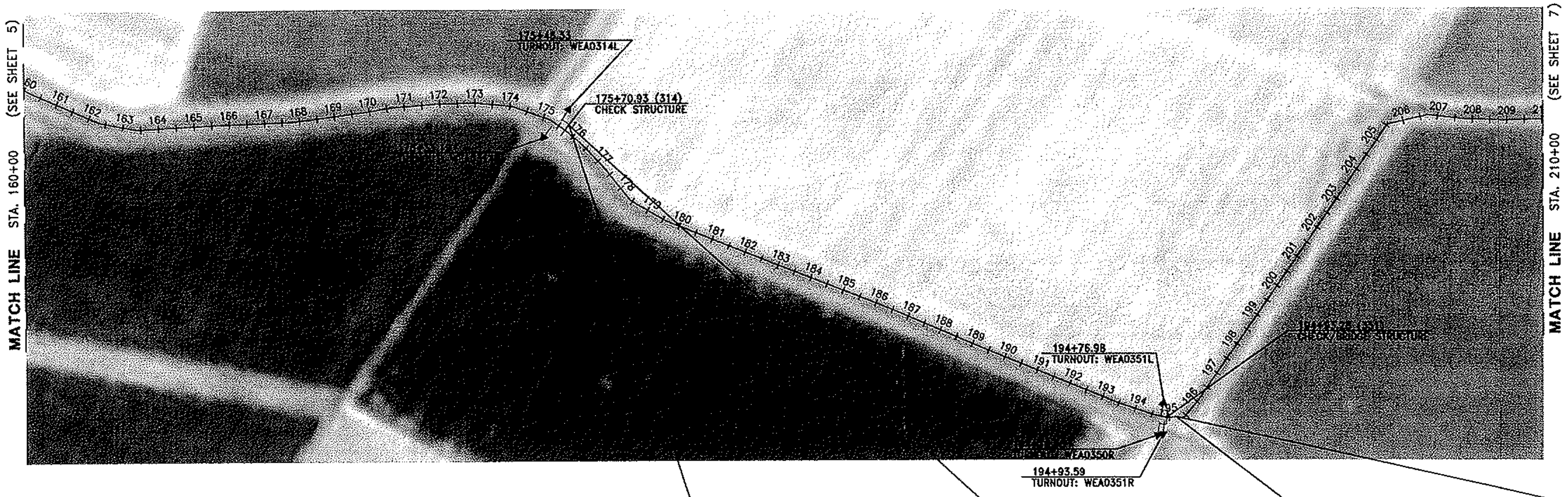

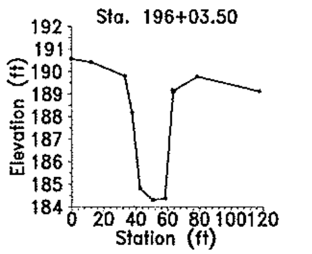

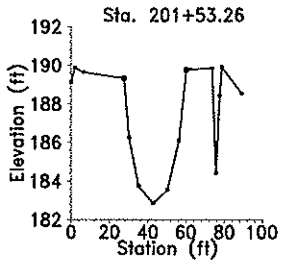

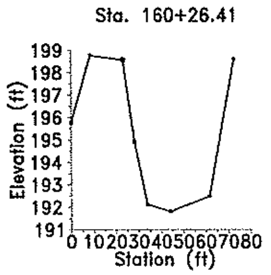

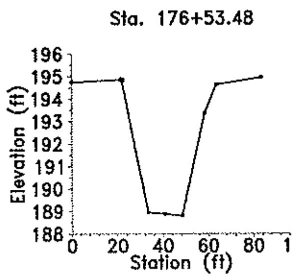

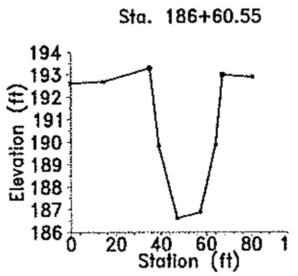

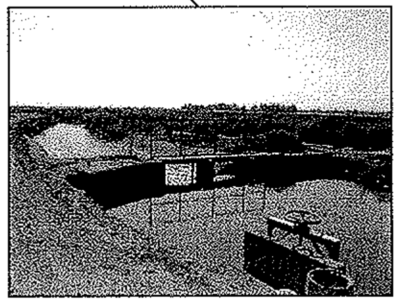

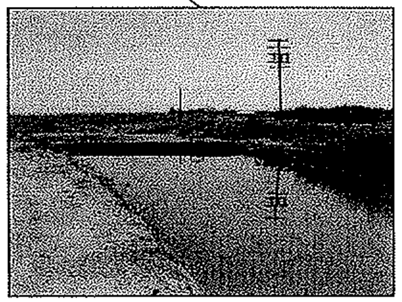

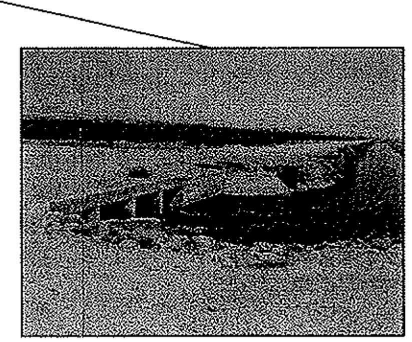

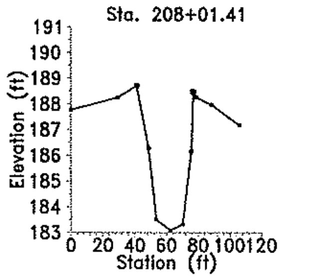

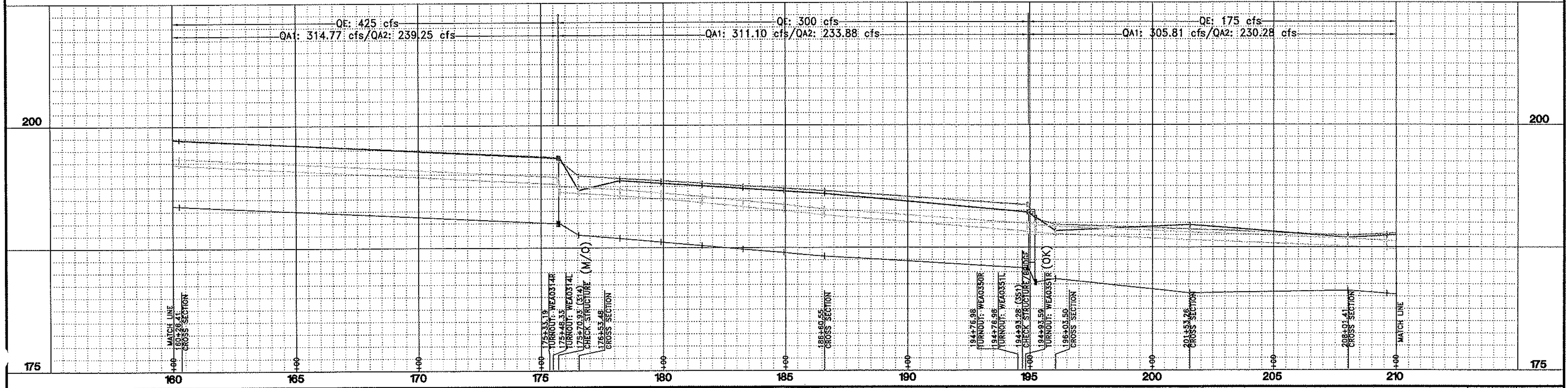

NO.	REVISIONS DESCRIPTION	DATE	BY

BENCHMARK ELEV. ________
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
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DESIGNED BY: ________
R.C.E. ________ DATE ________
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WEST ADAMS CANAL - ARRANGED FLOW
PLAN AND PROFILE
STA. 160+00 TO STA. 210+00

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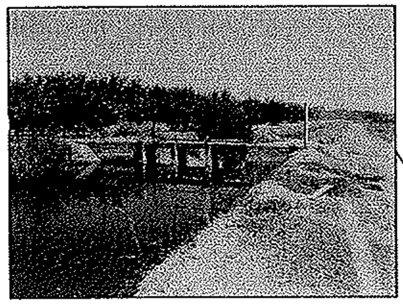

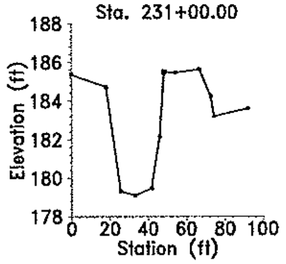

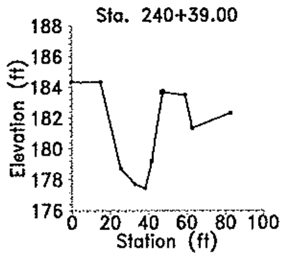

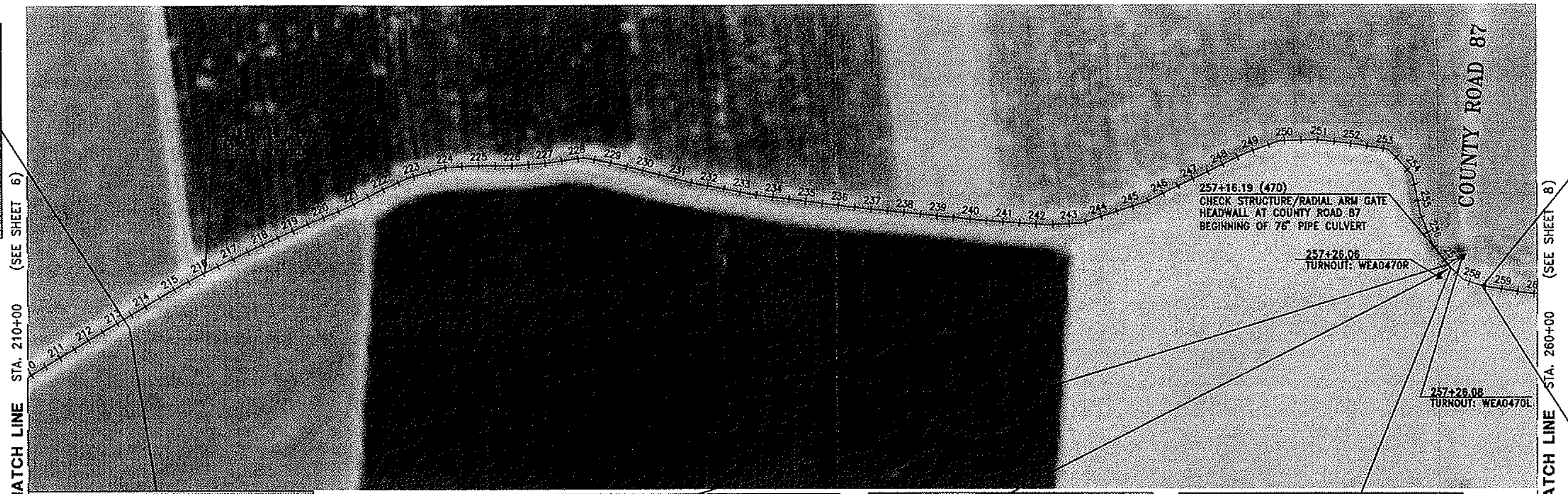

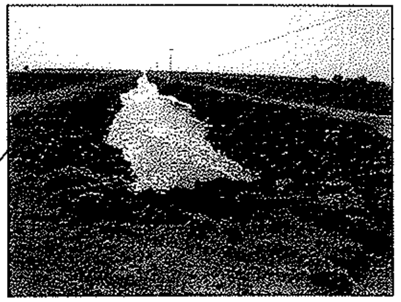

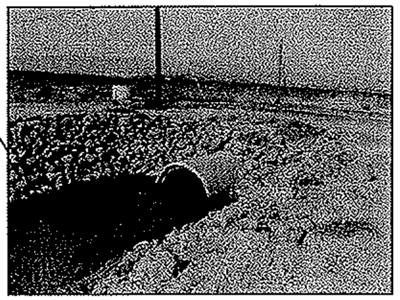

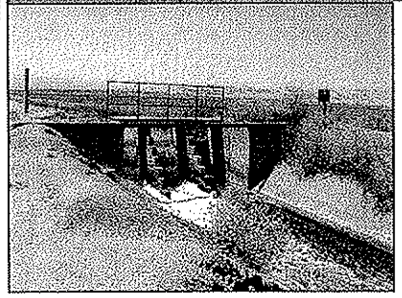

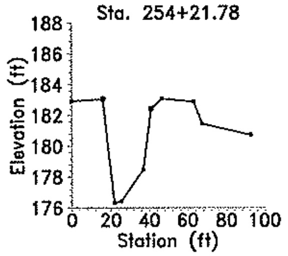

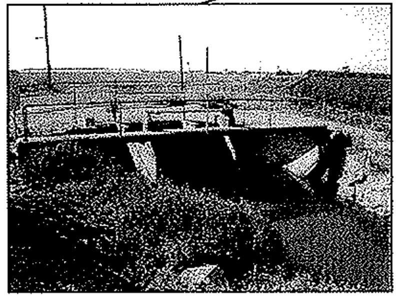

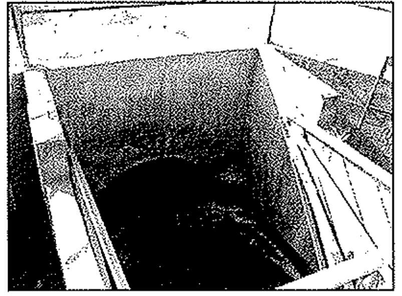

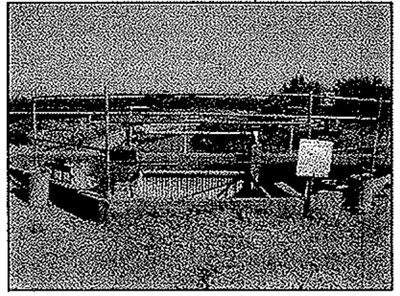

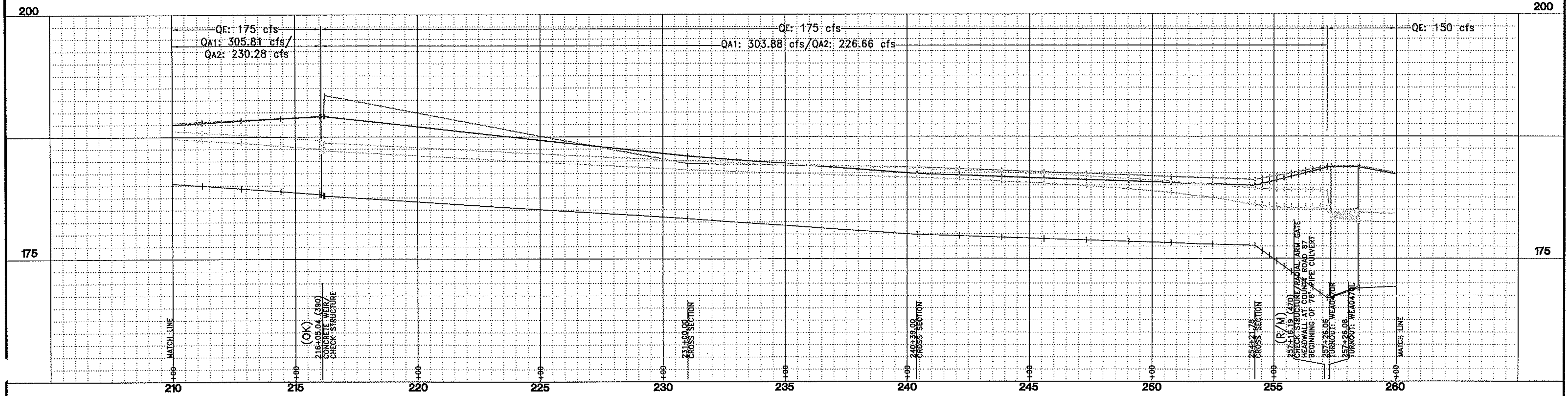

REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ________
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE ________
DESIGNED BY: ________
R.C.E. ________ DATE ________
CHECKED BY: ________
R.C.E. ________ DATE ________

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WEST ADAMS CANAL - ARRANGED FLOW
PLAN AND PROFILE
STA. 210+00 TO STA. 260+00

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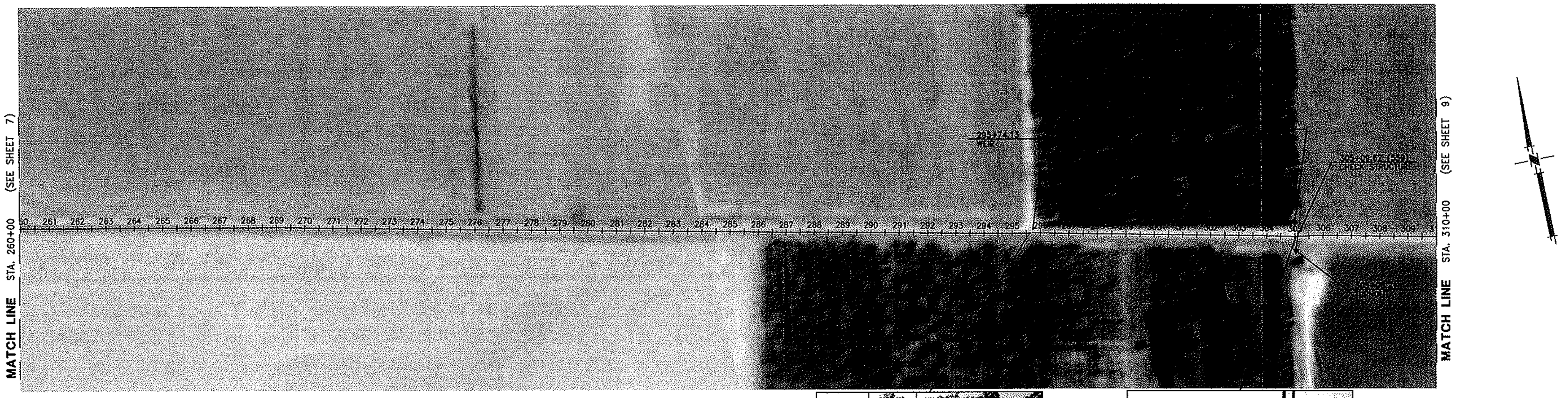

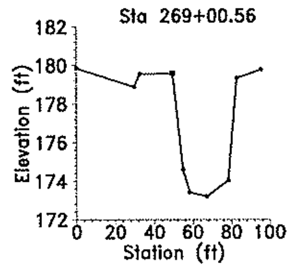

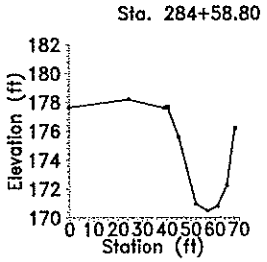

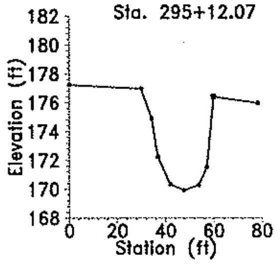

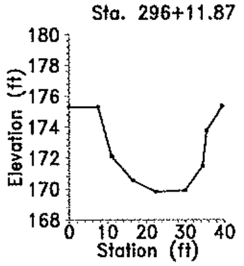

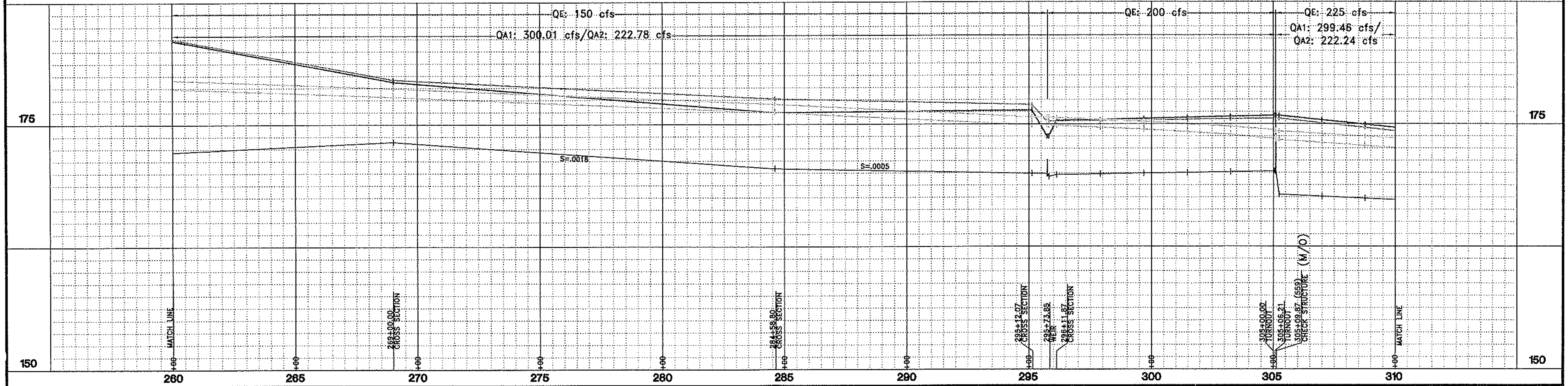

REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE ______

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R.C.E. ______ DATE ______

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WEST ADAMS CANAL - ARRANGED FLOW
PLAN AND PROFILE
STA. 260+00 TO STA. 310+00

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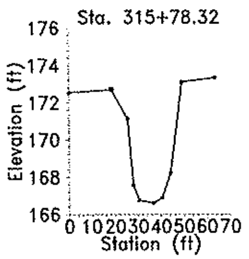

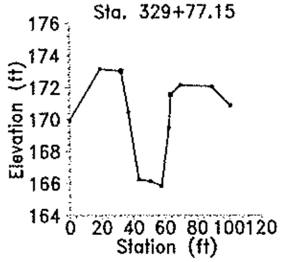

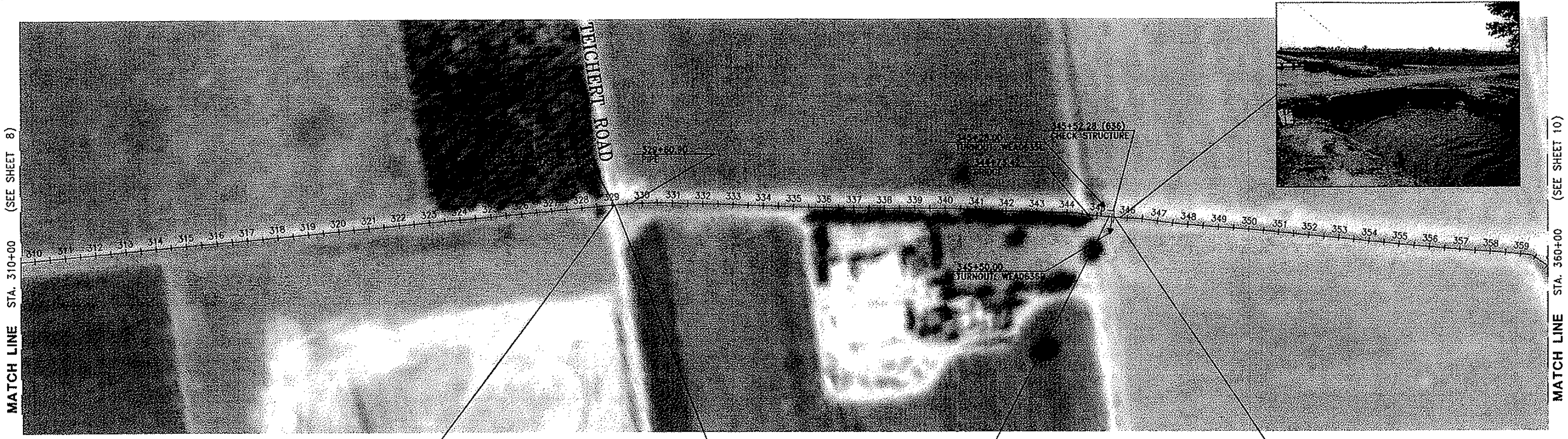

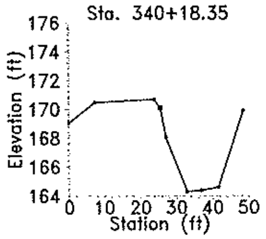

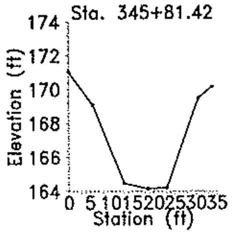

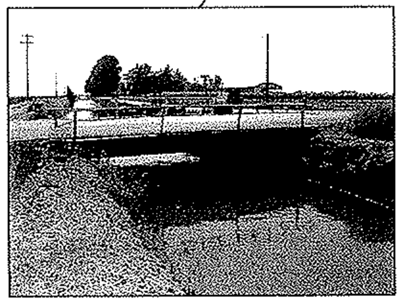

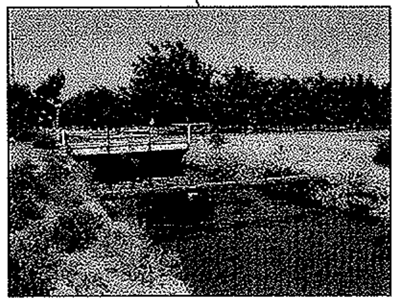

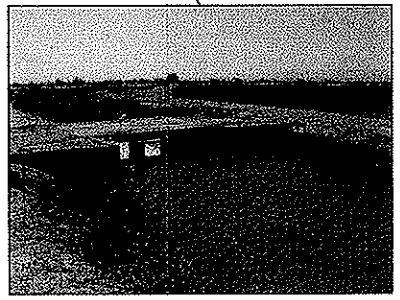

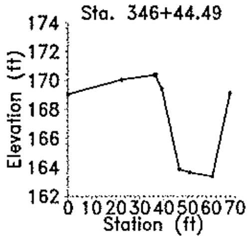

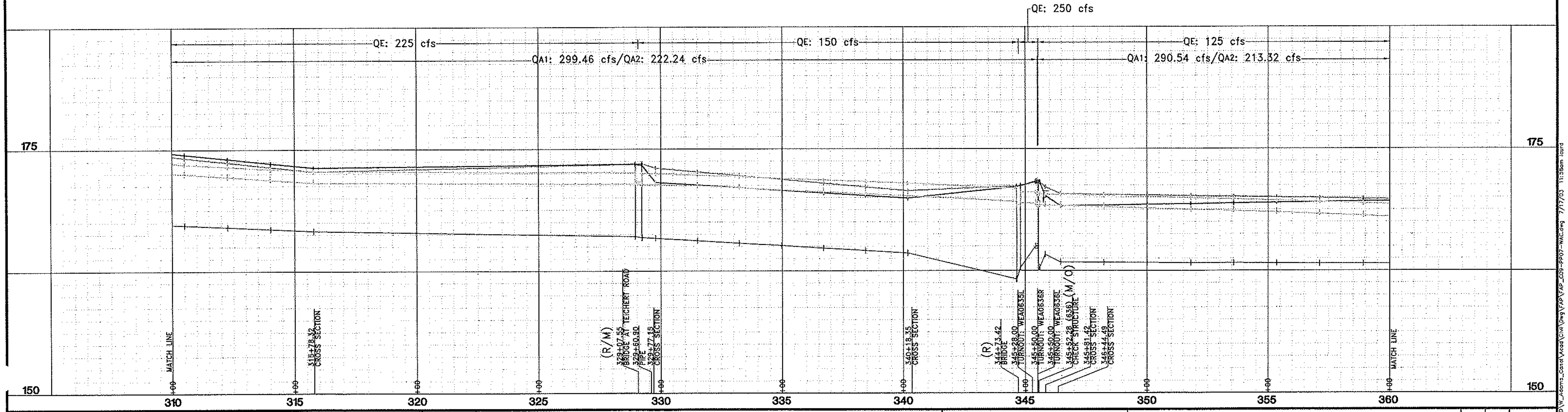

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(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1"=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

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DESIGNED BY: ______
R.C.E. ______ DATE ______
CHECKED BY: ______
R.C.E. ______ DATE ______

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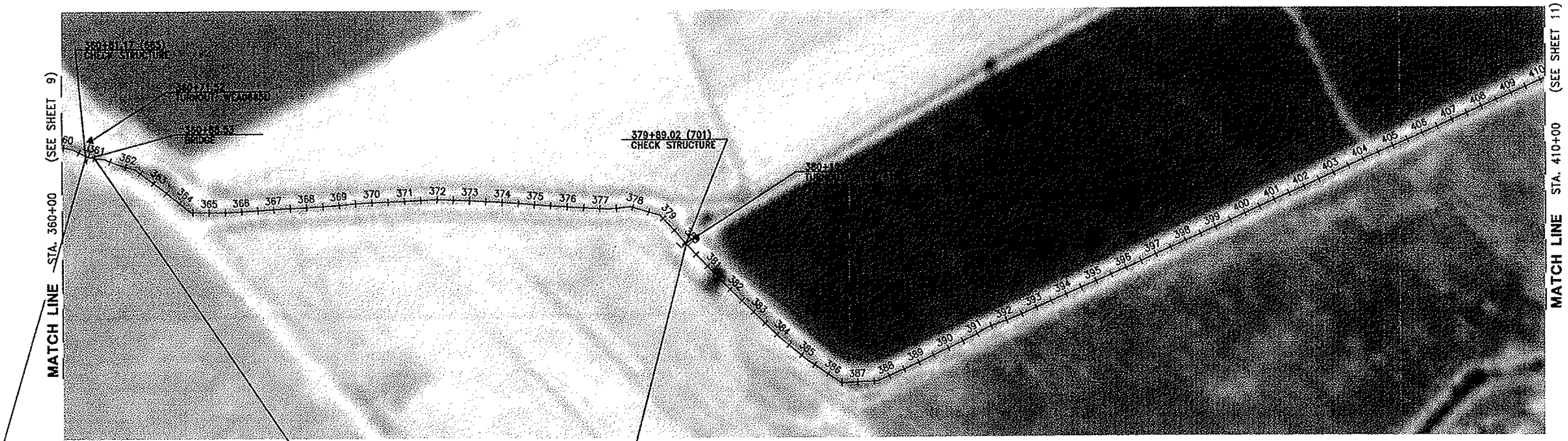

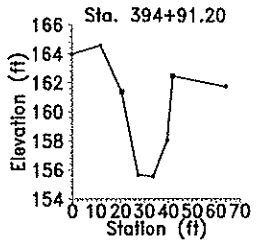

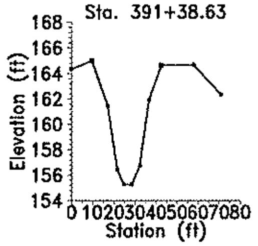

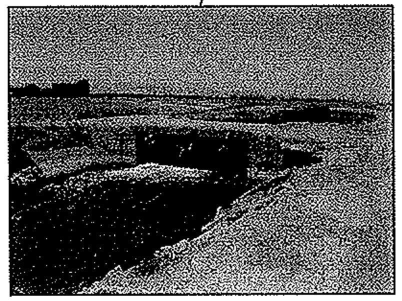

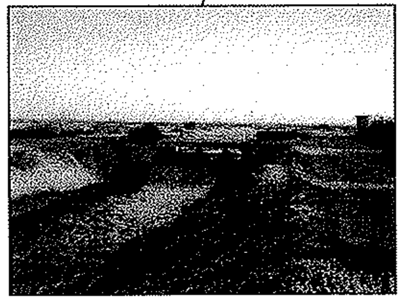

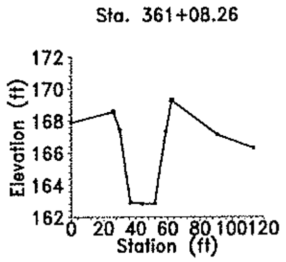

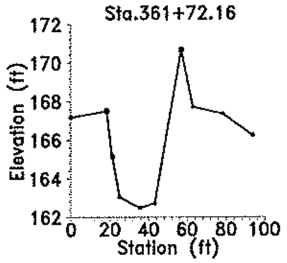

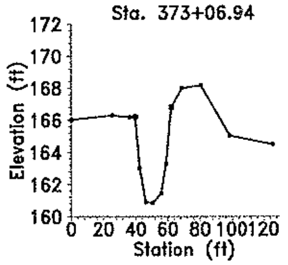

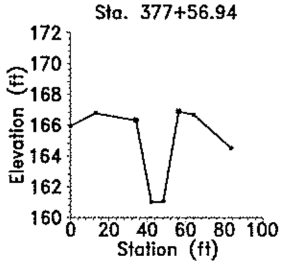

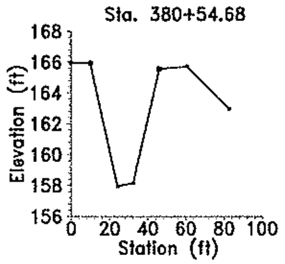

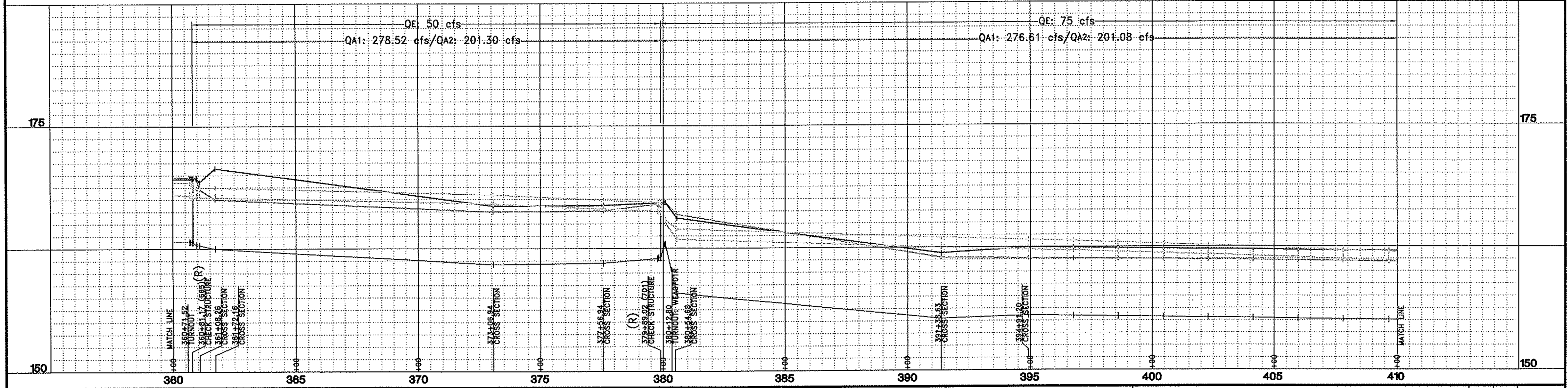

NO.	REVISIONS DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1"=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE 9-11-02
DESIGNED BY: ______
R.C.E. ______ DATE ______
CHECKED BY: ______
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PLAN AND PROFILE
STA. 360+00 TO STA. 410+00

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32

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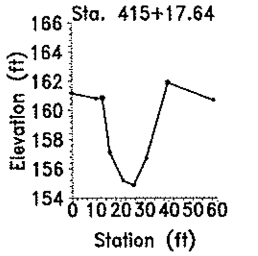

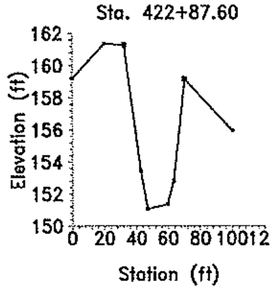

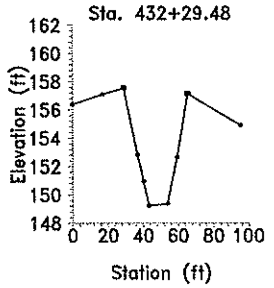

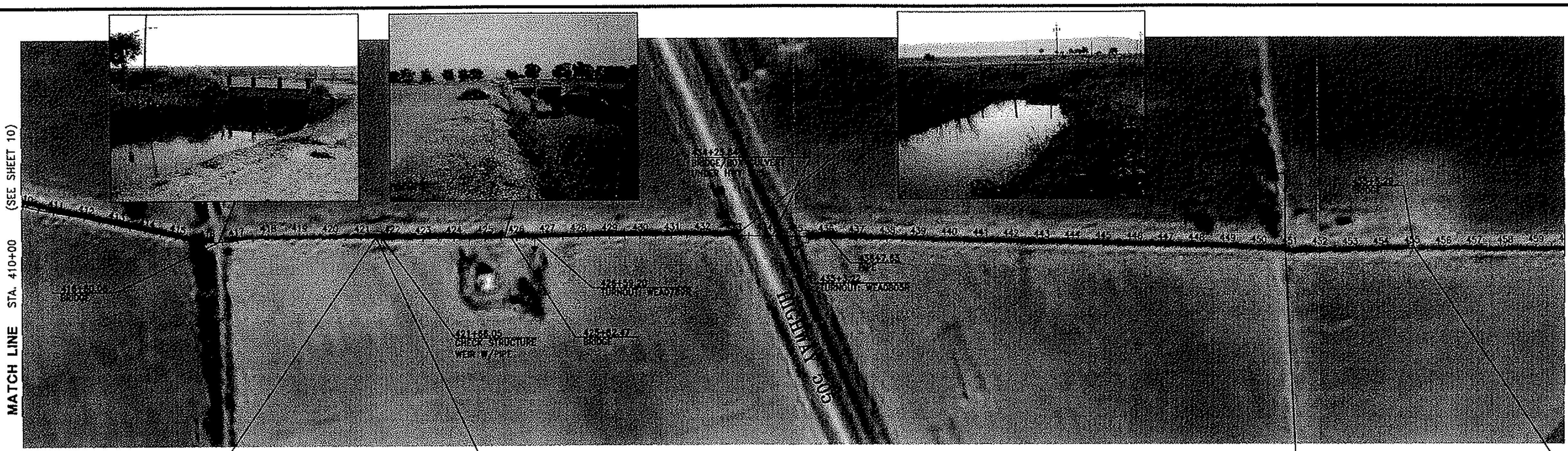

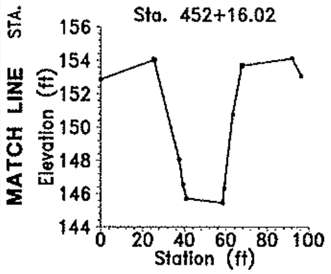

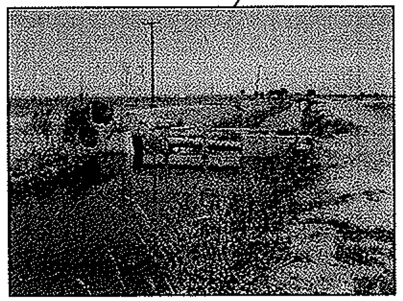

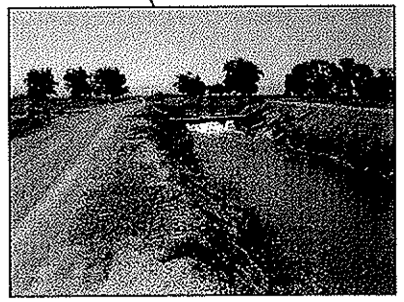

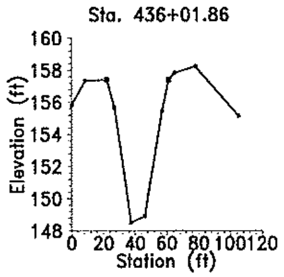

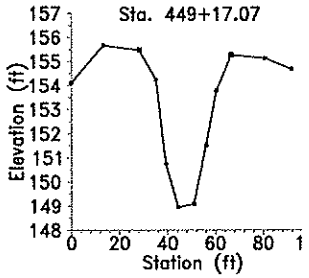

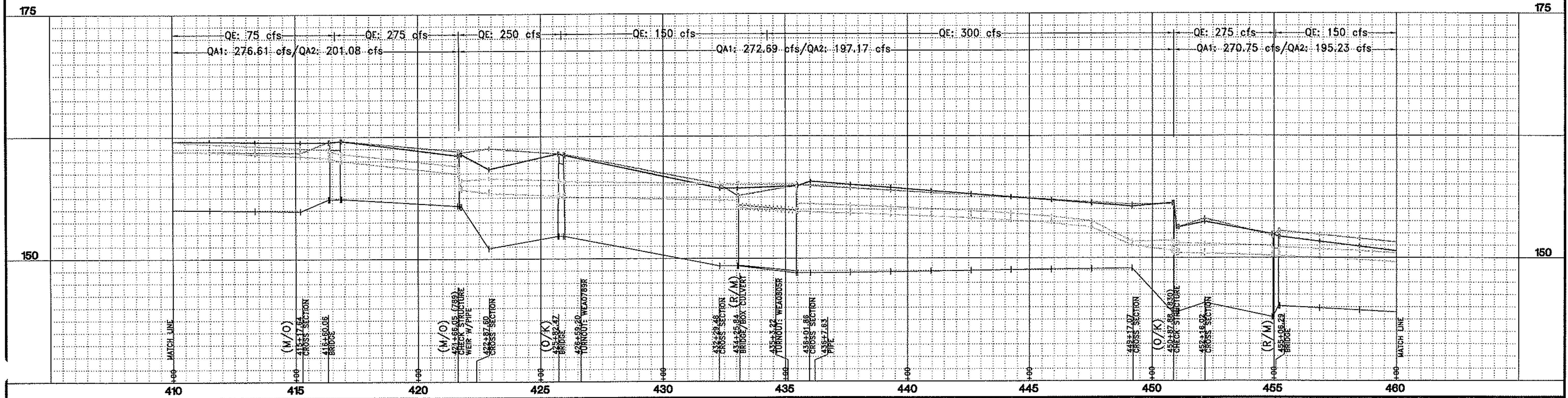

REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
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YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
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DESIGNED BY: ______
R.C.E. ______ DATE ______
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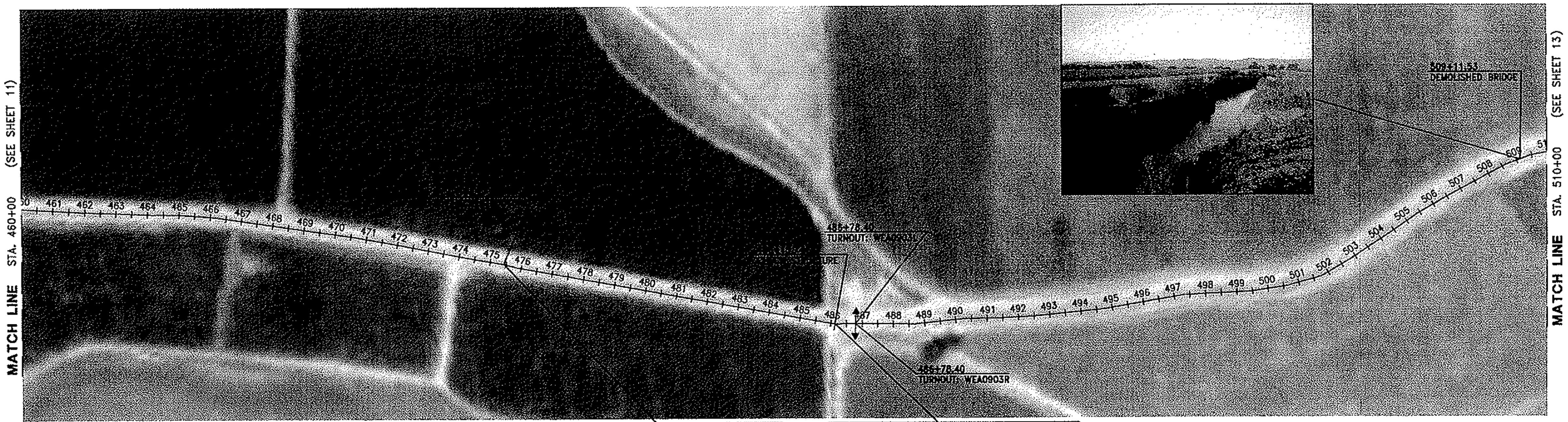

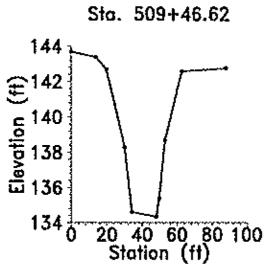

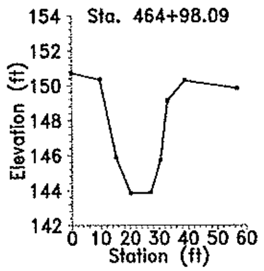

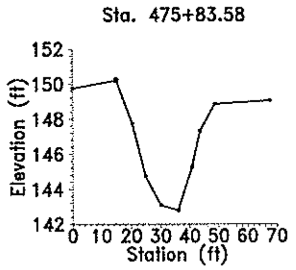

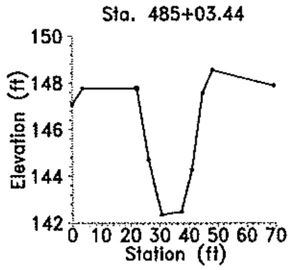

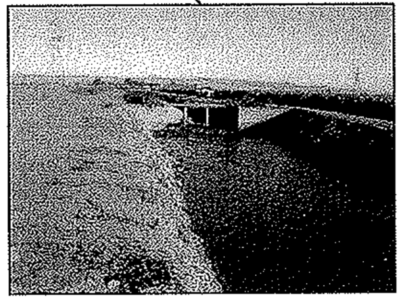

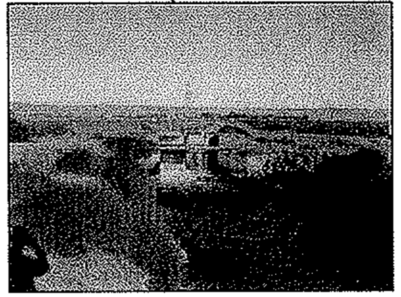

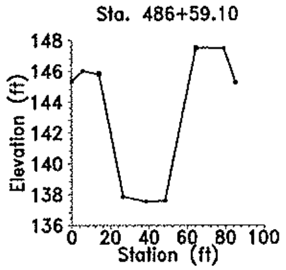

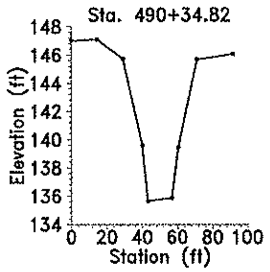

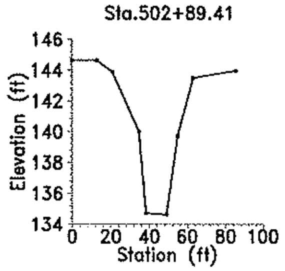

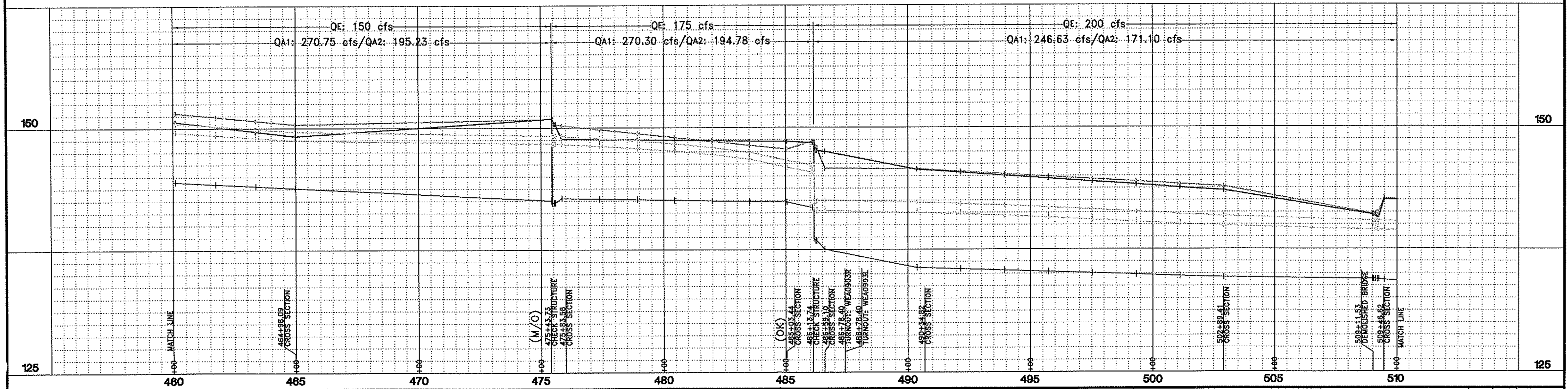

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YOLO COUNTY FLOOD CONTROL
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32

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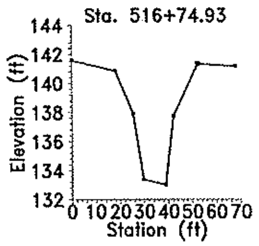

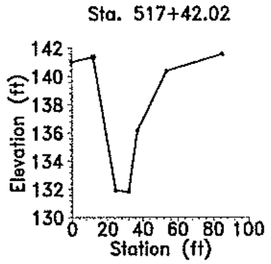

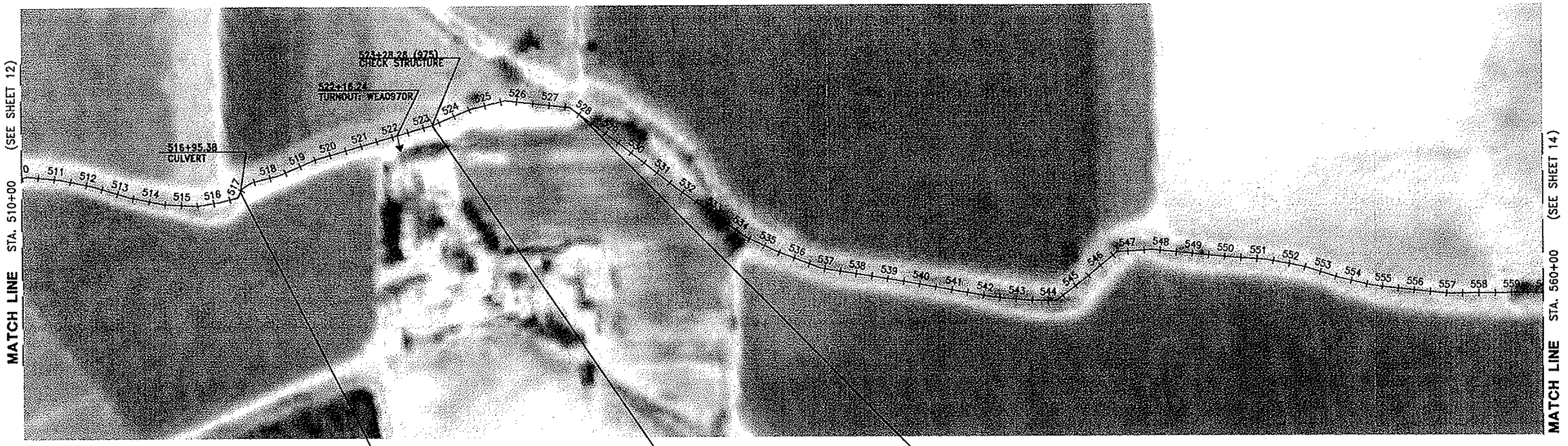

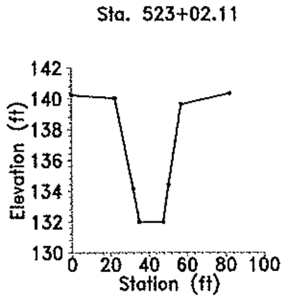

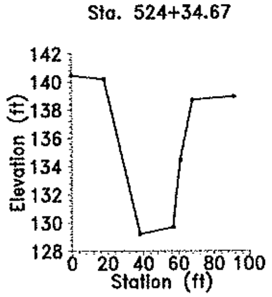

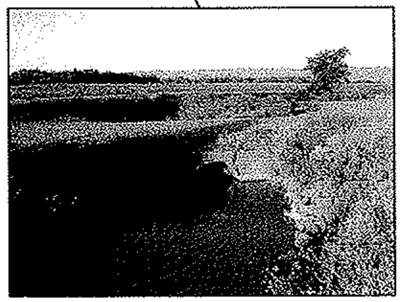

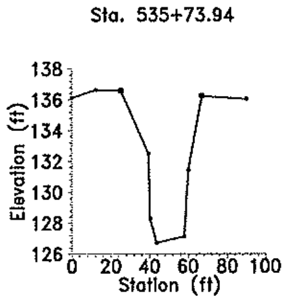

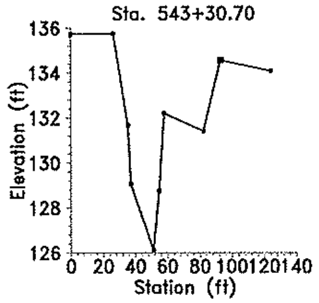

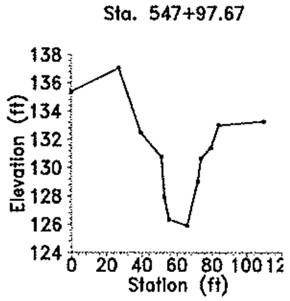

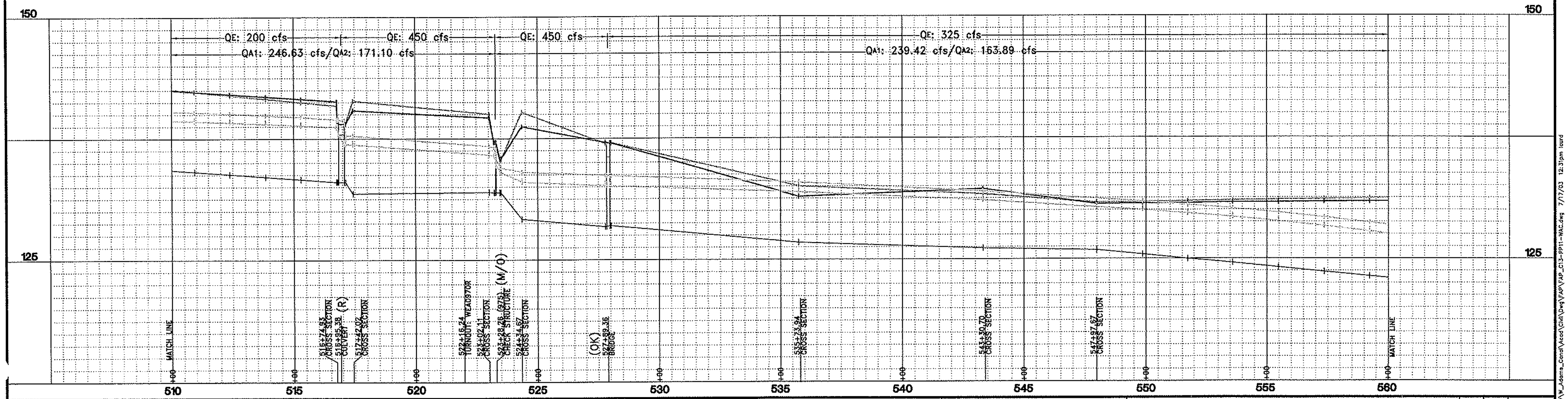

REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1"=10'

YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE 9-16-02

DESIGNED BY: ______
R.C.E. ______ DATE ______

CHECKED BY: ______
R.C.E. ______ DATE ______

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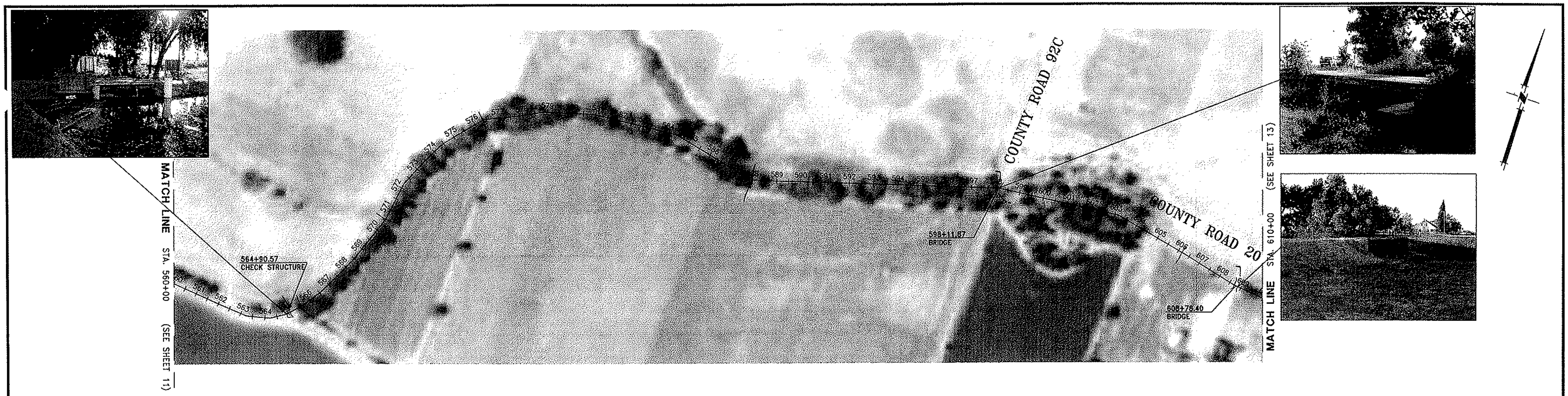
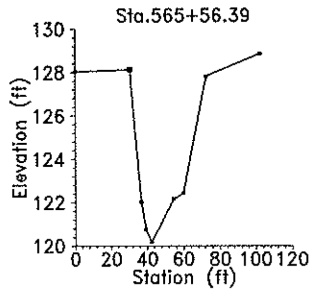
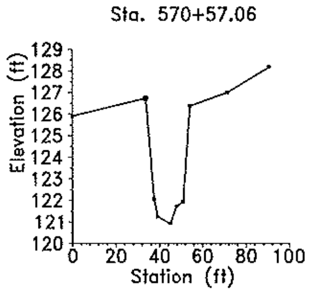
WEST ADAMS CANAL - ARRANGED FLOW
PLAN AND PROFILE
STA. 510+00 TO STA. 560+00

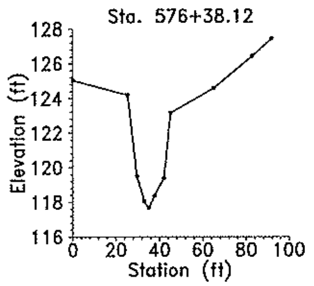
SHEET
13
— OF —
32

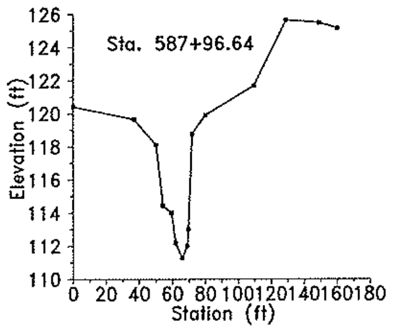
J:\Jobs\8108-YCFC_WCD\W_Adams_Canal\Acad\Civil\Dwg\FAP\FAP_C13-PP11-WAC.dwg 7/17/03 12:31pm lcard

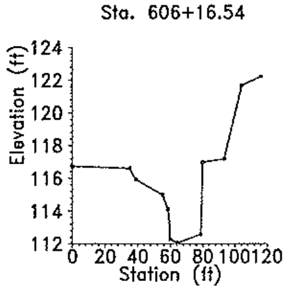


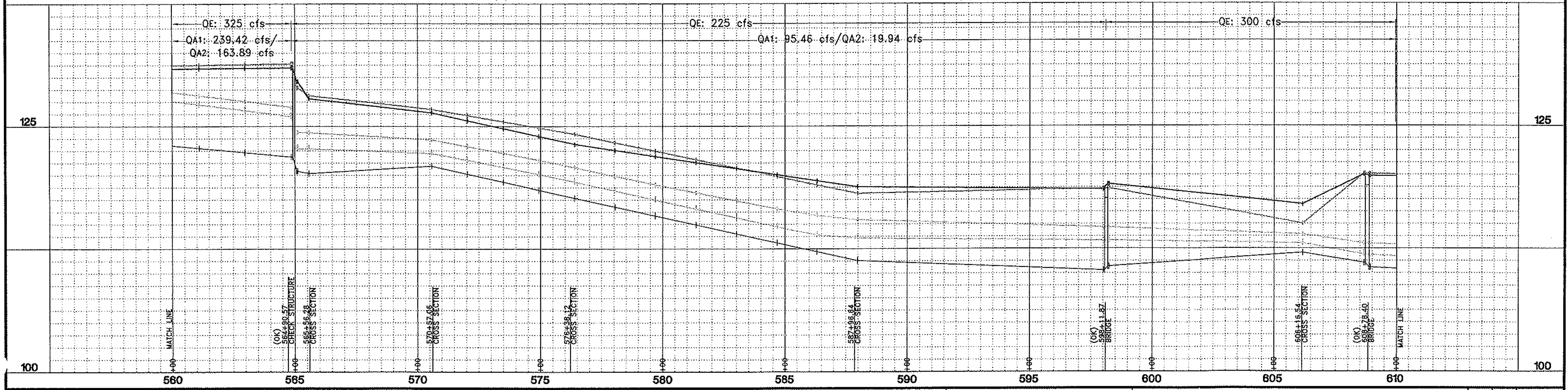












REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE 9-16-02
DESIGNED BY: ______
R.C.E. ______ DATE ______
CHECKED BY: ______
R.C.E. ______ DATE ______

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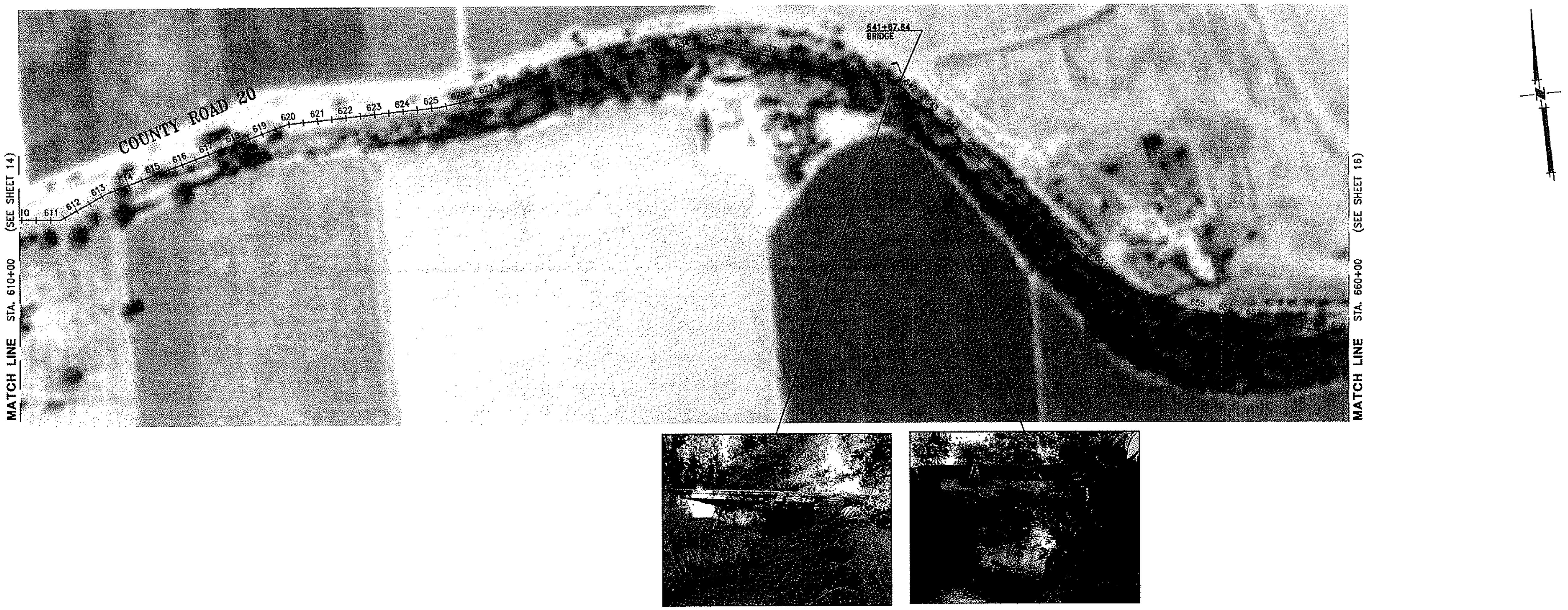
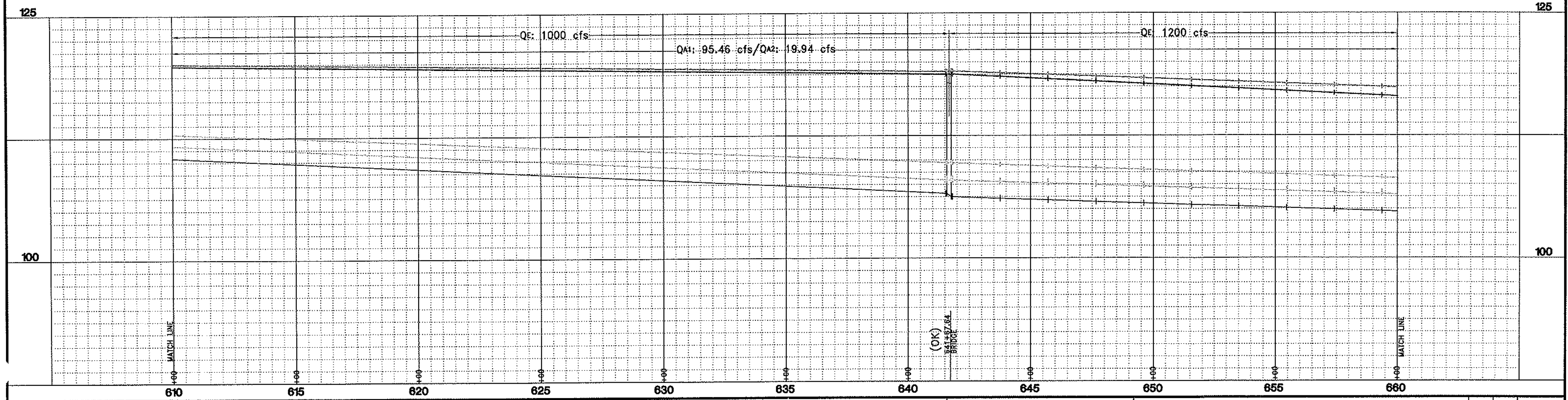
WEST ADAMS CANAL - ARRANGED FLOW
PLAN AND PROFILE
STA. 560+00 TO STA. 610+00

SHEET
14
— OF —
32

J:\Jobs\8108-YCFC_WCD\W_Adams_Canal\Acad\Civil\Dwg\FAP\FAP_C14-PP12-WAC-Ch1.dwg 7/17/03 10:36pm jbolymore





NO.	REVISIONS DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE 9-16-02
DESIGNED BY: ______
R.C.E. ______ DATE ______
CHECKED BY: ______
R.C.E. ______ DATE ______

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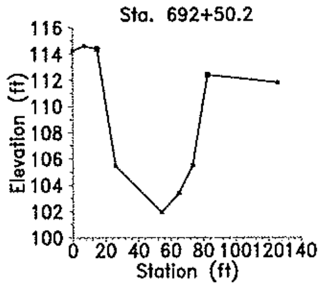
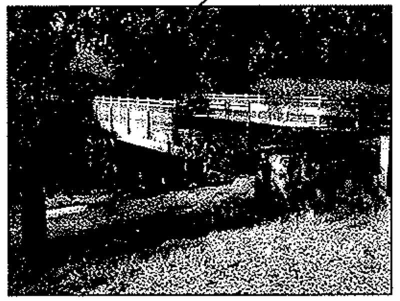
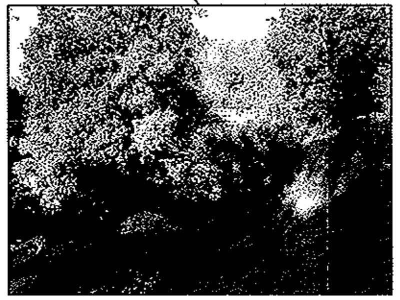
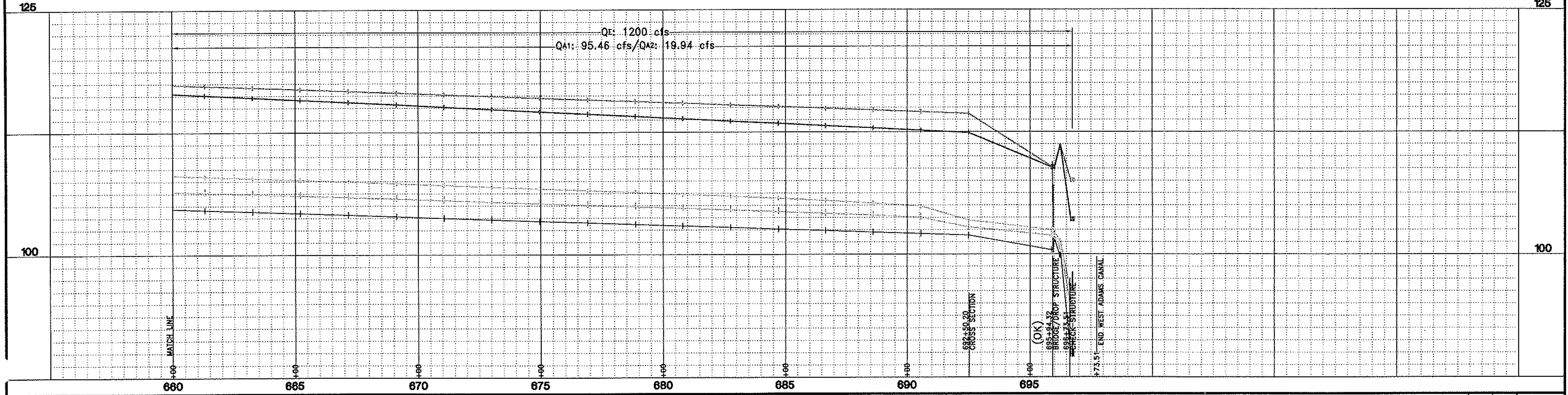
WEST ADAMS CANAL - ARRANGED FLOW
PLAN AND PROFILE
STA. 610+00 TO STA. 660+00

SHEET
15
— OF —
32









NO.	REVISIONS DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1"=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE 9-20-02
DESIGNED BY: ______
R.C.E. ______ DATE ______
CHECKED BY: ______
R.C.E. ______ DATE ______

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WEST ADAMS CANAL – ARRANGED FLOW
PLAN AND PROFILE
STA. 660+00 TO STA. 697+73.51

SHEET
16
— OF —
32

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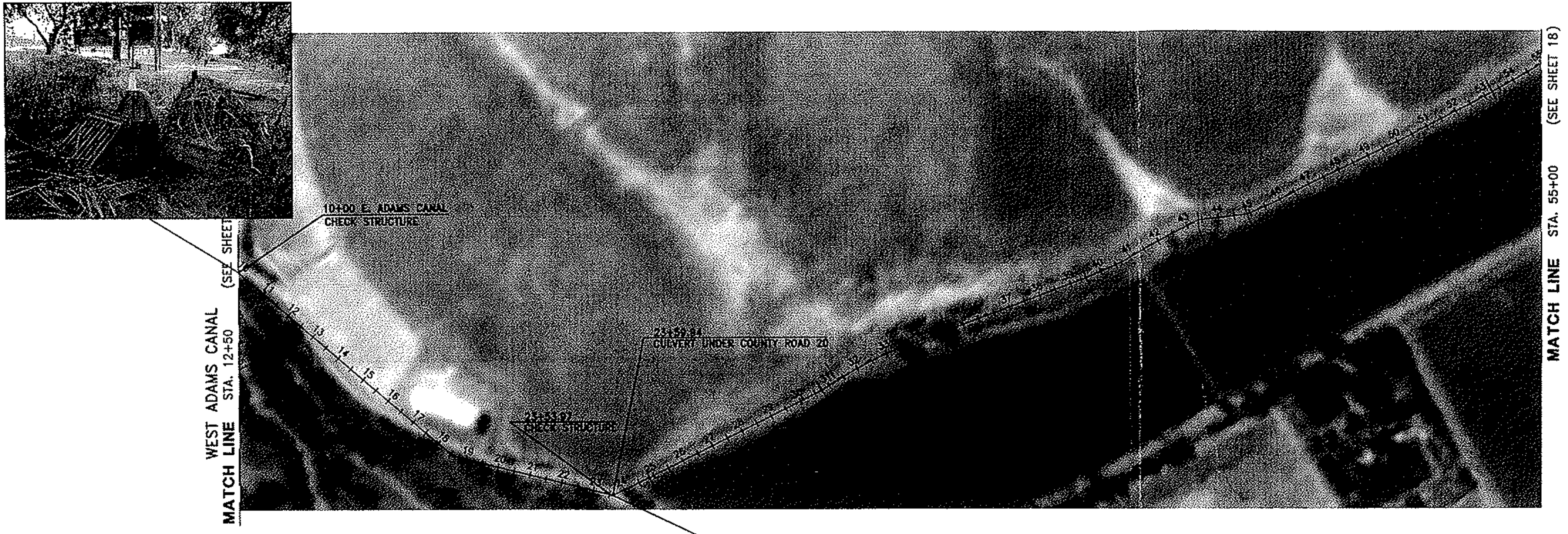

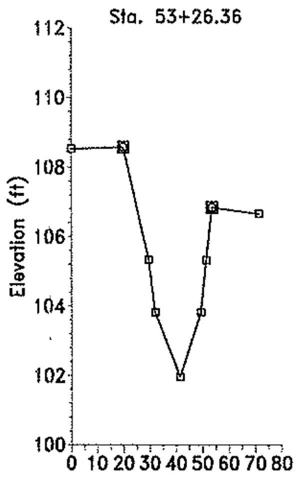

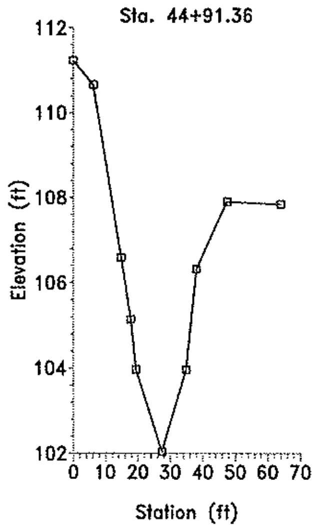

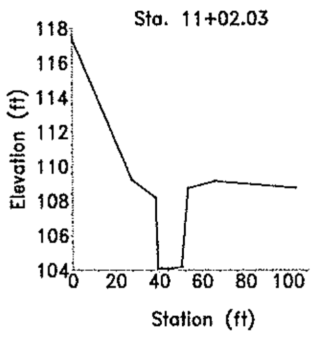

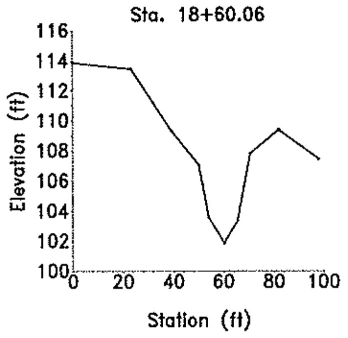

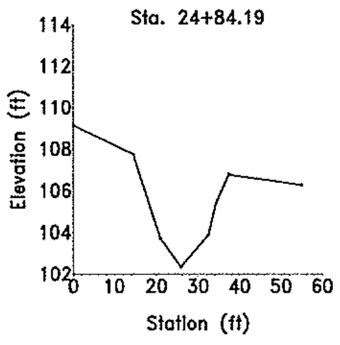

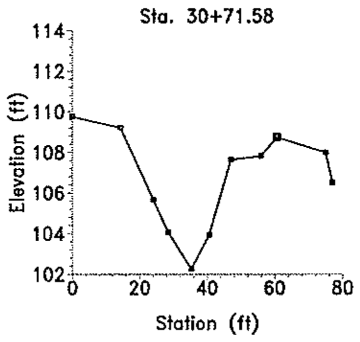

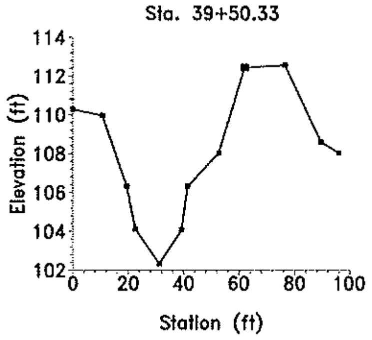

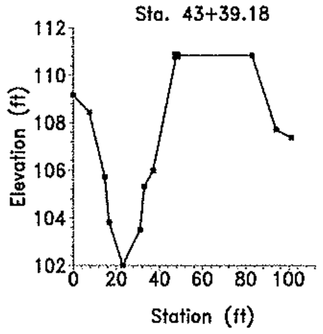

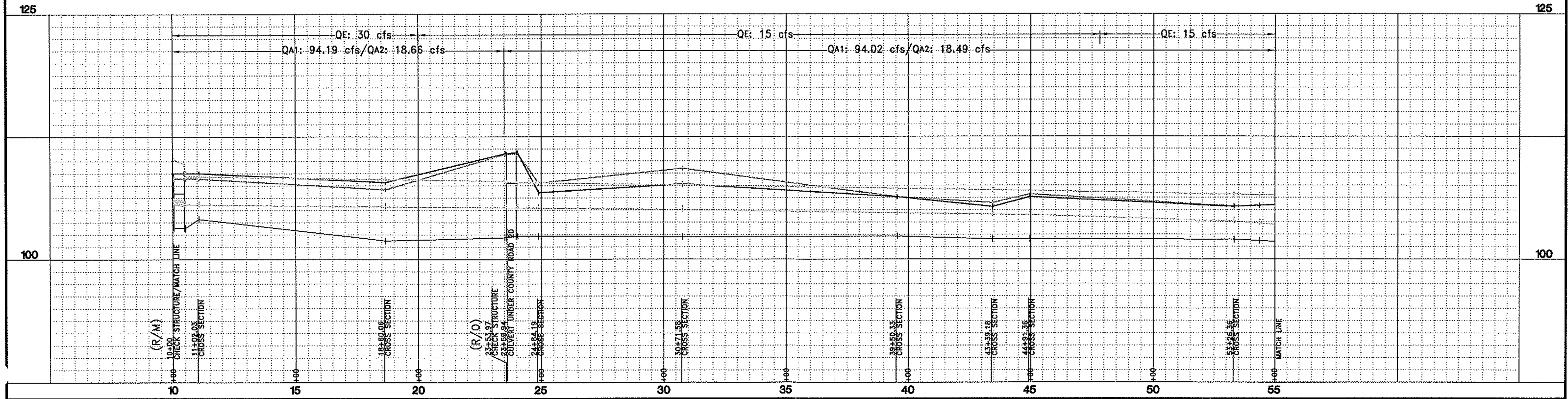

REVISIONS
NO. DESCRIPTION DATE BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1"=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC
DATE 9-25-02 DATE
DESIGNED BY: ______
R.C.E. ______ DATE ______
CHECKED BY: ______
R.C.E. ______ DATE ______

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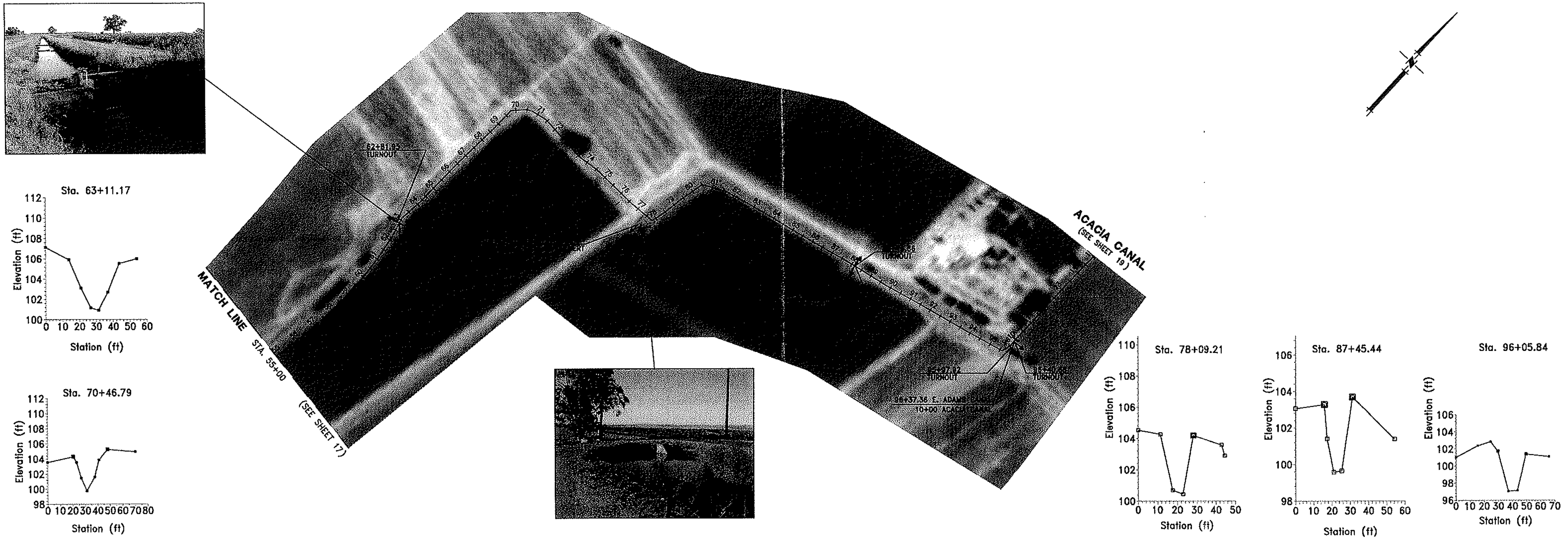
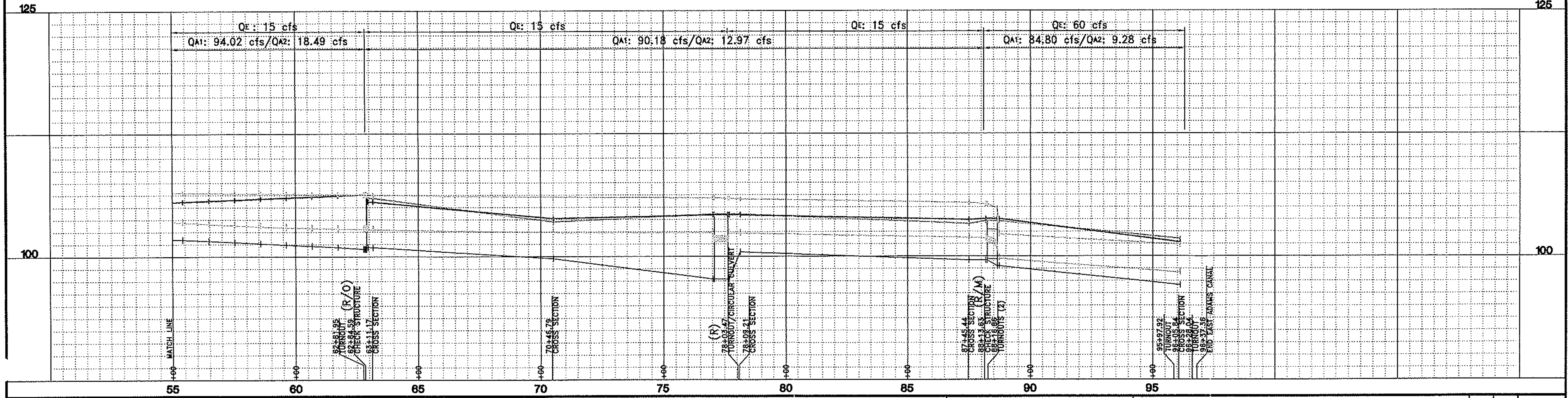
EAST ADAMS CANAL - ARRANGED FLOW
PLAN AND PROFILE
STA. 10+00 TO STA. 55+00

SHEET
17
OF
32

J:\Jobs\8108-YCFC_WCD\W_Adams_Canal\Acad\Civil\Dwg\FAP\FAP_C17-PP15-WAC.dwg 7/17/03 10:07pm laurd





REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1"=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC/SF
DATE 9-28-02 DATE
DESIGNED BY: ______
R.C.E. ______ DATE ______
CHECKED BY: ______
R.C.E. ______ DATE ______

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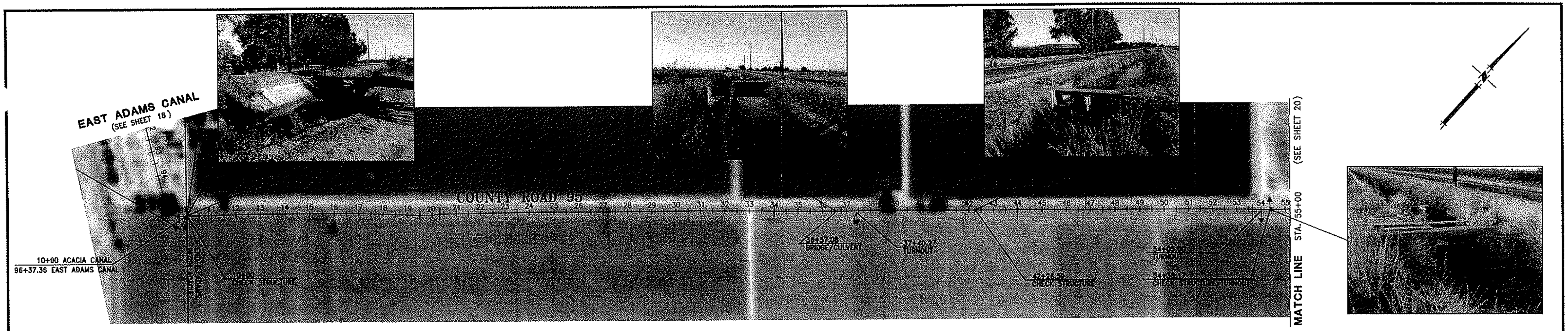
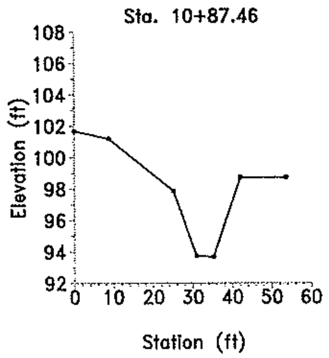
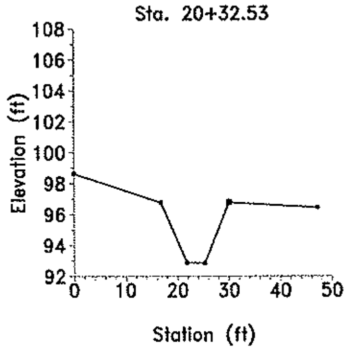
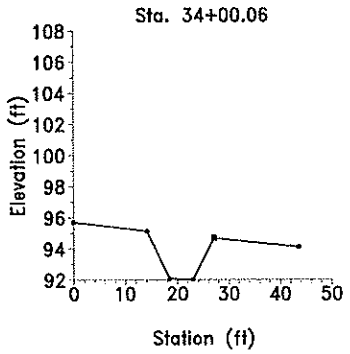
EAST ADAMS CANAL - ARRANGED FLOW
PLAN AND PROFILE
STA. 55+00 TO STA. 97+37.36

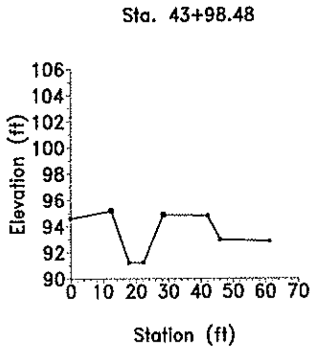
SHEET
18
OF
32

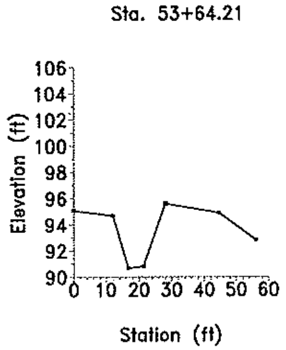


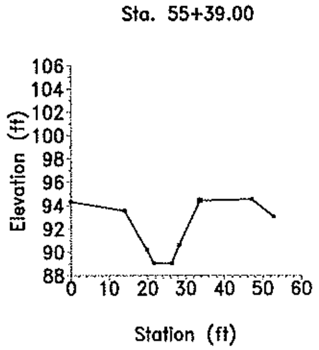


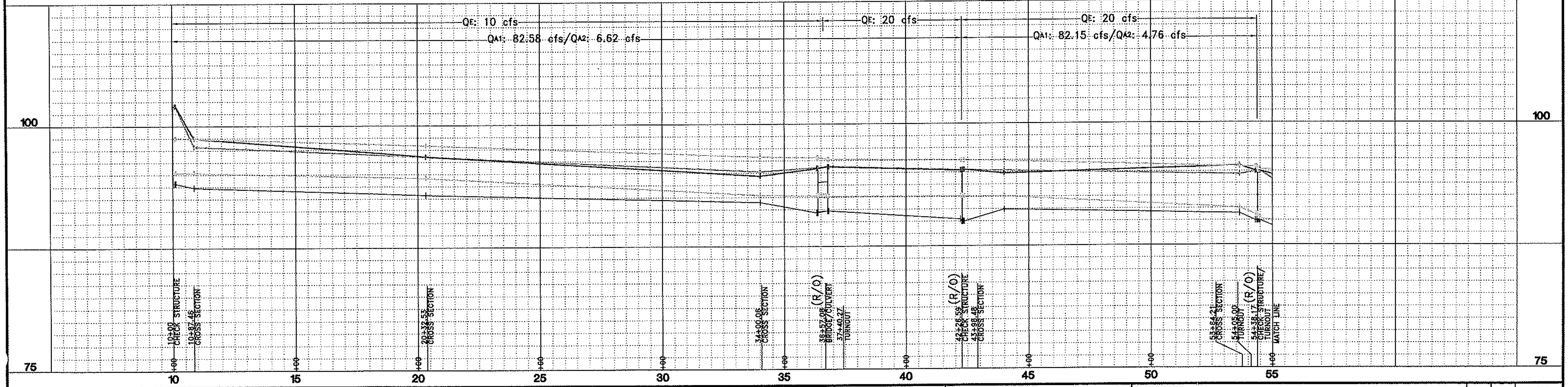












REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC/SE
DATE 9-25-02 DATE

DESIGNED BY: ______
R.C.E. ______ DATE ______

CHECKED BY: ______
R.C.E. ______ DATE ______

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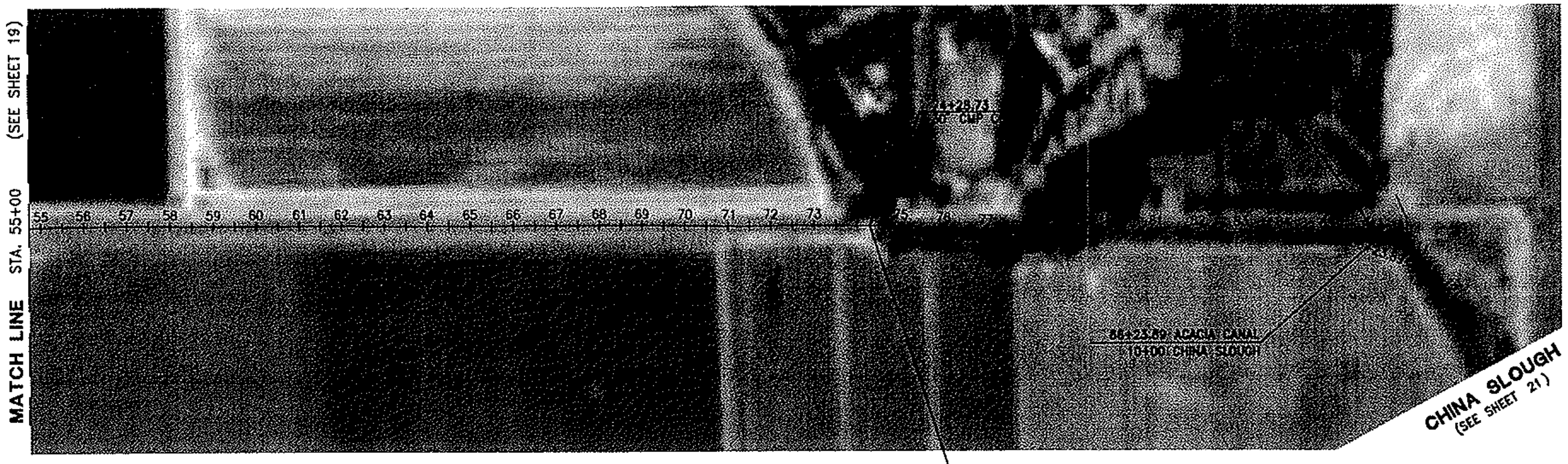
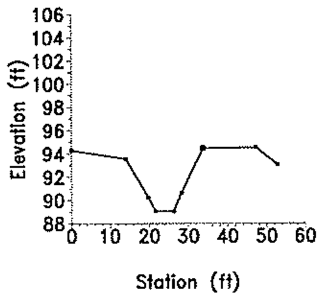
ACACIA CANAL - ARRANGED FLOW
PLAN AND PROFILE
STA. 10+00 TO STA. 55+00

SHEET
19
OF
32



Sta. 55+39.00



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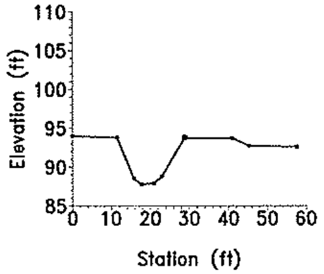

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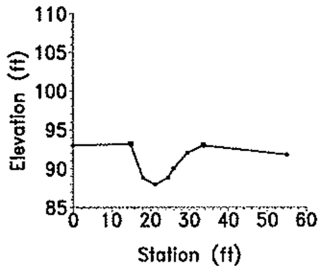

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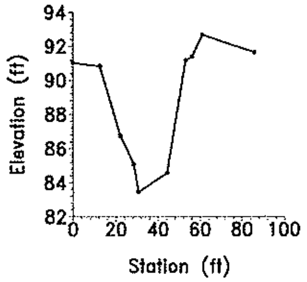

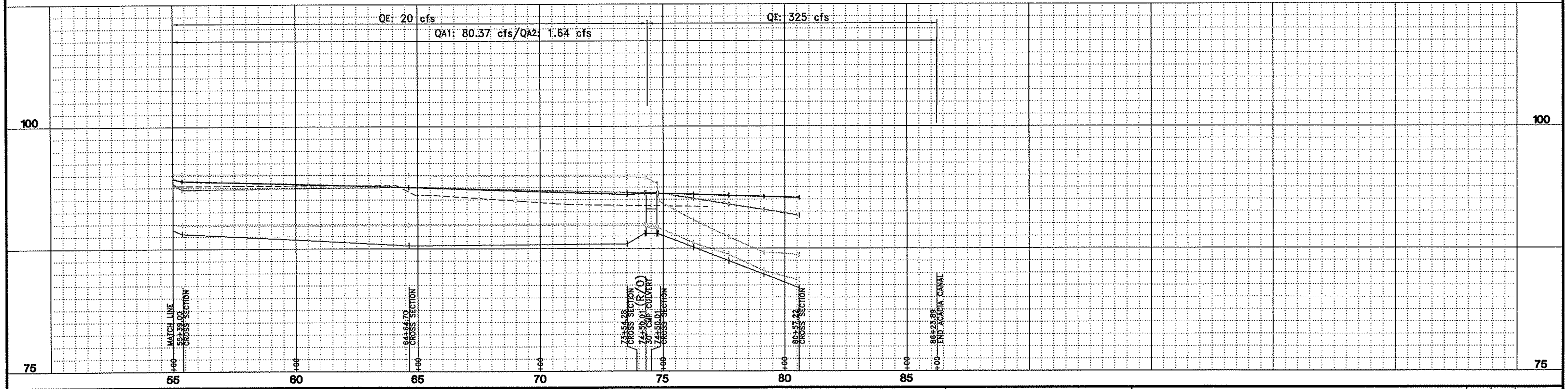

REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCHMARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL
& WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC/SE
DATE 9-25-02 DATE
DESIGNED BY: ______
R.C.E. ______ DATE ______
CHECKED BY: ______
R.C.E. ______ DATE ______

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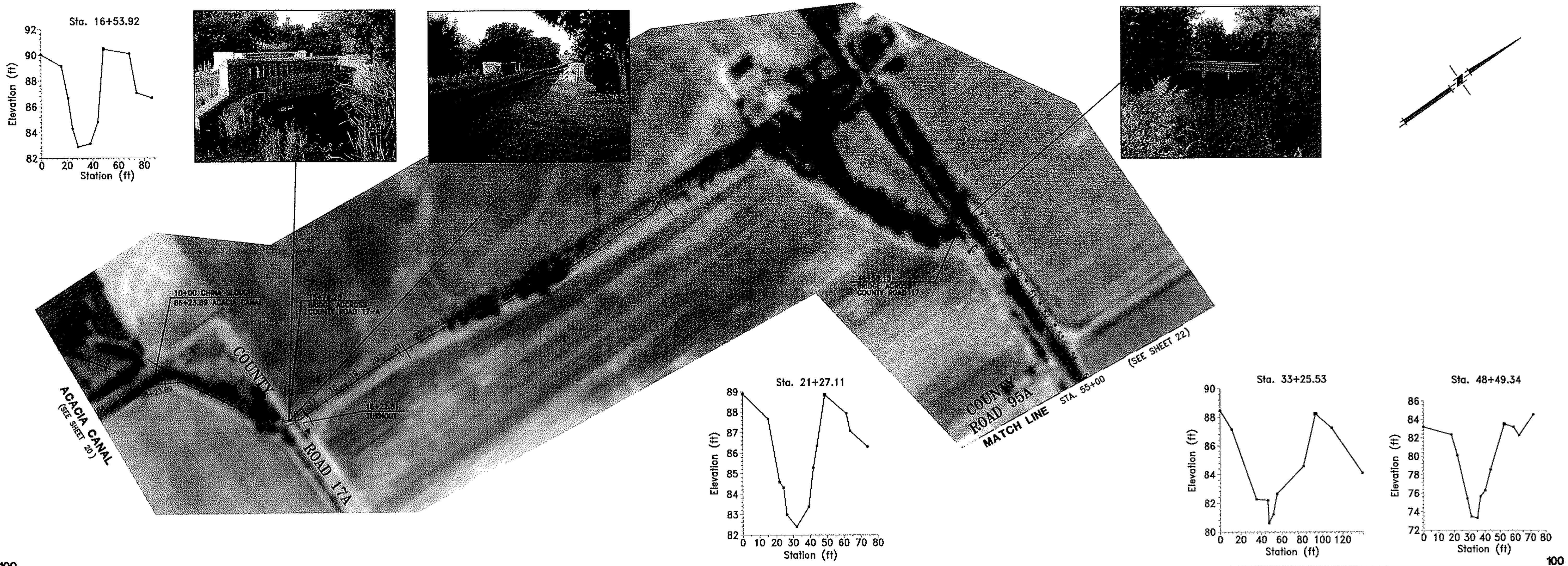
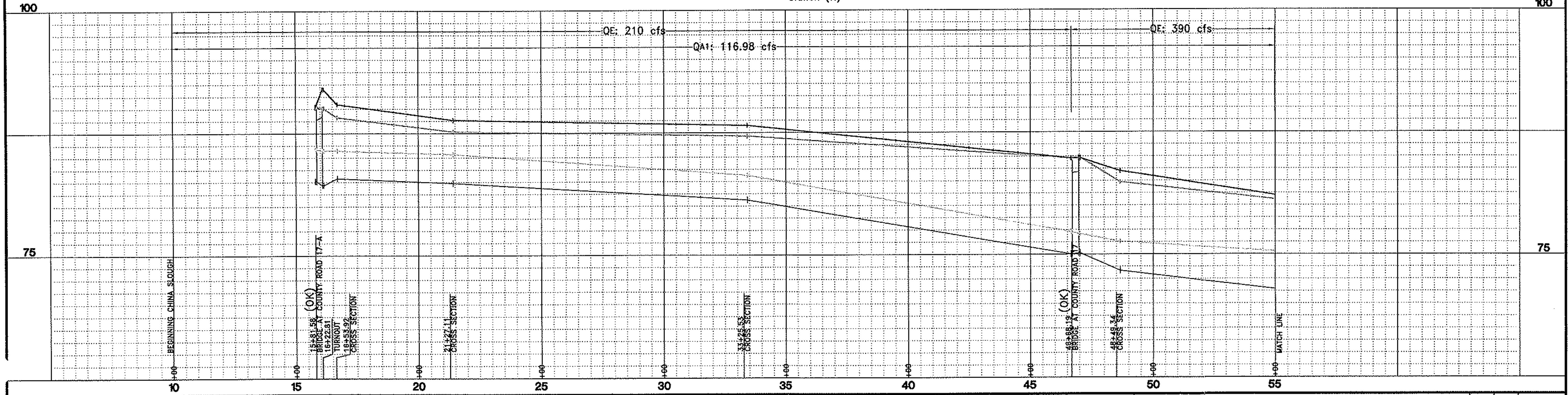
ACACIA CANAL - ARRANGED FLOW
PLAN AND PROFILE
STA. 55+00 TO STA. 86+23.89

SHEET
20
OF
32





NO.	REVISIONS DESCRIPTION	DATE	BY

BENCH MARK ELEV. ______
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(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC/SE
DATE 9-25-02 DATE
DESIGNED BY: ______
R.C.E. ______ DATE ______
CHECKED BY: ______
R.C.E. ______ DATE ______

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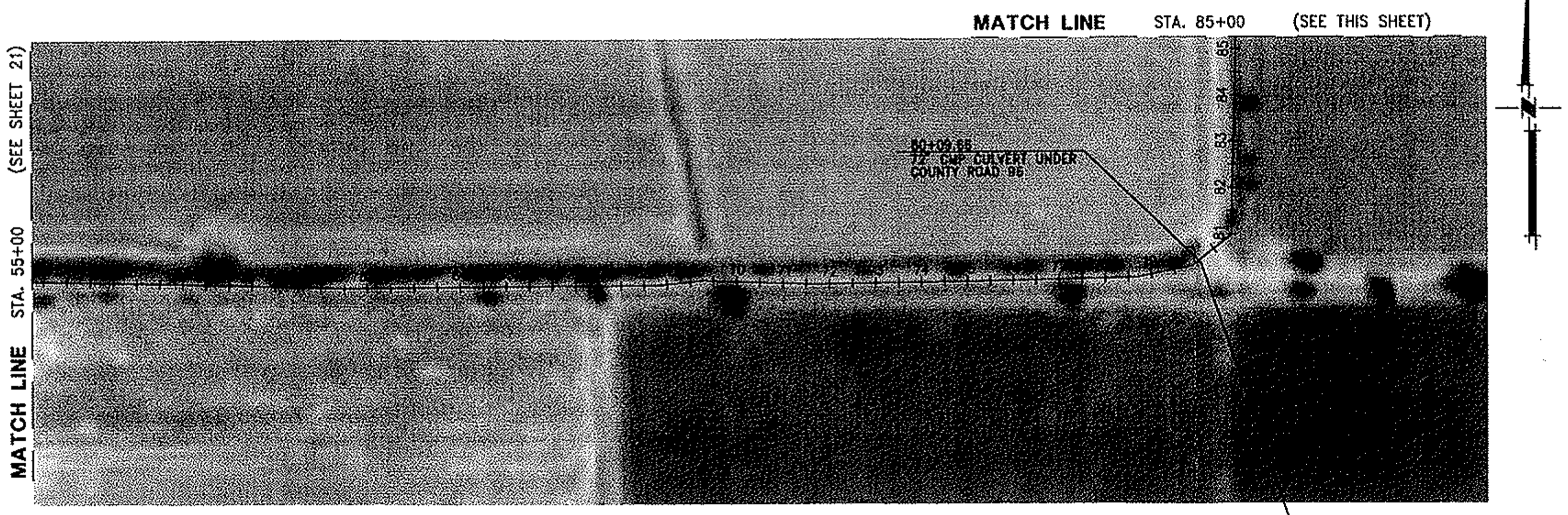
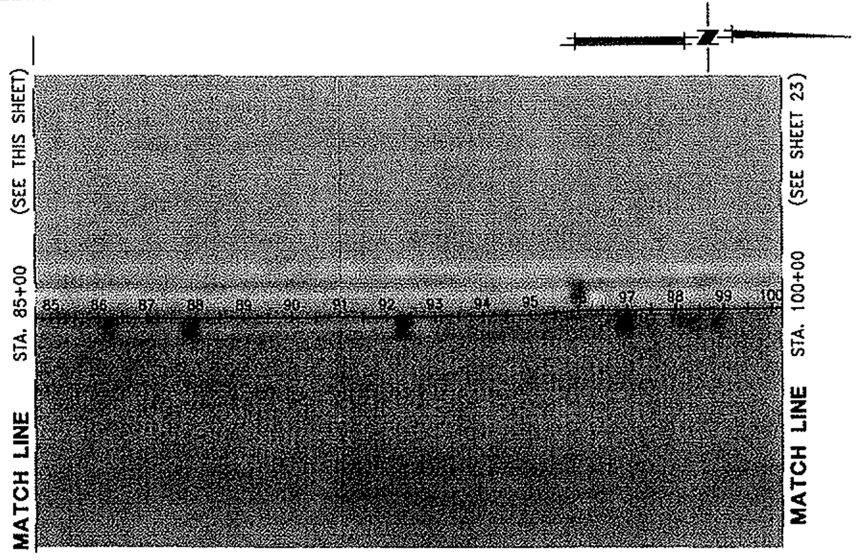
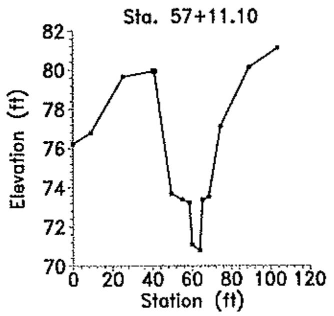
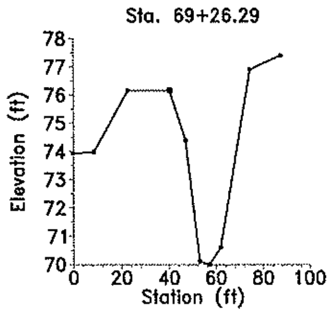
YCFCWCD/YZWD CONJUNCTIVE WATER USE FEASIBILITY STUDY
CHINA SLOUGH - ARRANGED FLOW
STA. 10+00 TO STA. 55+00

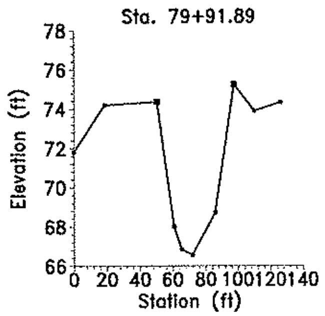
SHEET
21
OF
32

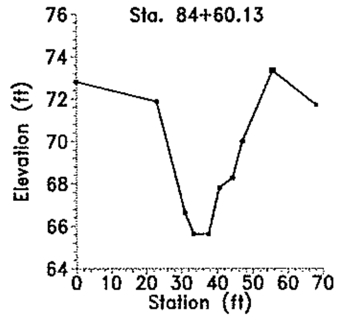


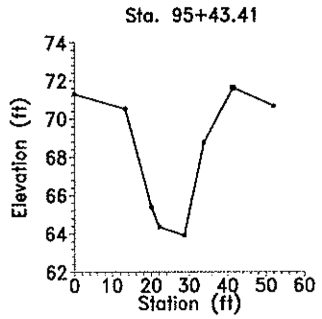


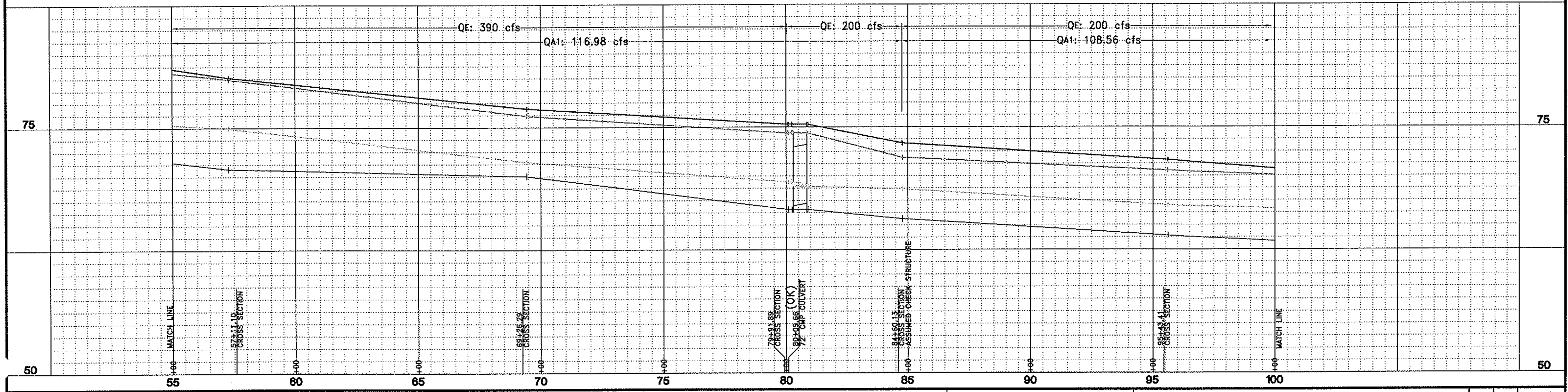












REVISIONS			
NO.	DESCRIPTION	DATE	BY

BENCH MARK ELEV. ______
DESCRIPTION:
(SEE SHEET NO. 1)

SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

DRAWN BY: JB/LC/SE
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CHINA SLOUGH - ARRANGED FLOW
PLAN AND PROFILE
STA. 55+00 TO STA. 100+00

SHEET
22
OF
32

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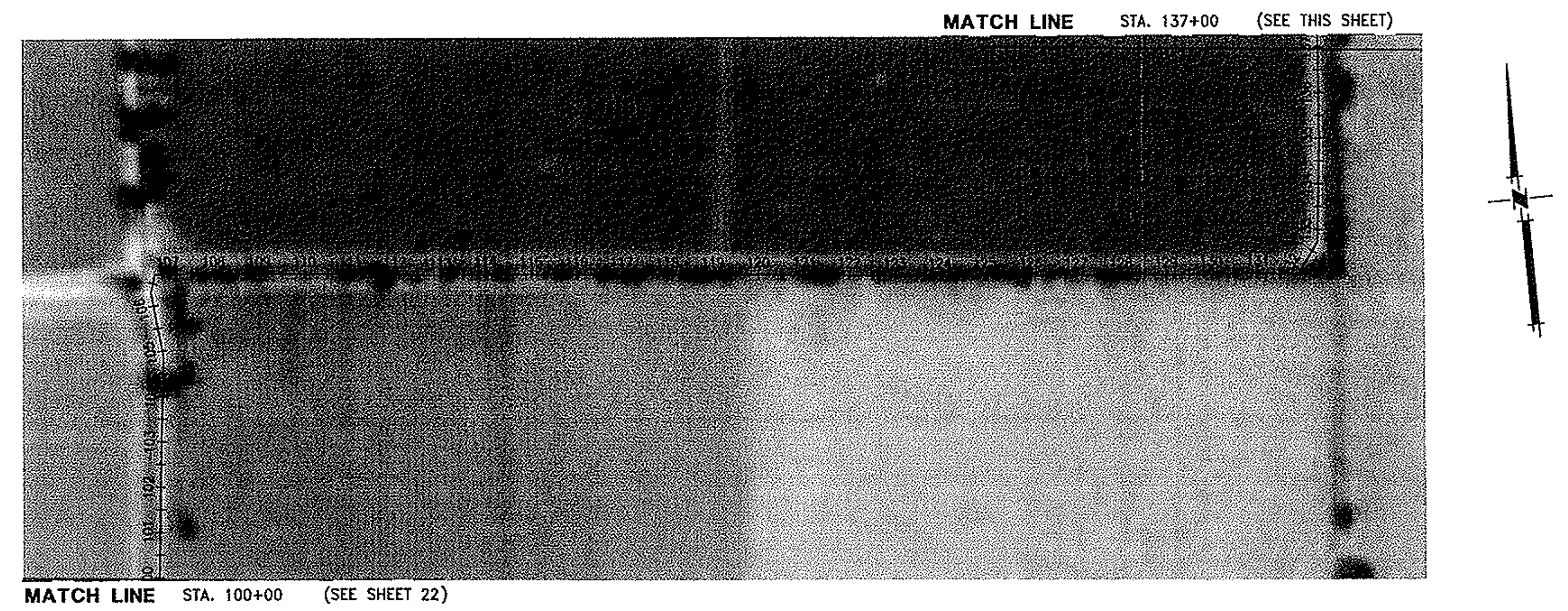

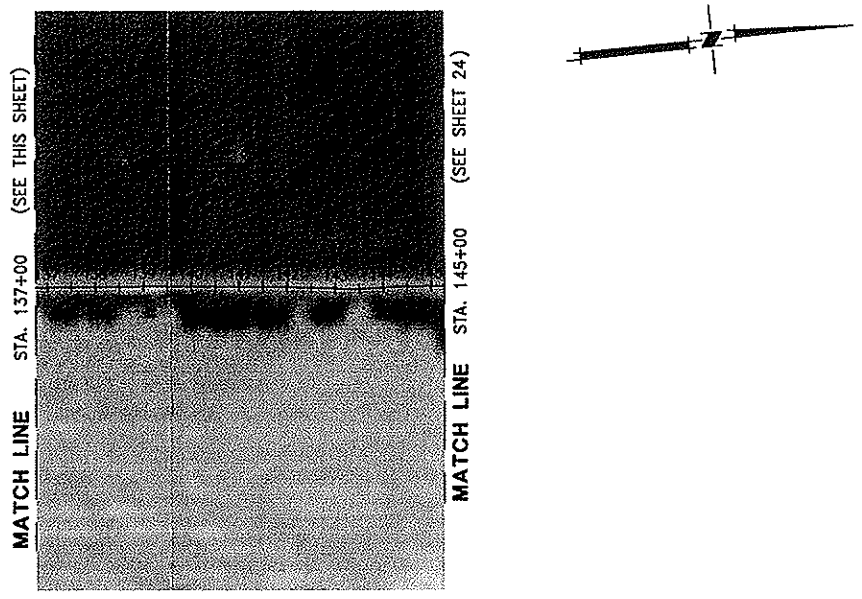

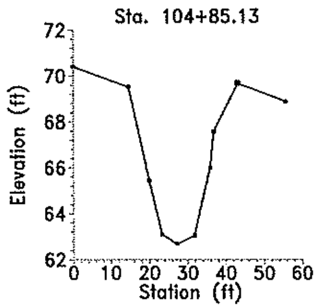

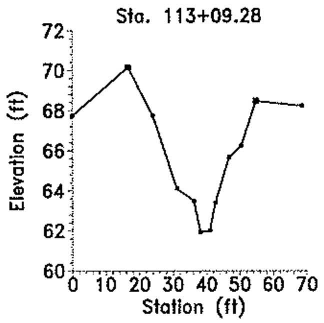

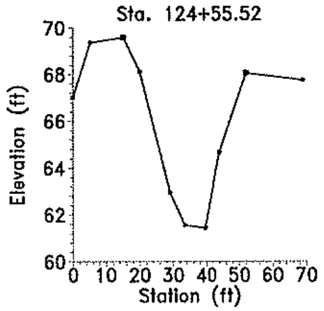

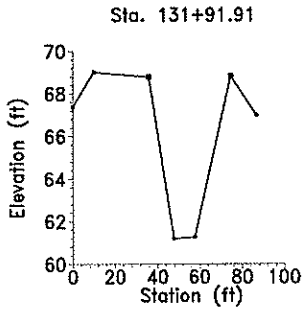

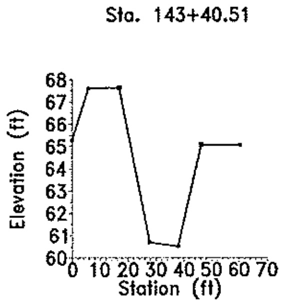

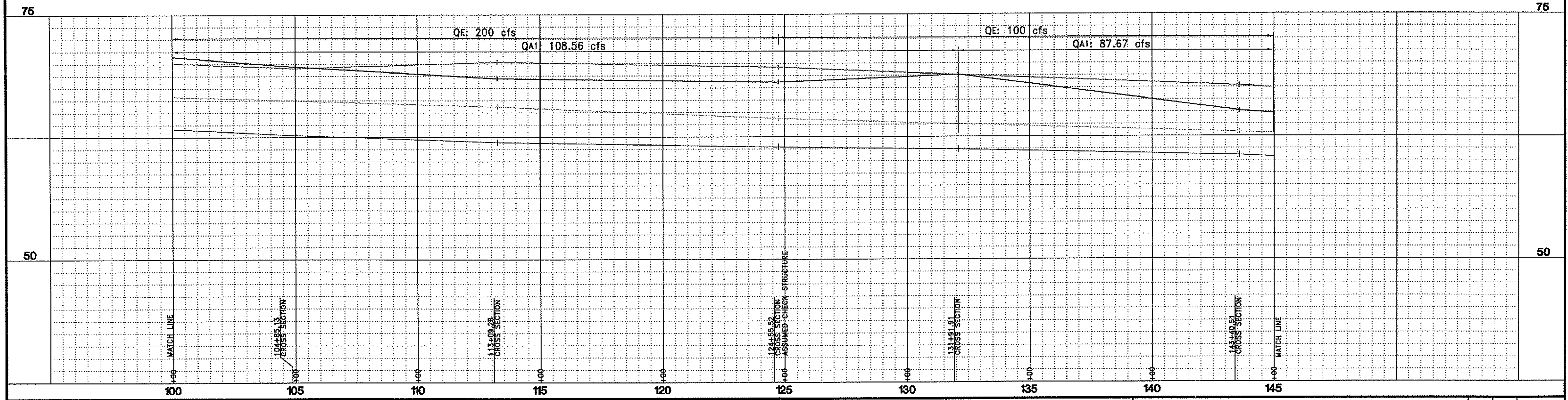

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CHINA SLOUGH - ARRANGED FLOW
PLAN AND PROFILE
STA. 100+00 TO STA. 145+00

SHEET
23
OF
32

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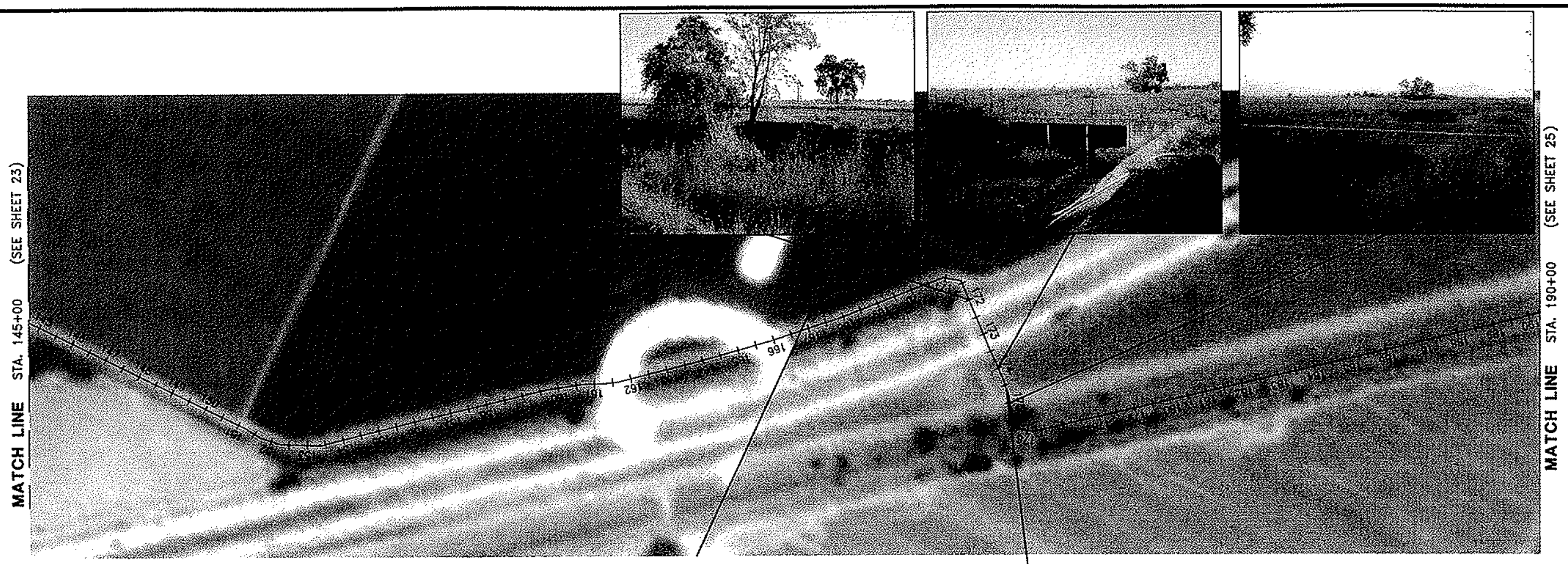

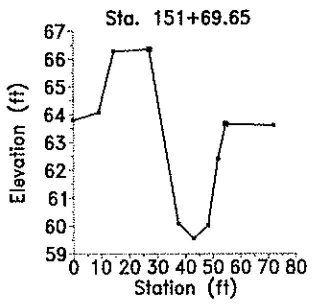

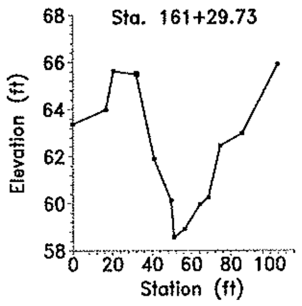

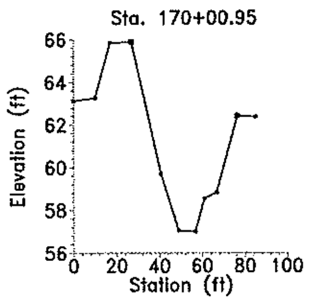

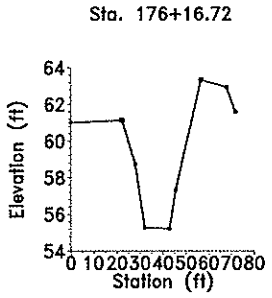

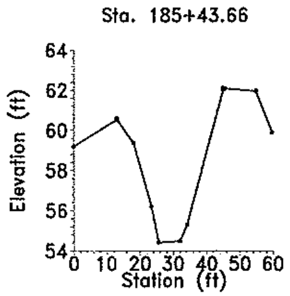

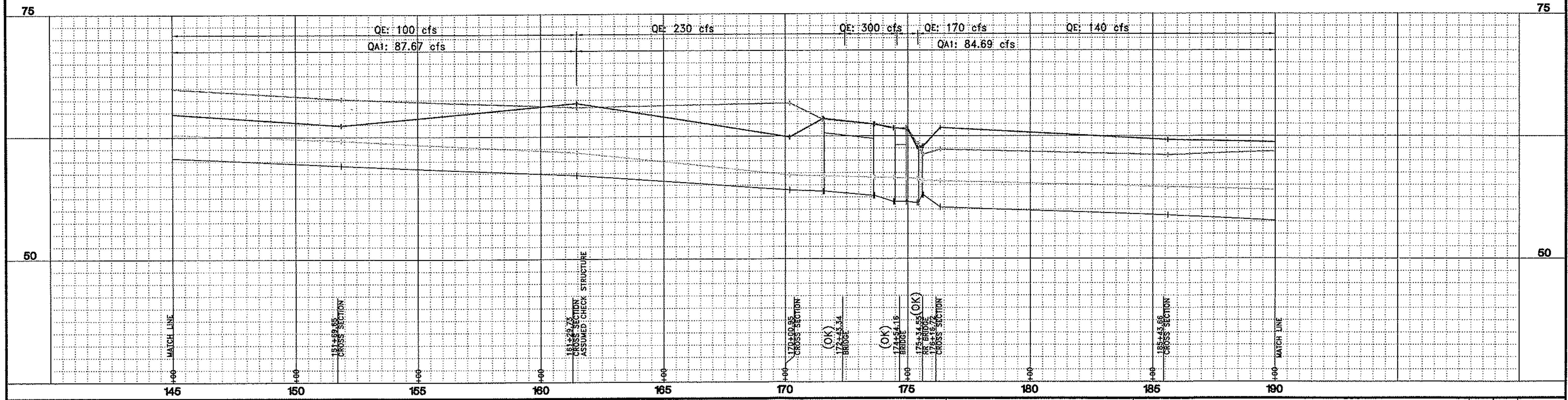

REVISIONS

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BENCHMARK ELEV. ________
DESCRIPTION:
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SCALE
H: 1"=200'
V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

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CHINA SLOUGH - ARRANGED FLOW
PLAN AND PROFILE
STA. 145+00 TO STA. 190+00

SHEET
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— OF —
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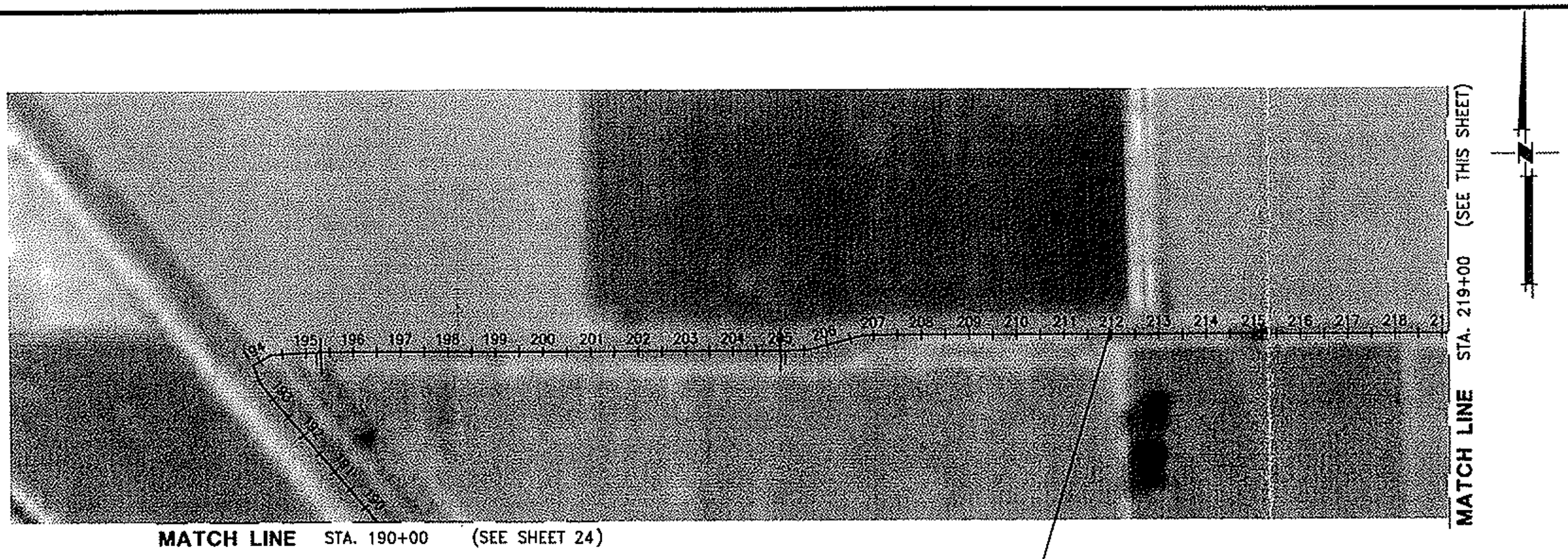

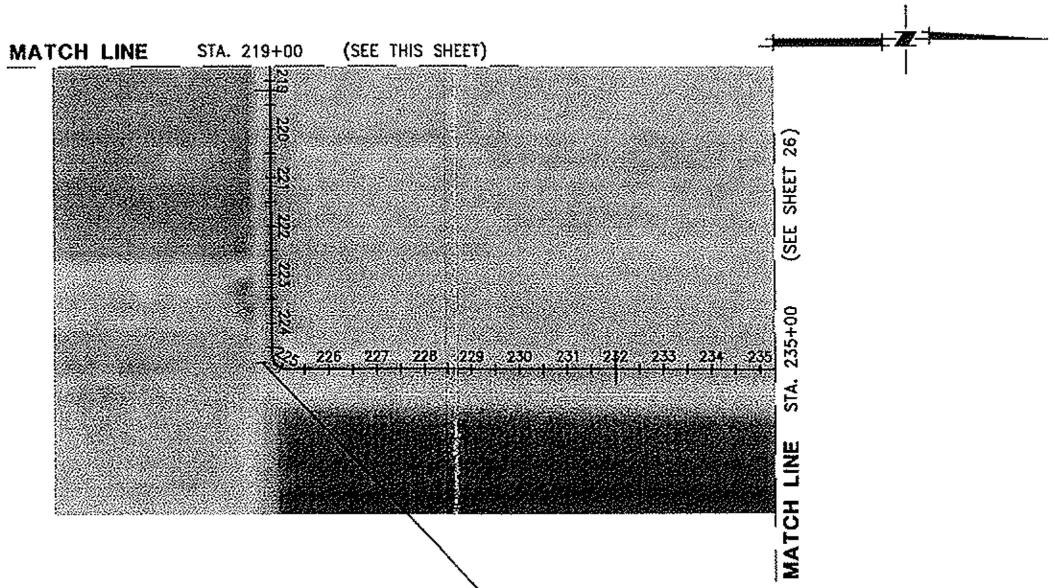

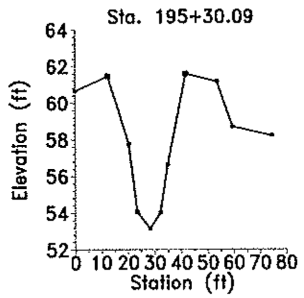

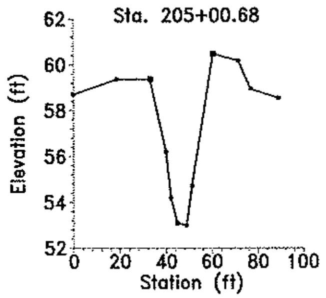

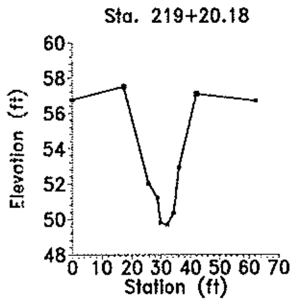

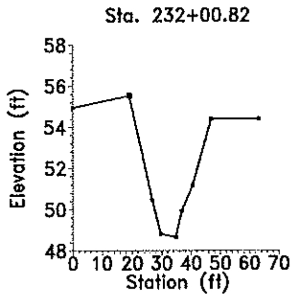

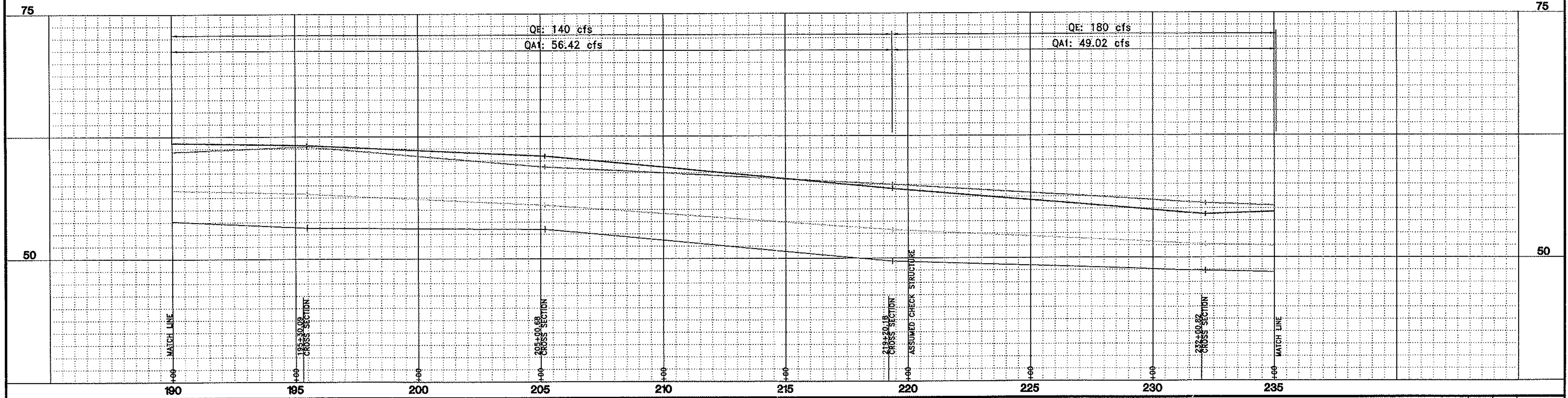

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BENCHMARK ELEV. ______
DESCRIPTION:
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SCALE
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YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

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CHINA SLOUGH - ARRANGED FLOW
PLAN AND PROFILE
STA. 190+00 TO STA. 235+00

SHEET
25
— OF —
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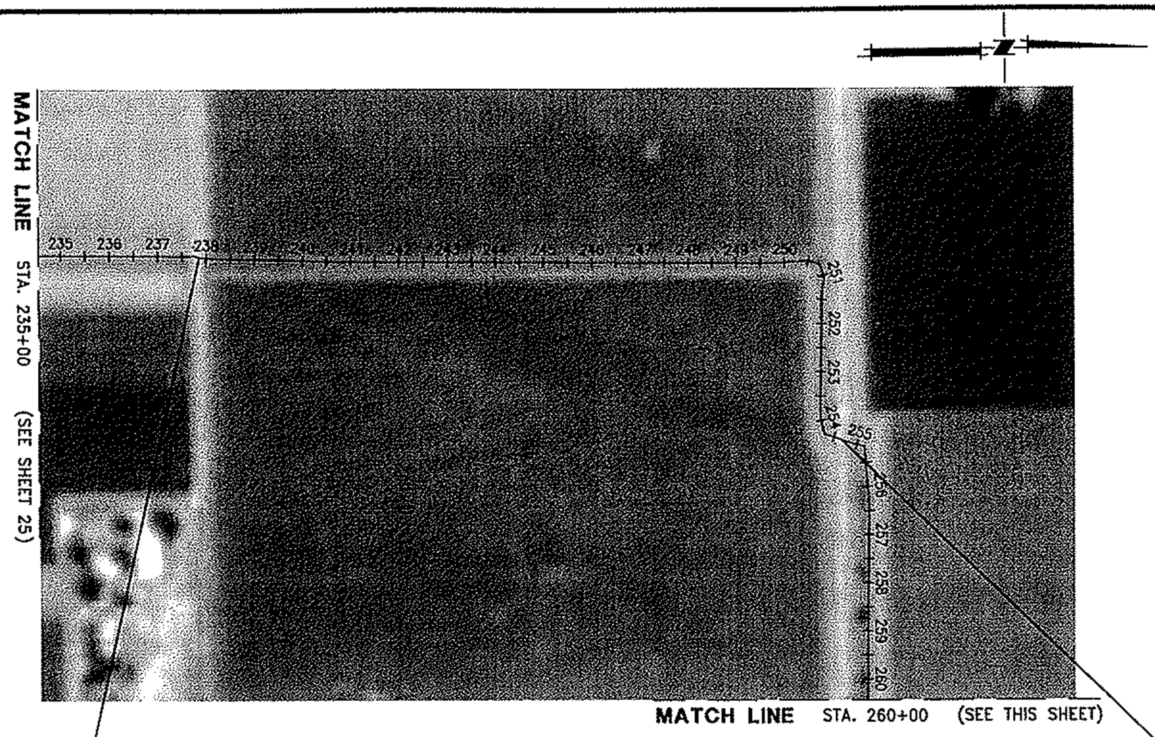

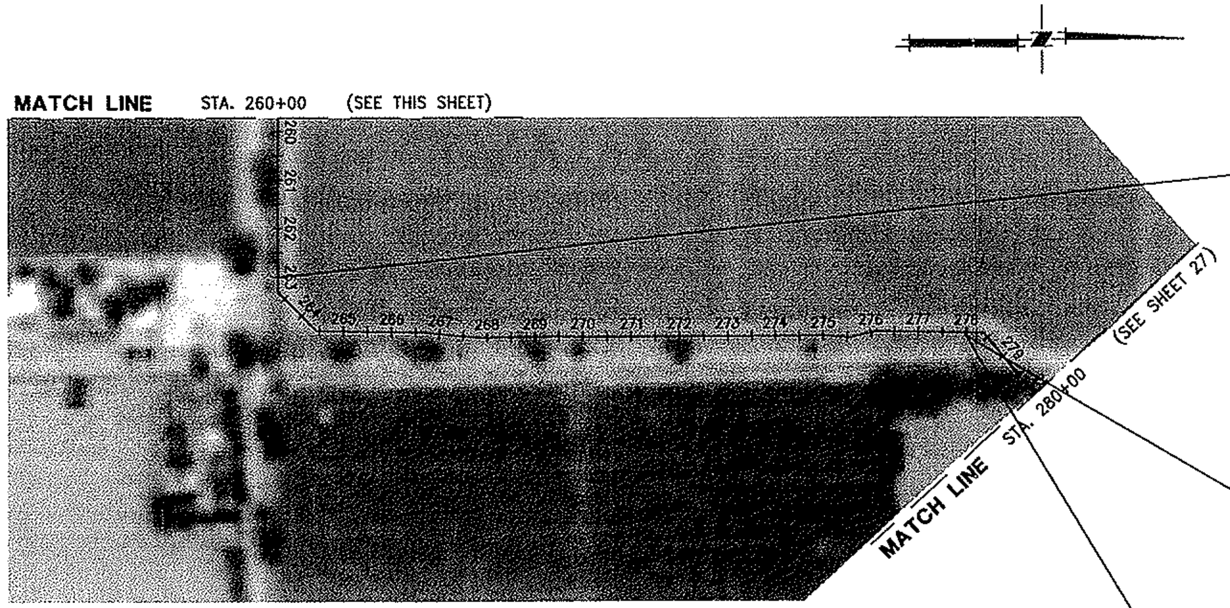

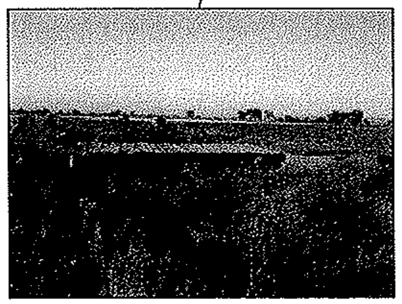

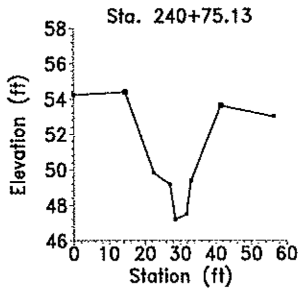

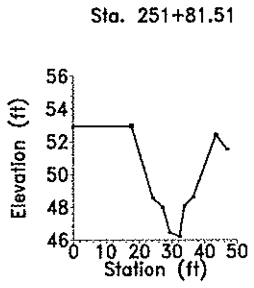

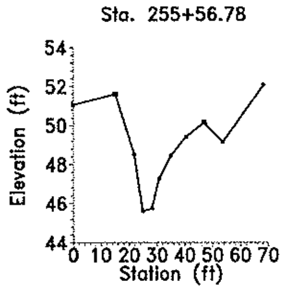

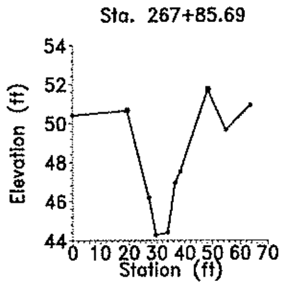

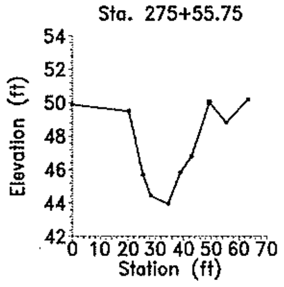

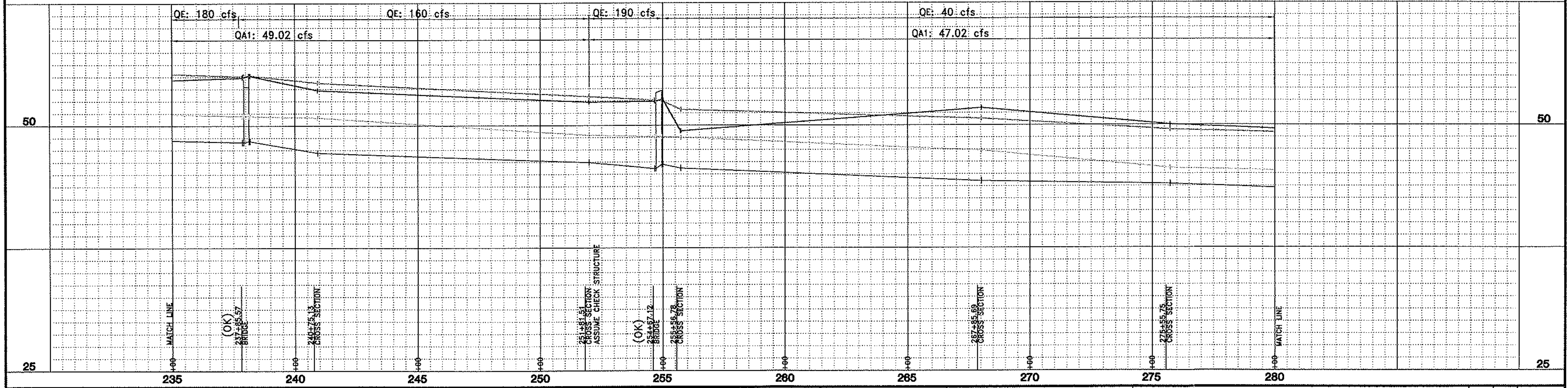

REVISIONS

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BENCHMARK ELEV. ______
DESCRIPTION:
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SCALE
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V: 1'=10'

YOLO COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

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CHINA SLOUGH – ARRANGED FLOW
PLAN AND PROFILE
STA. 235+00 TO 280+00

SHEET
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OF
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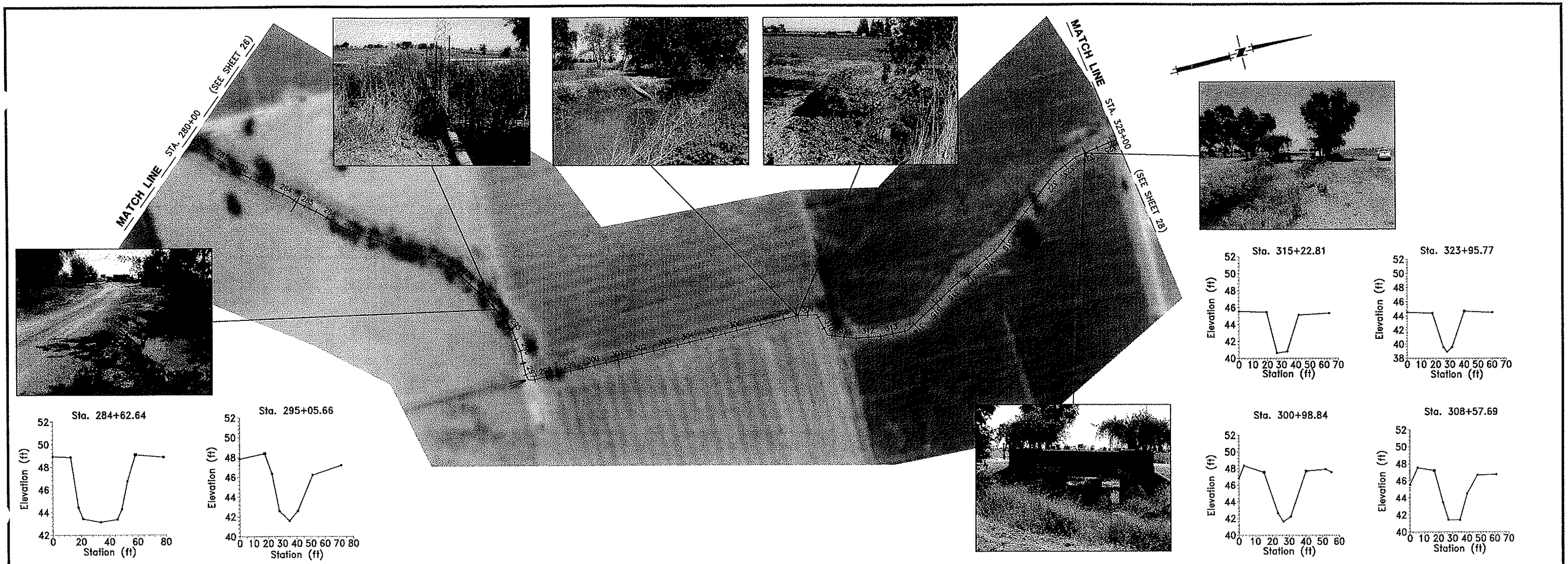

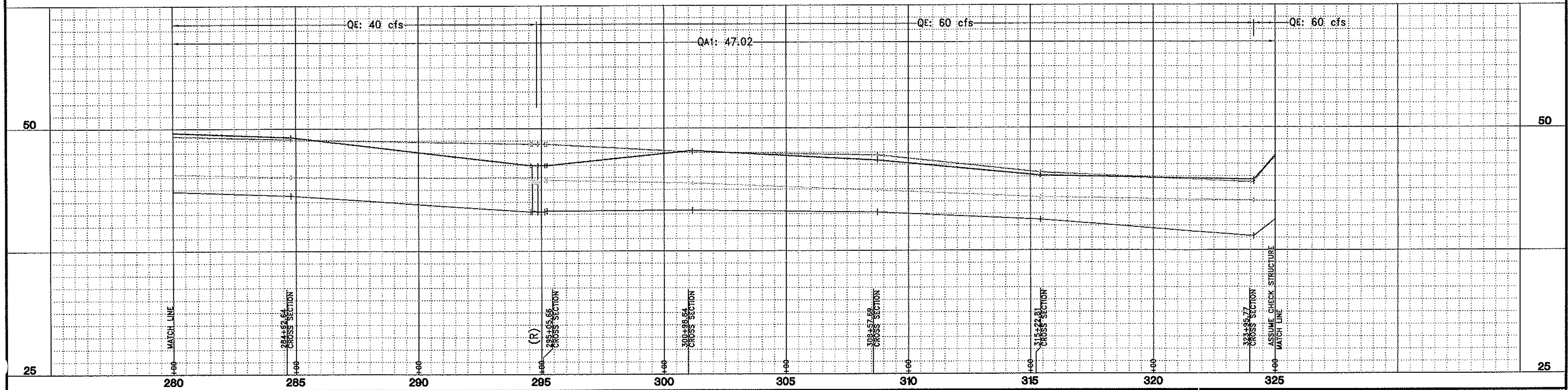

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PLAN AND PROFILE
STA. 280+00 TO STA. 325+00

SHEET
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OF
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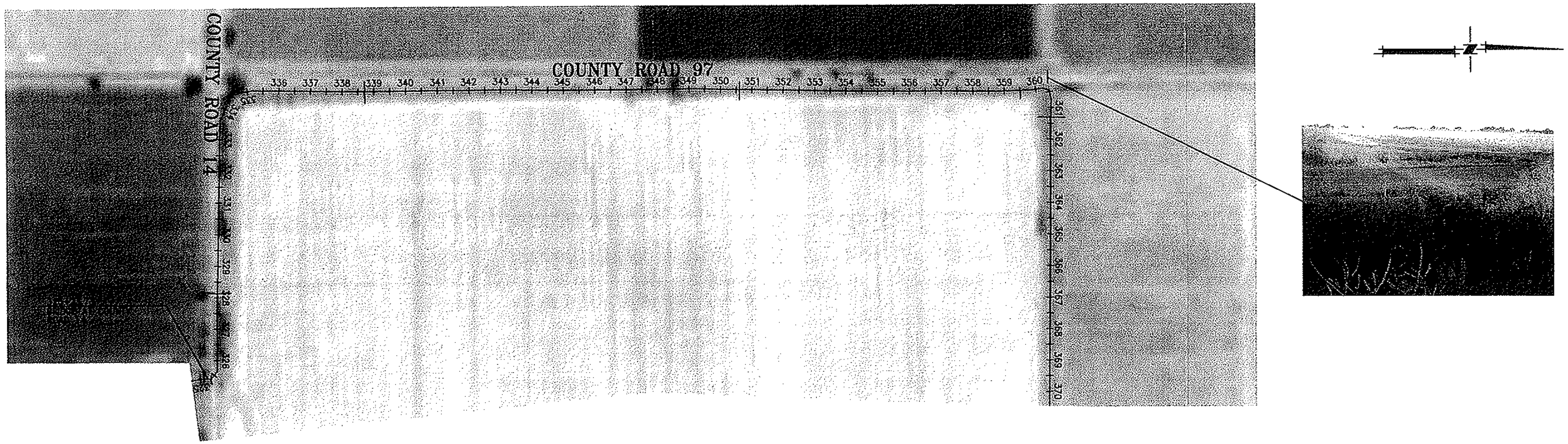

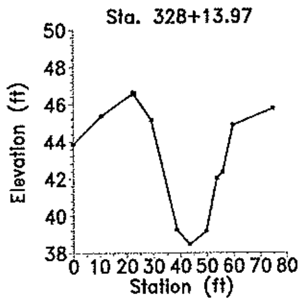

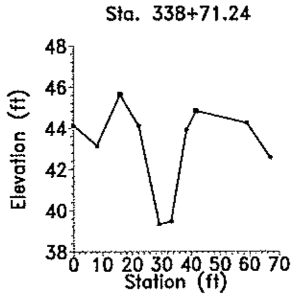

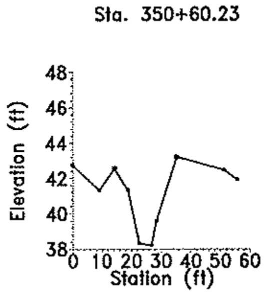

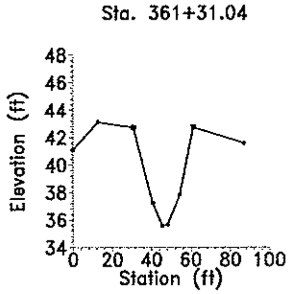

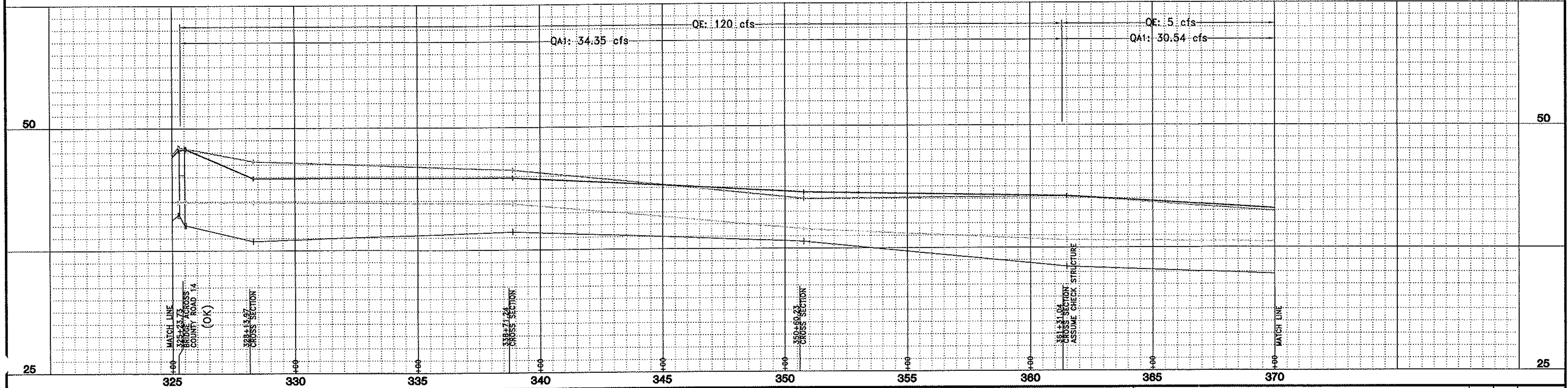

REVISIONS

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SHEET
28
— OF —
32

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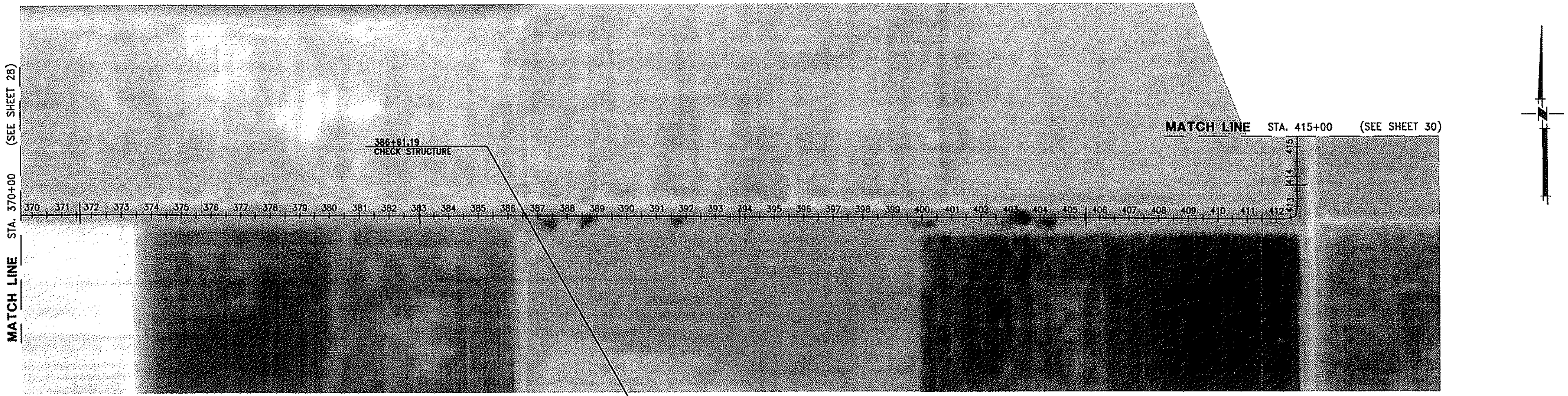

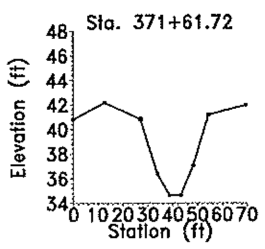

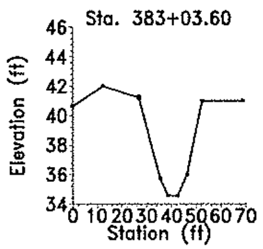

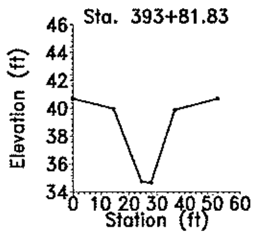

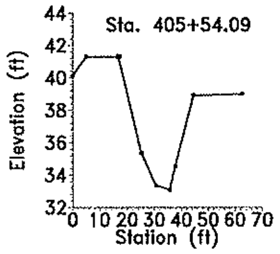

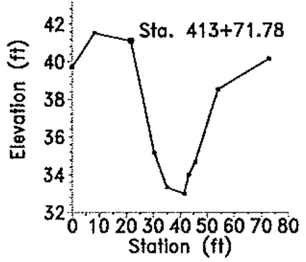

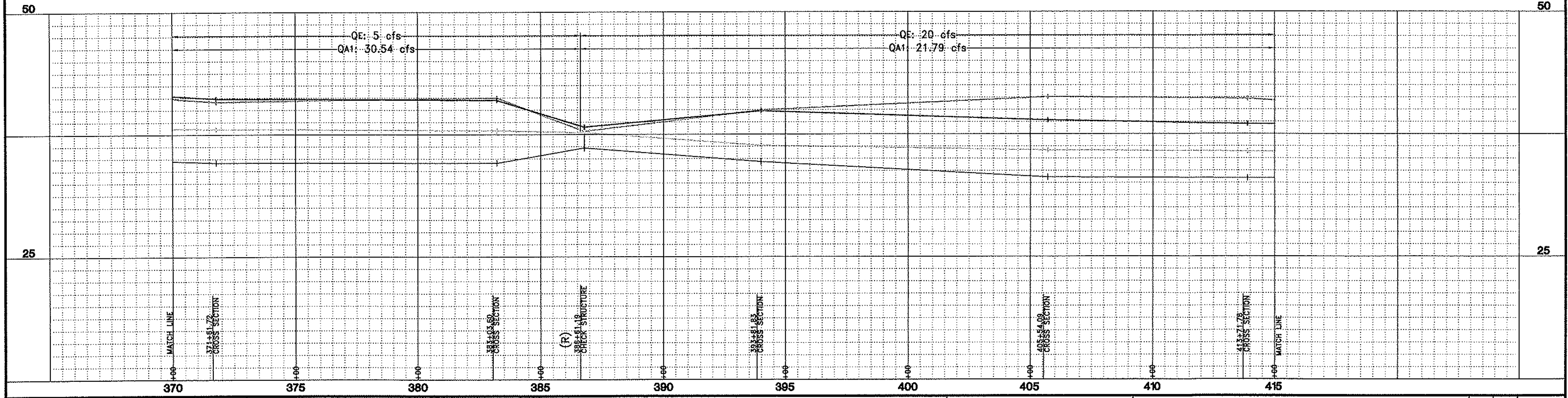

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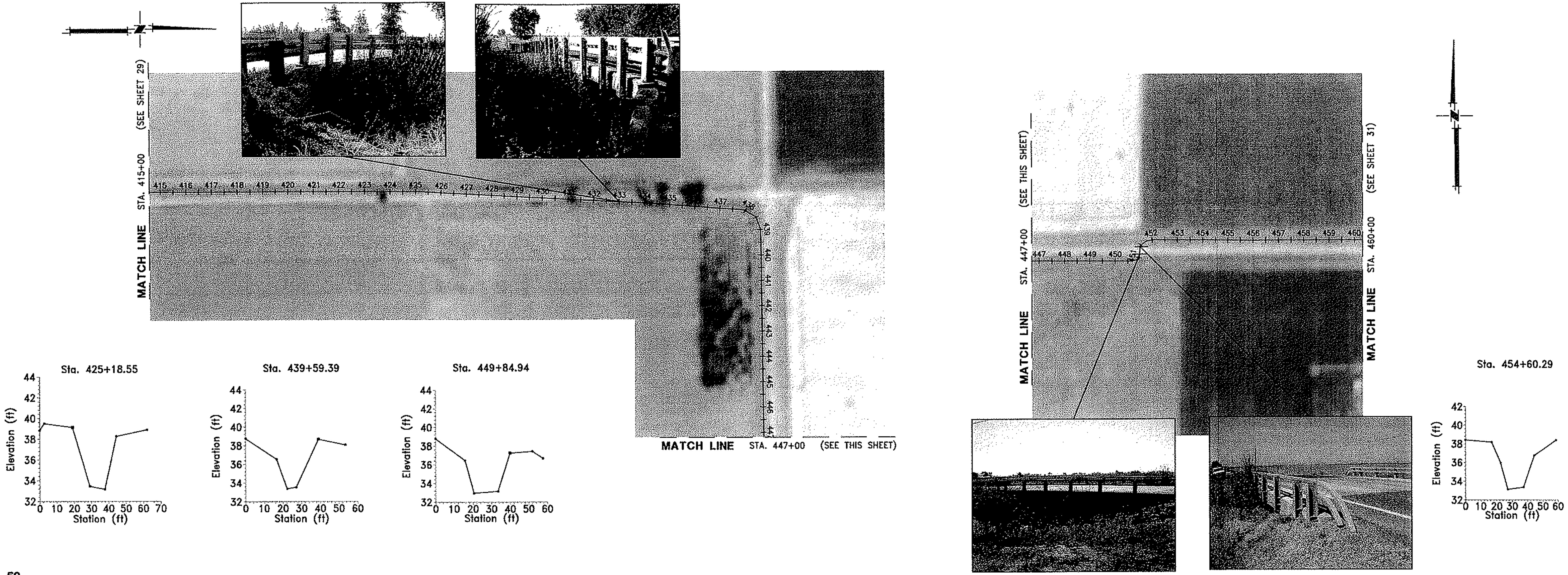

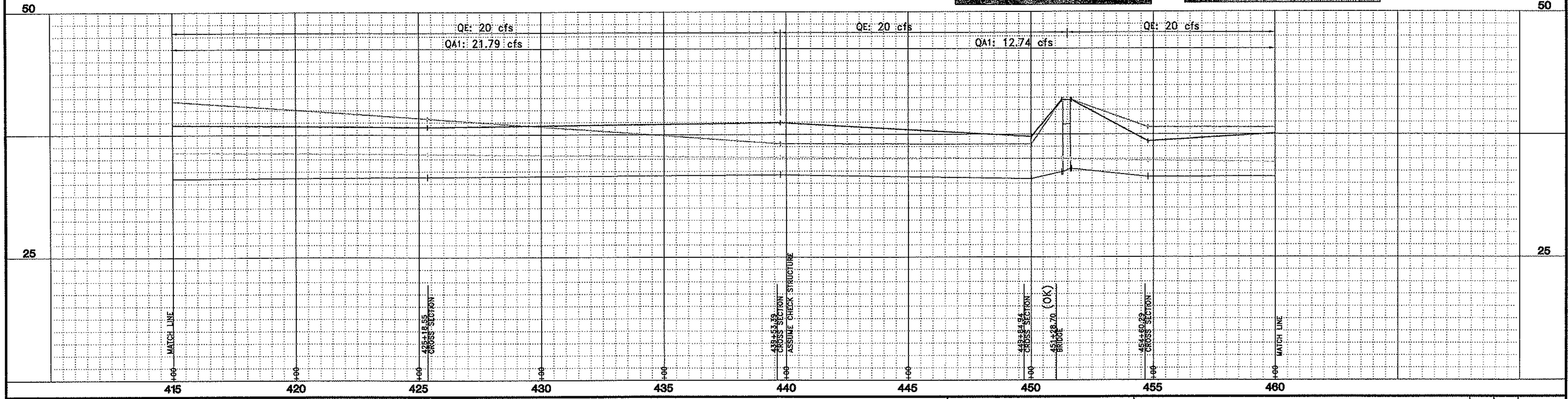

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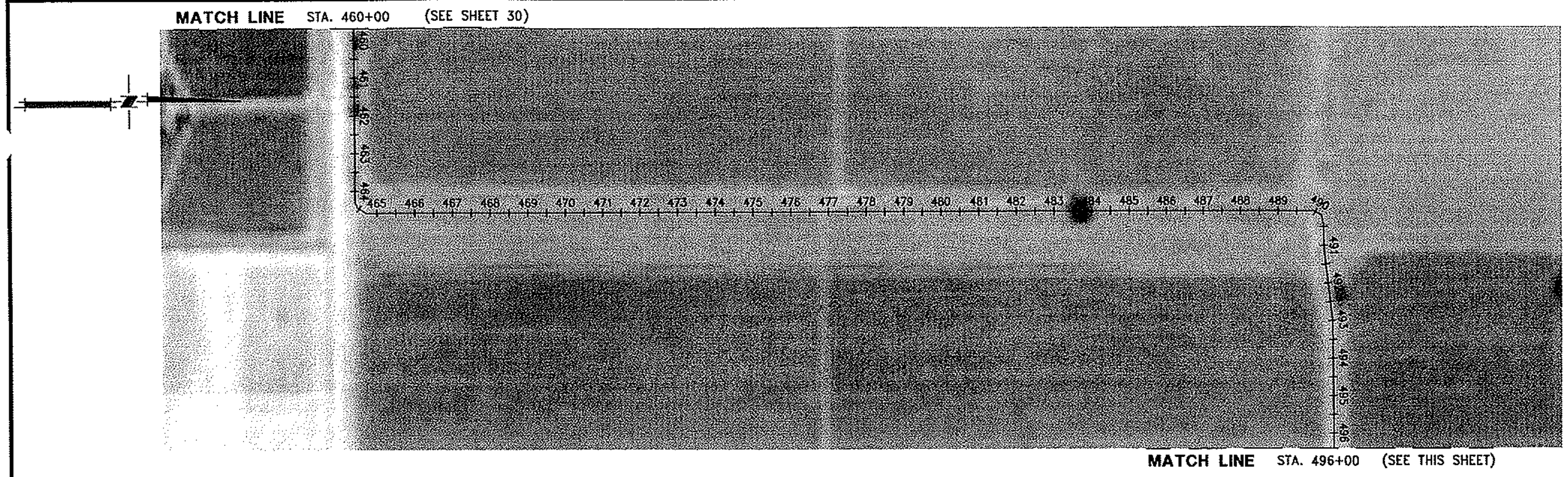

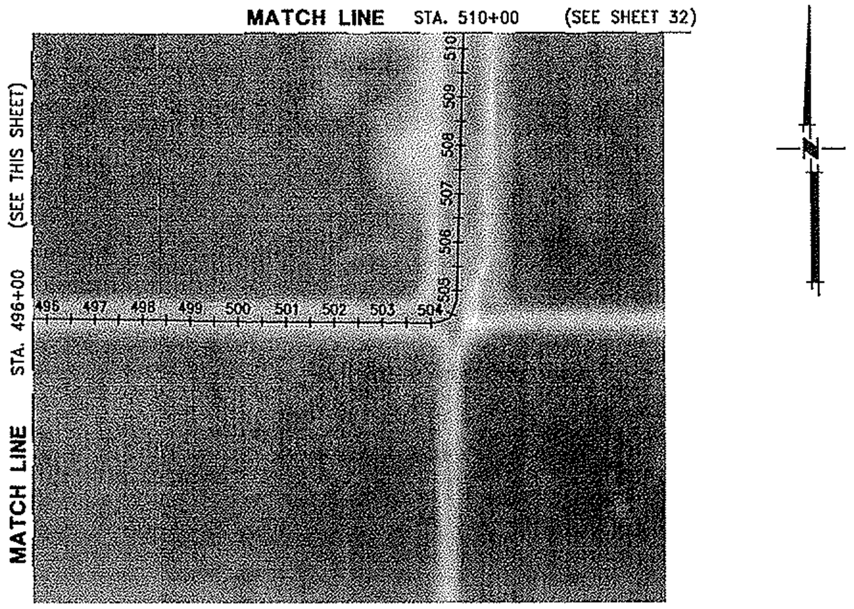

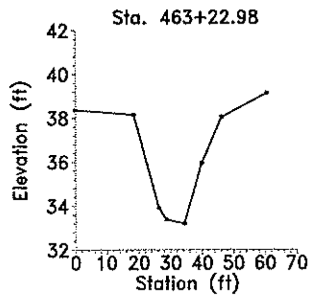

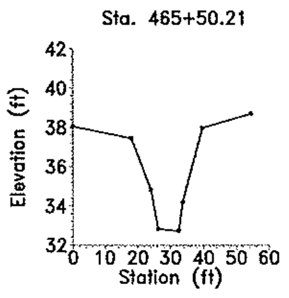

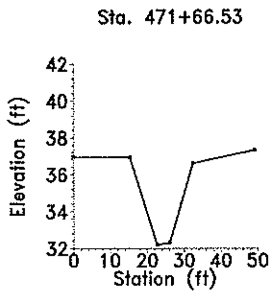

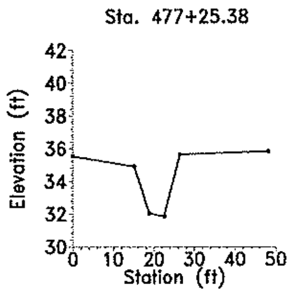

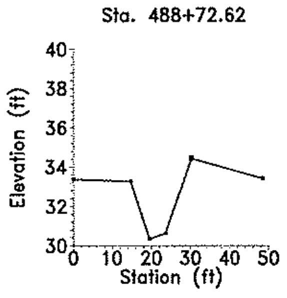

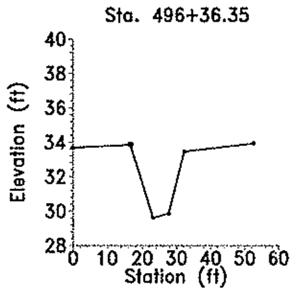

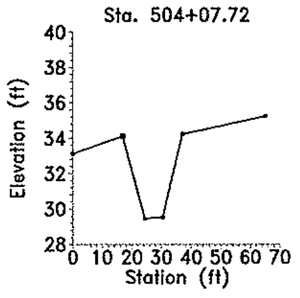

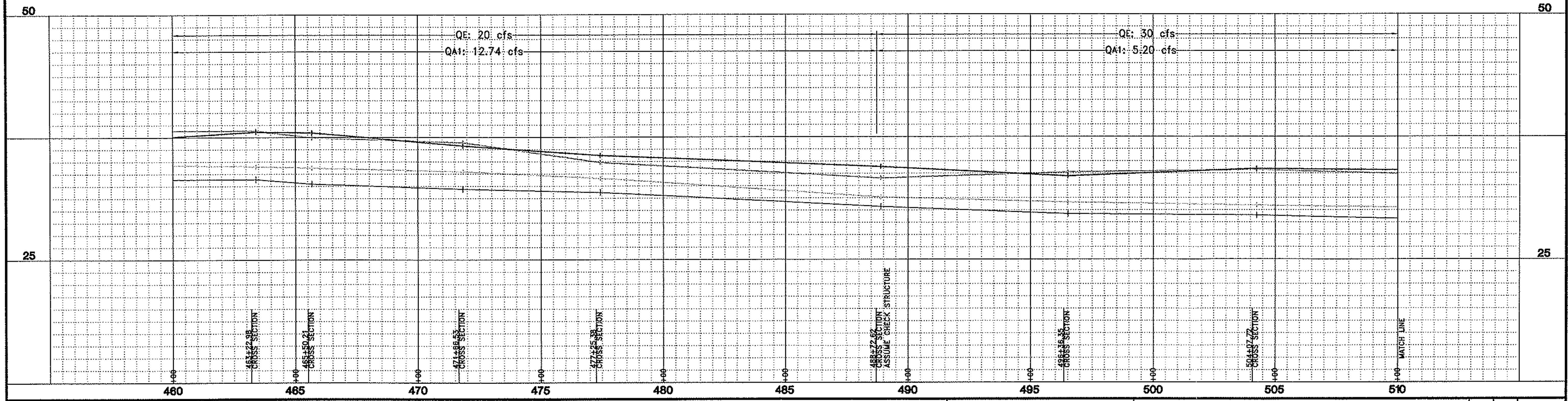

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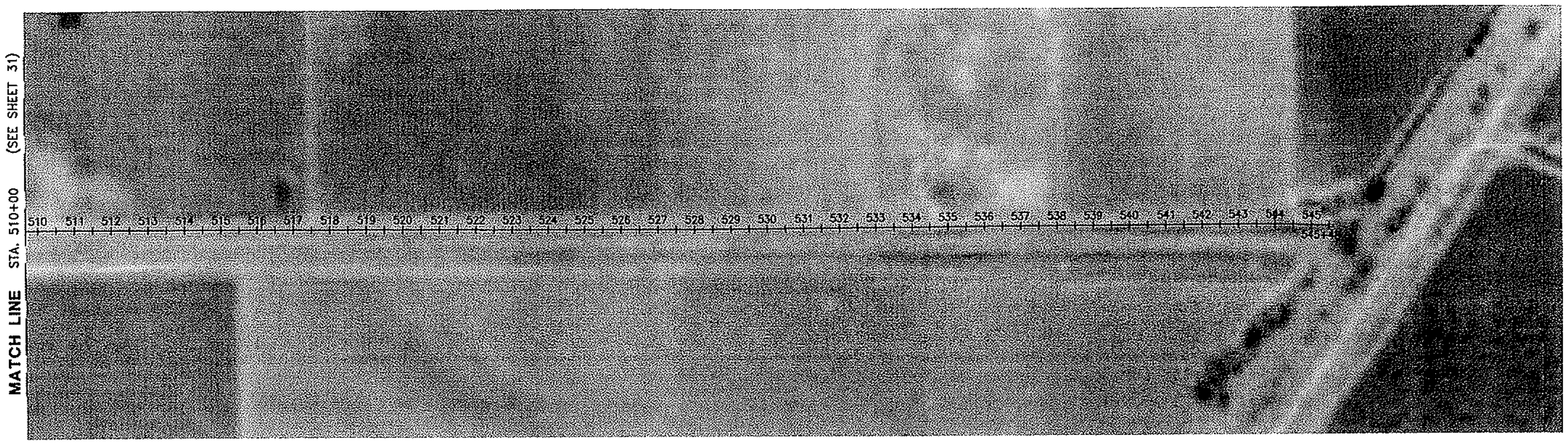

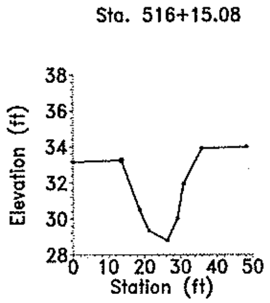
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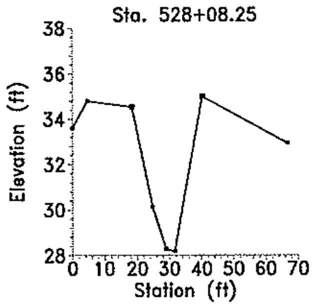
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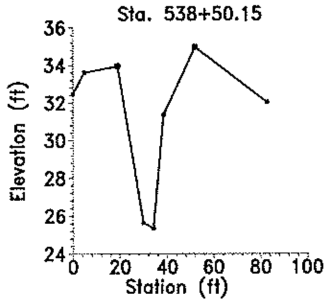
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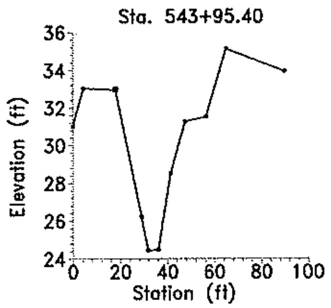
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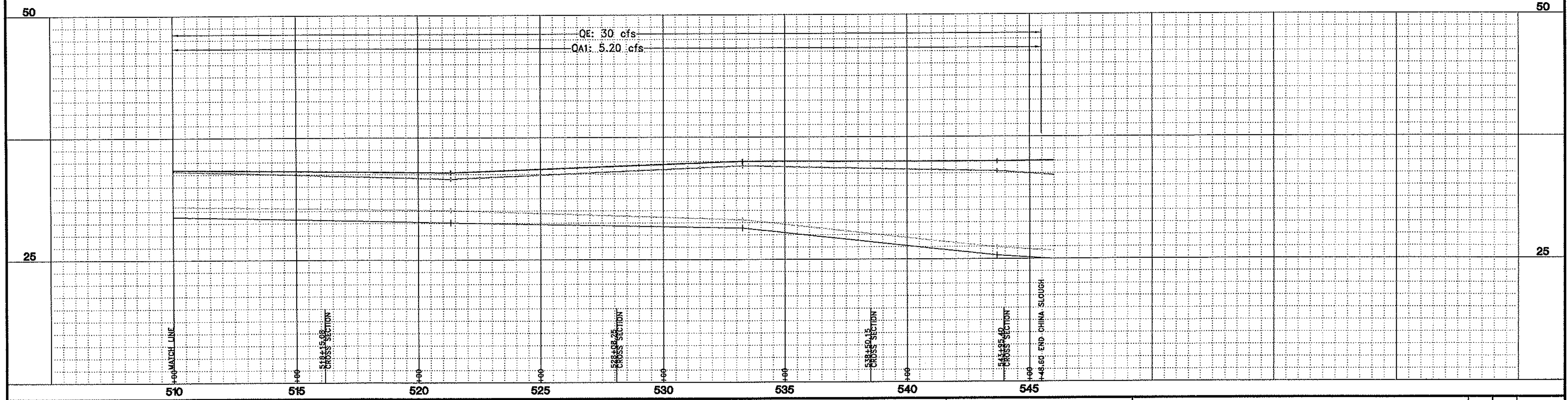

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Projects in the Yolo
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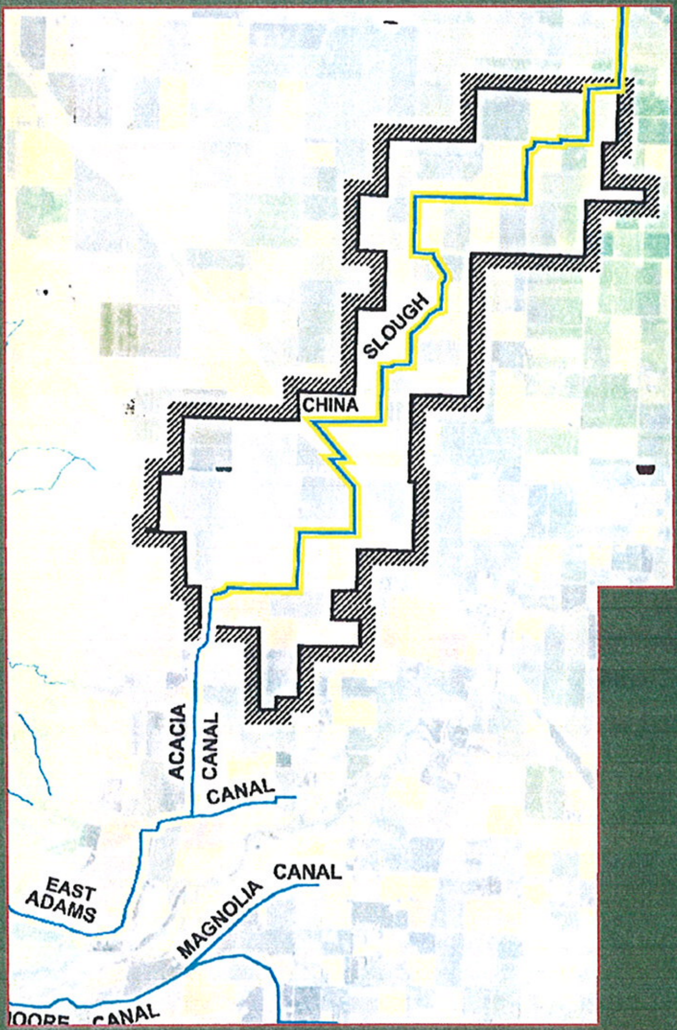
WRIME, Inc.
July 2003

Appendix F

Lower Colusa Basin Integrated Groundwater and Surface water Model (LCBIGSM)

Analysis of Conjunctive Use Projects in the Yolo Zamora Area



Prepared for:

Wood-Rodgers

RIME Water Resources & Information Management Engineering, Inc.

July 2003

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SECTION 1 INTRODUCTION AND PURPOSE

The Yolo County Flood Control and Water Conservation District (District) is working with Yolo-Zamora Water District (YZWD) to evaluate the feasibility of conjunctive use projects in the Yolo-Zamora area. Several groundwater simulation models were developed and used previously in the Yolo County for various purposes. One of these models is the Lower Colusa Basin Integrated Groundwater and Surface water Model (LCBIGSM), developed by the California Department of Water Resources (DWR) for evaluation of potential conjunctive use projects in the Colusa Basin area in Yolo and Colusa counties.

The LCBIGSM was initially developed using the historic data for period 1980 to 1995. The LCBIGSM was updated in 2003 to include the historic period 1980 to 2000 and the model was recalibrated (WRIME, 2003). The LCBIGSM is an integrated model that simulates both groundwater flow and streamflow. The model's input database includes the historic land and water use data, which can be modified to evaluate changes in land use and water supply in the model area. These features of the LCBIGSM make it suitable for use in the District's feasibility evaluations of conjunctive use projects in the Yolo Zamora area.

The LCBIGSM study area, as shown in Figure 1.1, is bounded by:

1. Highway 20, a groundwater divide, on the north;
2. Sacramento River on the east;
3. Cache Creek on the south; and
4. Coastal Range, the extent of the groundwater basin, on the west.

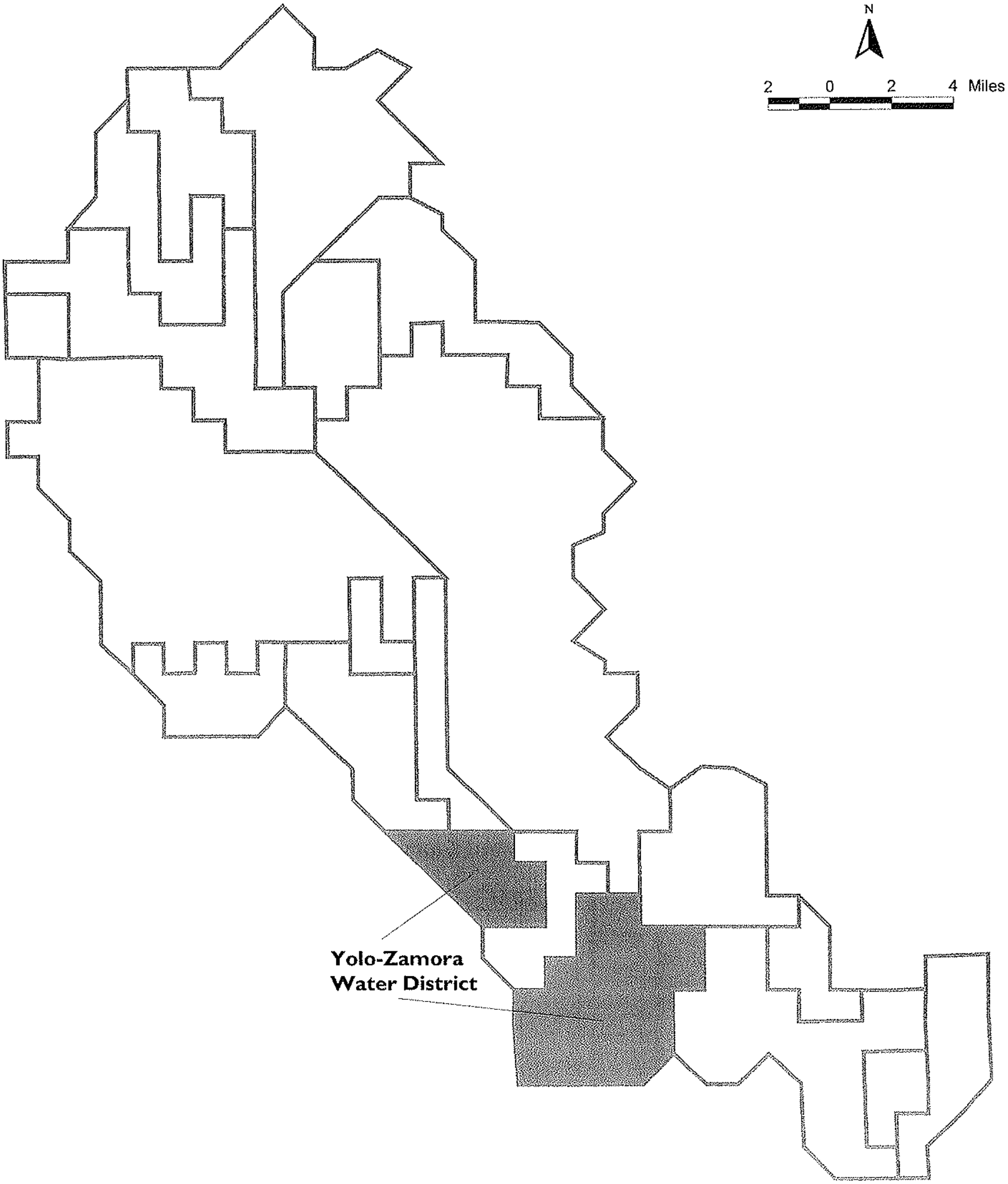
The model area is divided into 21 subregions, which includes Yolo Zamora project study area as two independent subregions.

SCOPE OF WORK

As part of the feasibility study, WRIME, Inc. assisted Wood-Rodgers to complete the analysis of four conjunctive use alternatives in the Yolo-Zamora area using the LCBIGSM.

The scope of work for WRIME consists of the following three tasks:

- Task 1 - Develop LCBIGSM Baseline conditions consistent with 2000 level-of-development;



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Analysis of Conjunctive Use Projects in the Yolo-Zamora Area

LCBIGSM Study Area

JULY 2003

FIGURE 1.1

- Task 2 – Develop conjunctive use project alternatives; and
- Task 3 – Evaluate the impacts of the conjunctive use project alternatives.

The purposes of this technical memorandum are to:

1. Summarize the development of the Baseline conditions;
2. Summarize the project alternatives; and
3. Present the impacts of the project alternatives.

SECTION 2 BASELINE CONDITION

A Baseline condition is defined as a set of land and water use, water supply and demand, surface water diversions and groundwater use that would collectively set the specific level of development. As a result, the Baseline condition is a modified version of the historic calibrated LCBIGSM with changes to land and water use conditions and hydrologic conditions. For the present study, the Baseline condition represents the land use and water demand and supply mix for the Lower Colusa groundwater basin for the year 2000. For the Baseline condition, it is assumed that the water demand and supply mix remains unchanged over the entire model simulation period, which is chosen to be a 72 year historic hydrologic period corresponding to 1922 – 1994. This historic period is widely used for statewide planning projects. The Baseline condition represents what could reasonably be expected to occur in the future if there are no changes to water demand and supply system.

The baseline model provides the reference frame for comparison of the alternatives. The alternatives are versions of the Baseline condition LCBIGSM with different alternative scenarios of land and water use conditions and/or conjunctive use programs. The water demand and/or water supply are modified from the Baseline condition to reflect a proposed condition as defined by an alternative. The alternatives for this study consist of changing the source of water supply in Yolo-Zamora area. The model results are used to determine the comparative impacts of different alternative with reference to the Baseline condition.

BASELINE CONDITION DATA

The Table 2.1 lists the data used in developing the Baseline condition. It should be noted that the simulation period incorporates hydrologic data from October 1921 through September 1994. This period is consistent with that of CALSIM II. CALSIM II is the statewide surface water operations model developed by California Department of Water Resources and is used for statewide surface water modeling. The hydrologic period included in CALSIM II is from 1921 and to 1994.

Table 2.1
Baseline Condition Data

Data Type	Source and Comments
Initial Groundwater Level	Groundwater levels are equal to the September 2000 levels as determined by the historical calibrated LCBIGSM.
Land Use Acreage	Land use acreage is equal to the year 2000 values used in the historical calibrated LCBIGSM.
Precipitation	1921 through 1979 precipitation data were incorporated from Central Valley Ground and Surface water Model (CVGSM), 1980 through 1994 precipitation data were incorporated from the historical calibrated LCBIGSM
Stream Inflow	Stream inflow data were incorporated from CALSIM II – Existing Conditions (2001) Benchmark Study, with exceptions noted. For Cache Creek, historical record from October 1921 through 1994 was used. For Knights Landing Ridge Cut missing data were estimated base on data using a regression analysis with Sacramento River 40-30-30 Hydraulic Index.
Agricultural Water Demand	Agricultural water demand was estimated for the October 1921 through September 1994 hydrologic period. For this estimation, evapotranspiration, irrigation efficiency, and soil moisture requirement data were incorporated from the historical calibrated LCBIGSM.
Surface Water Diversions	Regression relationships were developed between historical LCBIGSM surface water diversions and the Sacramento River 40-30-30 Hydrologic Index. Regression relationships were utilized to estimate surface water diversion data for the Baseline condition. Surface water diversion data were further refined based on agricultural water demand.
Groundwater Pumping	Agricultural groundwater pumping was assumed equal to the difference between agricultural water demand and surface water diversion. Urban groundwater pumping was assumed equal to urban demand.

SECTION 3 ALTERNATIVES DEVELOPMENT AND ANALYSIS

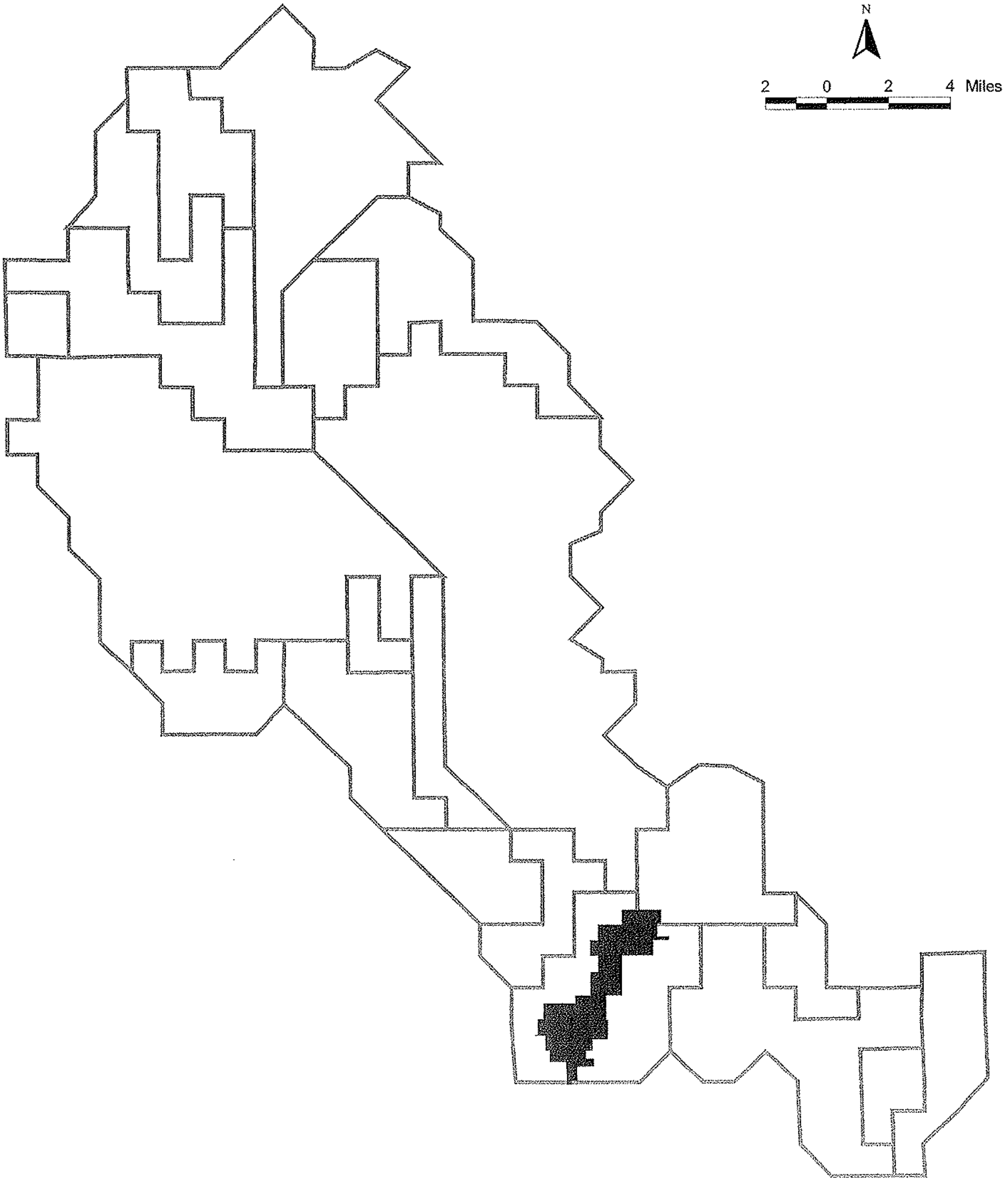
Three conjunctive use alternatives were developed and evaluated for the southern portion of the Yolo-Zamora Water District (YZWD). Alternatives 1 and 2 are operationally the same in regards to simulating the groundwater system. As a result, a single LCBIGSM alternative was developed to represent both of these alternatives. Figure 3.1 shows the Alternatives 1 and 2 conjunctive use project area plus the boundary of the YZWD with reference to the LCBIGSM study area. Alternatives 3 and 4 are based on the same conjunctive use project area, which is different from the area associated with Alternatives 1 and 2. The conjunctive use project area associated with these two alternatives is shown in Figure 3.2.

In the Baseline condition, the entire agricultural water demand is met by groundwater pumping. The surface water supply in the alternatives offsets groundwater pumping on a volumetric basis. In the alternatives, a portion of agricultural demand is satisfied with surface water. The first three alternatives involve diverting water from Cache Creek and supplying for YZWD. The fourth alternative involves diverting water from the Colusa Basin Drain and supplying to YZWD. Table 3.1 presents the groundwater pumping and the associated surface water supply for the Baseline condition as well as the conjunctive use alternatives. The total water supply for the alternatives does not vary from the Baseline condition.

Table 3.1
Summary Average Annual Water Supplies in the Baseline Condition and Conjunctive Use Project Alternatives for the Yolo-Zamora Area

Scenario	Agricultural Pumping (AF)	Surface Water Supply (AF)
Baseline condition	37,530	0
Alternatives 1 and 2	31,360	6,170
Alternative 3	27,280	10,260
Alternative 4	23,130	14,400

The data from the Baseline condition was modified to reflect the above water supply Alternatives with LCBIGSM. Three alternative scenarios were then developed and simulated using the LCBIGSM. The results from the simulation and the associated impacts of the alternatives are discussed in the next section.



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Analysis of Conjunctive Use Projects in the Yolo-Zamora Area

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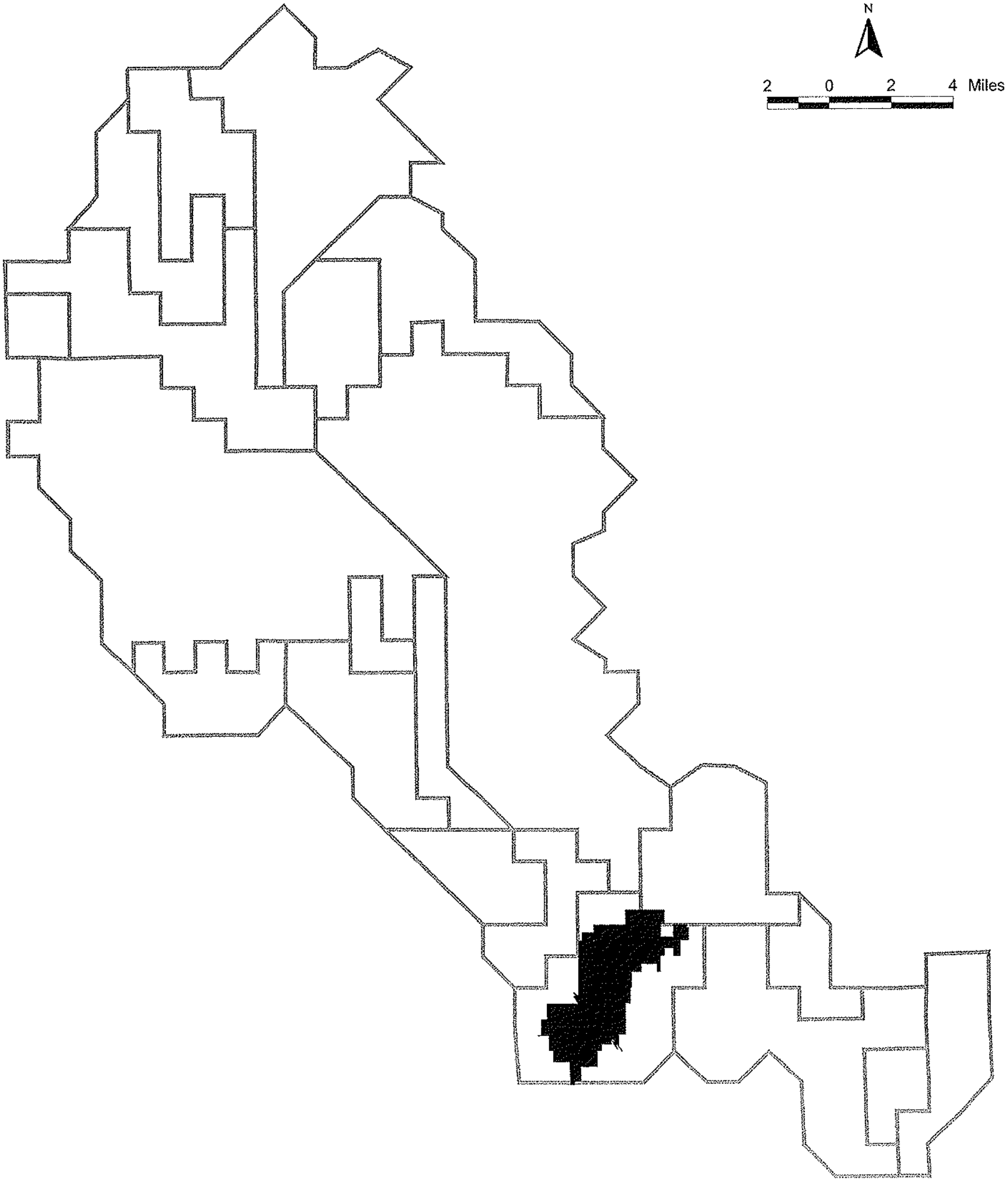
Alternatives 1 and 2 - Conjunctive Use Project Area

FIGURE 3.1



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Analysis of Conjunctive Use Projects in the Yolo-Zamora Area

Alternatives 3 and 4 - Conjunctive Use Project Area

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FIGURE 3.2

SECTION 4 RESULTS

In this section, the conjunctive use alternative analysis results are presented with reference to the Baseline condition and depicted as changes from the Baseline condition. This provides the basis for the relative comparison of one alternative with another.

Two different metrics were developed to measure the impacts of the conjunctive use alternatives. The first metric involves evaluating how groundwater recharge would be affected by the alternatives and the second metric involves evaluating the impacts of the alternatives on groundwater levels. Table 4.1 lists the sources of groundwater recharge from areas outside the Yolo-Zamora area and the average annual values of those sources for the Baseline condition.

Table 4.1
Average Annual Groundwater Recharge from Areas Outside the Yolo-Zamora Area for the Baseline Condition

Recharge from Cache Creek (AF)	Recharge from Dunnigan Hills Area (AF)	Recharge from East of Colusa Basin Drain (AF)	Total Boundary Recharge (AF)
2,970	8,320	12,110	23,400

Table 4.2 summarizes the impacts on groundwater recharge for the different conjunctive use alternatives and the resulting increase in groundwater levels.

Table 4.2
Summary of Average Annual Change for the Baseline Condition in Yolo-Zamora Groundwater Recharge and Levels

Alternative	Change in Recharge from Cache Creek (AF)	Change in Recharge from Dunnigan Hills Area (AF)	Change in Recharge from East of Colusa Basin Drain (AF)	Increase in Groundwater Levels (ft)
1 and 2	-110	-990	-5,040	5
3	-170	-1,550	-8,380	9
4	-220	-2,180	-11,790	13

Note: Negative recharge indicates a reduction in recharge from the Baseline condition.

The results reported in Tables 4.1 and 4.2 represent the average annual values for the entire simulation period (72 years). It can be concluded from Table 4.1 that groundwater recharge from outside the Yolo-Zamora area primarily originates from areas east of the Colusa Basin Drain. Also, Cache Creek provides approximately 13% groundwater recharge to the Yolo-

Zamora area. From Table 4.2, it can be concluded that groundwater recharge from outside the Yolo-Zamora area would diminish because of implementing the conjunctive use alternatives. This is to be expected because the groundwater system presumably would not be under as much stress as in the Baseline condition. In addition, the conjunctive use alternatives would also increase the average groundwater levels in the Yolo-Zamora from 5 to 13 feet, depending on the alternative.

Three hydrograph locations were selected to evaluate the impact on groundwater levels at specific locations. These locations are shown on Figure 4.1 and correspondences between the well numbers for Alternatives Analysis with State Well Numbers and calibration well number are provided in Table 4.3. These wells were selected to provide reasonable geographic coverage within the conjunctive use project area.

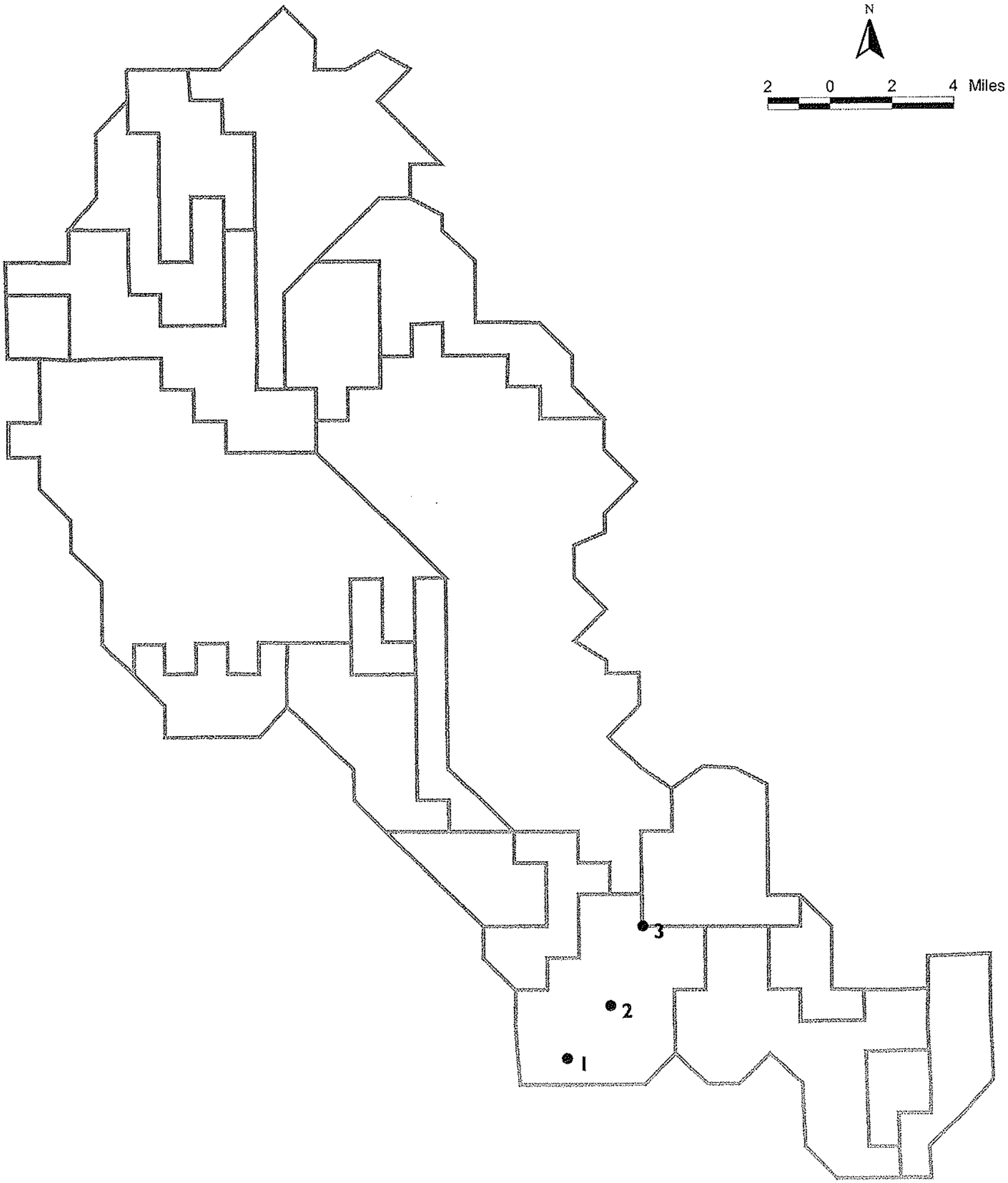
Table 4.3
Alternative Analysis Hydrograph State Well Numbers

Well Number by Conjunctive Use Alternatives	State Well Number	LCBIGSM Calibration Well Number
1	10N01E10G01M	1
2	11N01E35J02M	18
3	11N02E18N01M	20

Figures 4.2 through 4.5 present the change in average annual groundwater levels for the alternatives relative to the Baseline condition for each of the three wells. Please note that simulated groundwater levels in the Baseline condition do not indicate an increasing or decreasing trend over the simulation period.

A common characteristic for the alternatives that do not have a fixed water supply is the attenuation of groundwater levels during non-recharge cycles. An examination of the hydrographs for Alternatives 1 and 2 at all three well locations reveals a steep decline in water levels once a recharge cycle has stopped. In comparison, the hydrographs associated with Alternative 4 indicate that a sustained groundwater pumping reduction/conjunctive use program of 14,400 acre-feet per year would increase groundwater levels by about 15 feet, consistently.

Review of groundwater level difference contours provides another way to evaluate the change in groundwater levels due to the conjunctive use alternatives. The difference is calculated as the alternative groundwater level minus the Baseline condition groundwater level. The two periods selected for contouring are Fall (September), 1977 and Spring (March), 1983. These two



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Analysis of Conjunctive Use Projects in the Yolo-Zamora Area

Hydrograph Locations

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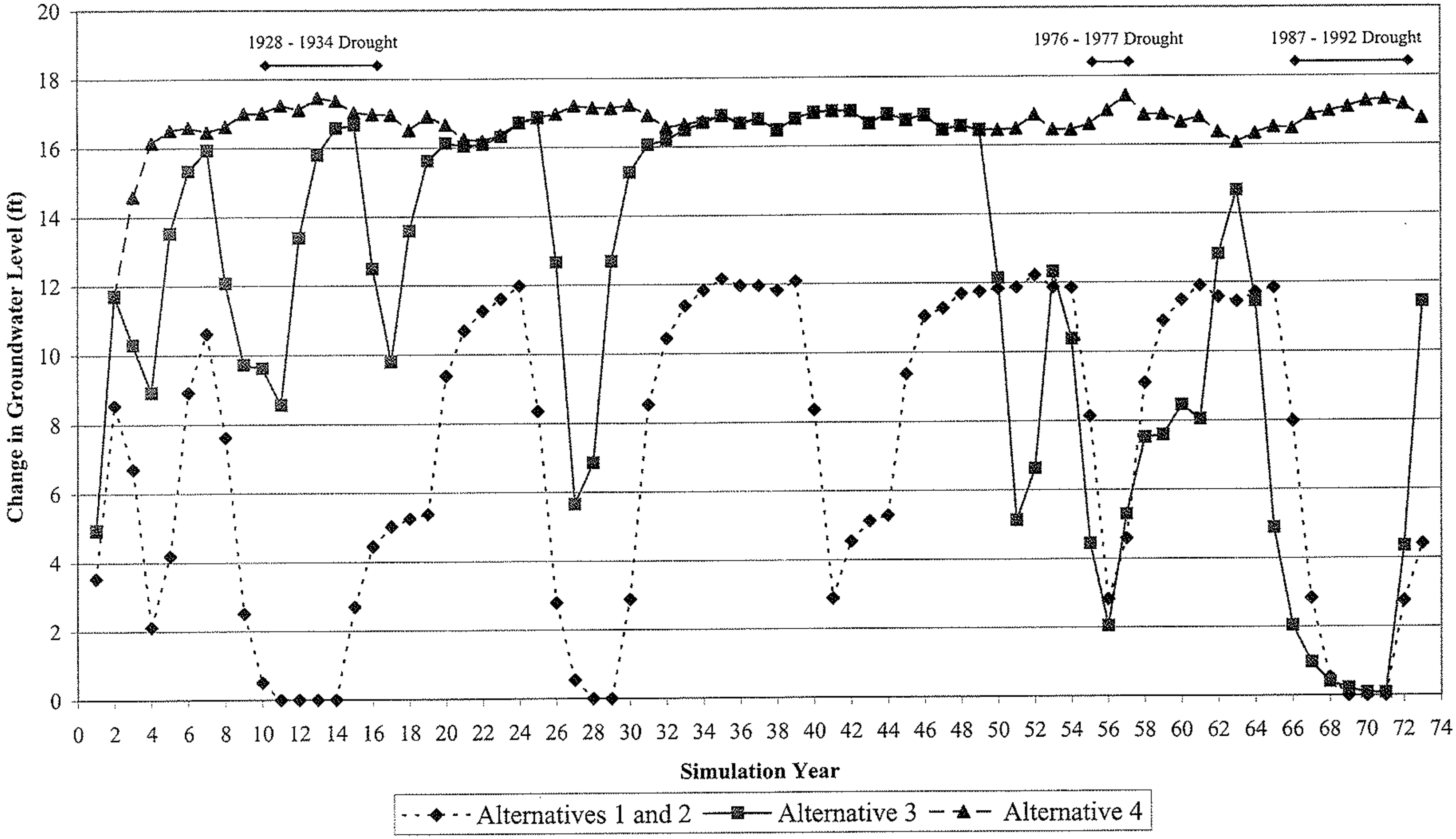
FIGURE 4.1



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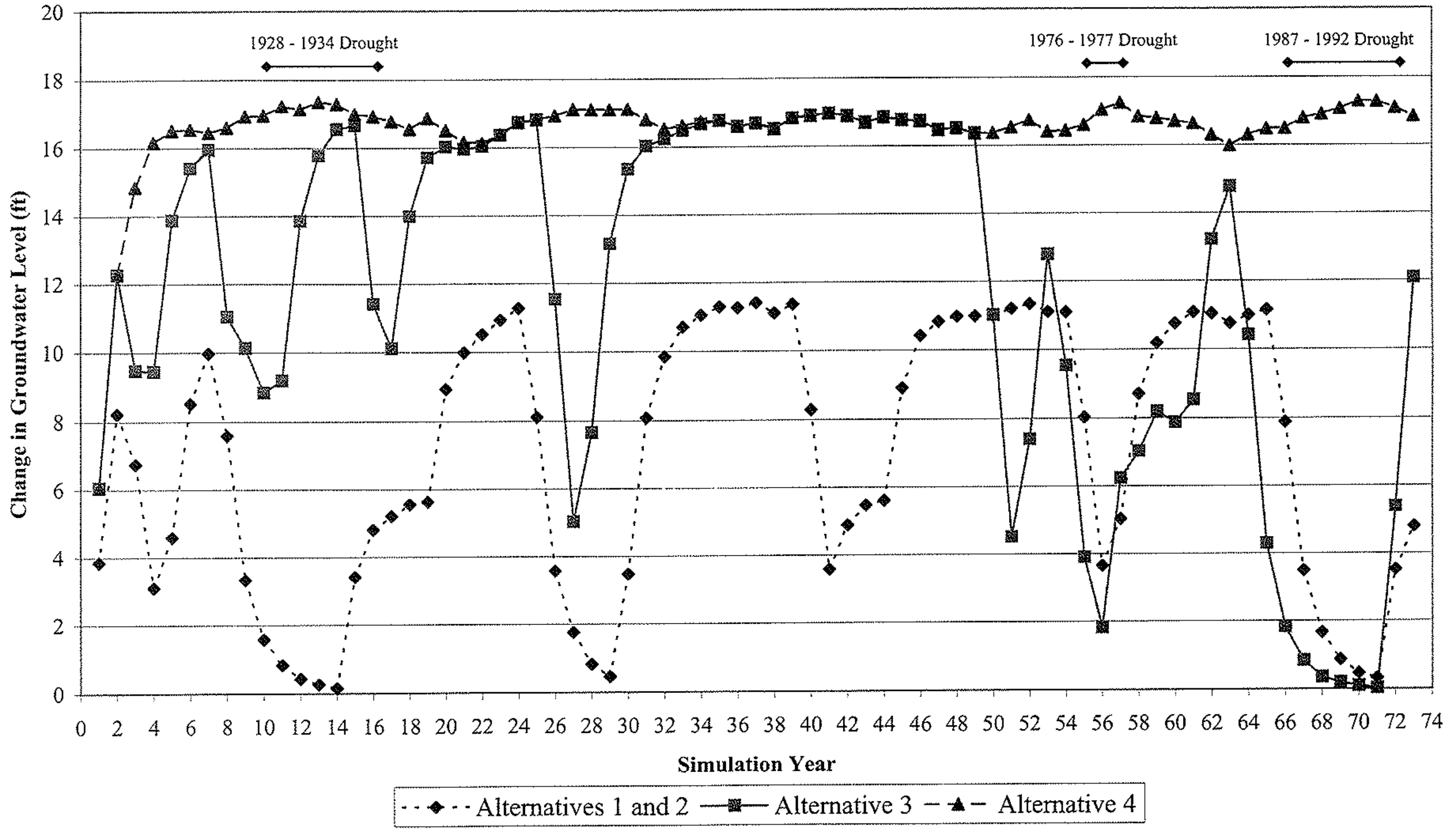
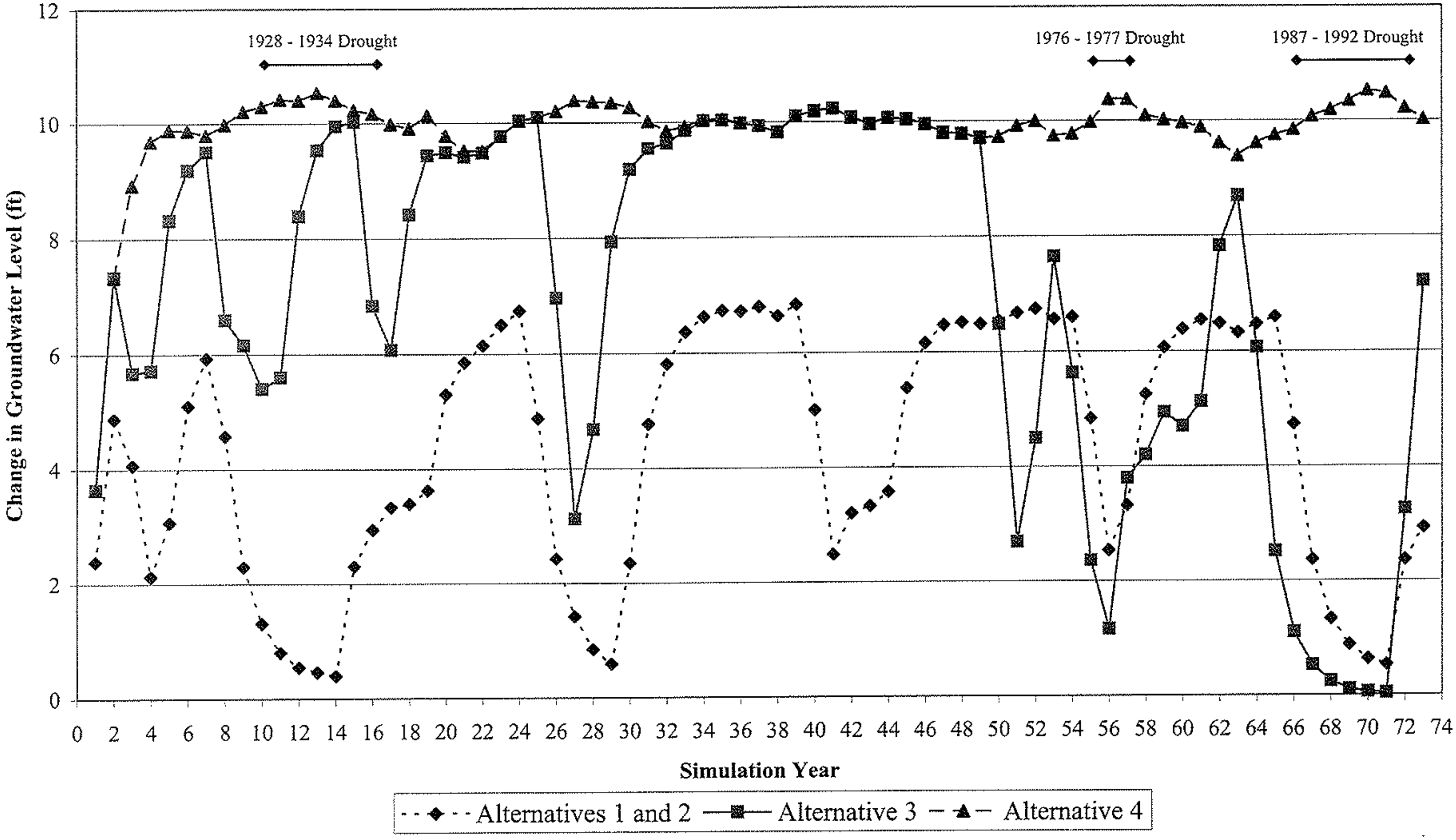
	Change in Average Annual Groundwater Levels from the Baseline Condition for Hydrograph Location 1	FIGURE 4.2



RIME	Analysis of Conjunctive Use Projects in the Yolo-Zamora Area **Change in Average Annual Groundwater Levels from the Baseline Condition for Hydrograph Location 2**	JULY 2003 FIGURE 4.3



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Analysis of Conjunctive Use Projects in the Yolo-Zamora Area

Change in Average Annual Groundwater Levels from the Baseline Condition for Hydrograph Location 3

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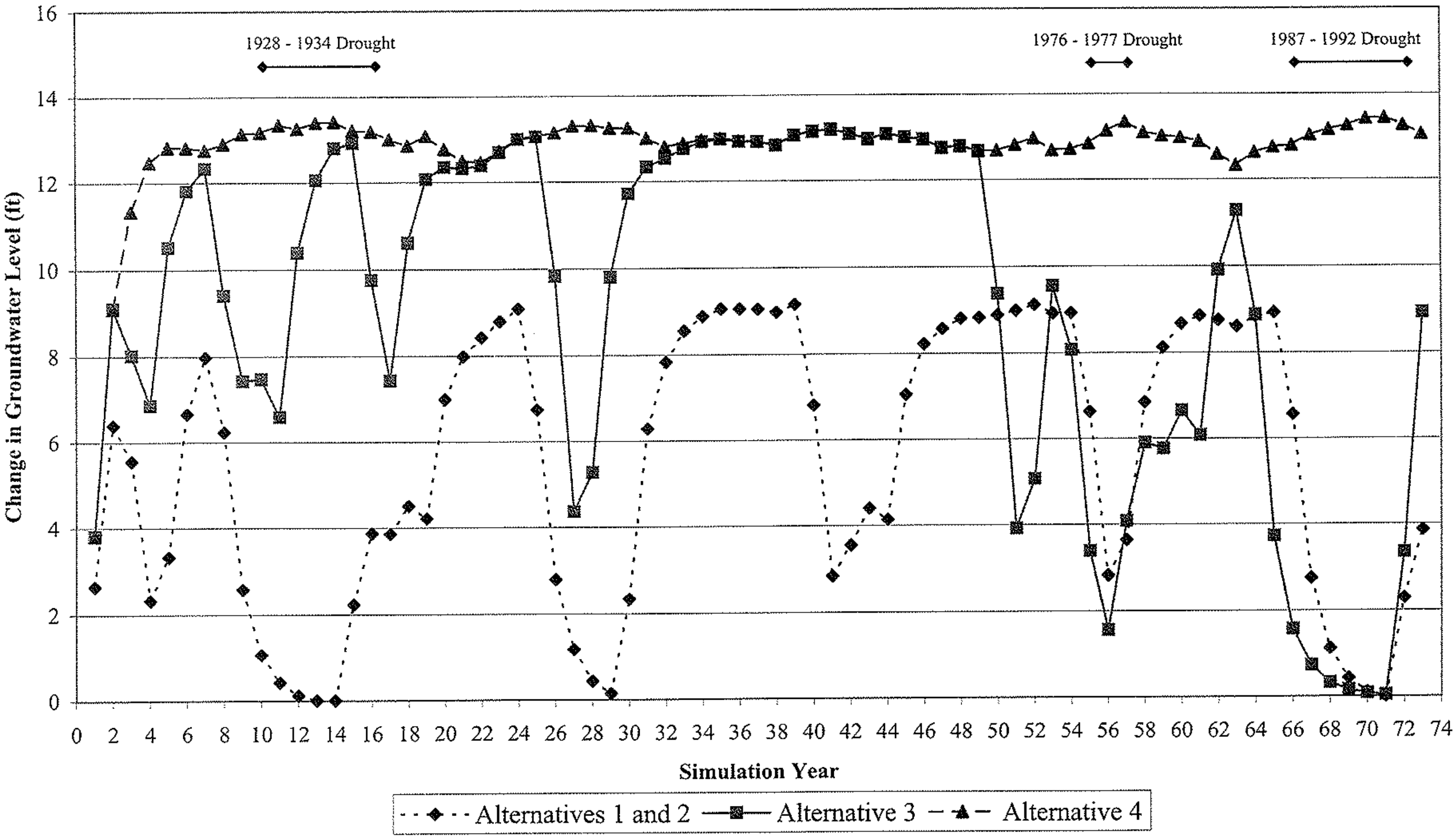
FIGURE 4.4



Analysis of Conjunctive Use Projects in the Yolo-Zamora Area

Change in Average Annual Yolo-Zamora Groundwater Levels from Baseline Condition

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FIGURE 4.5

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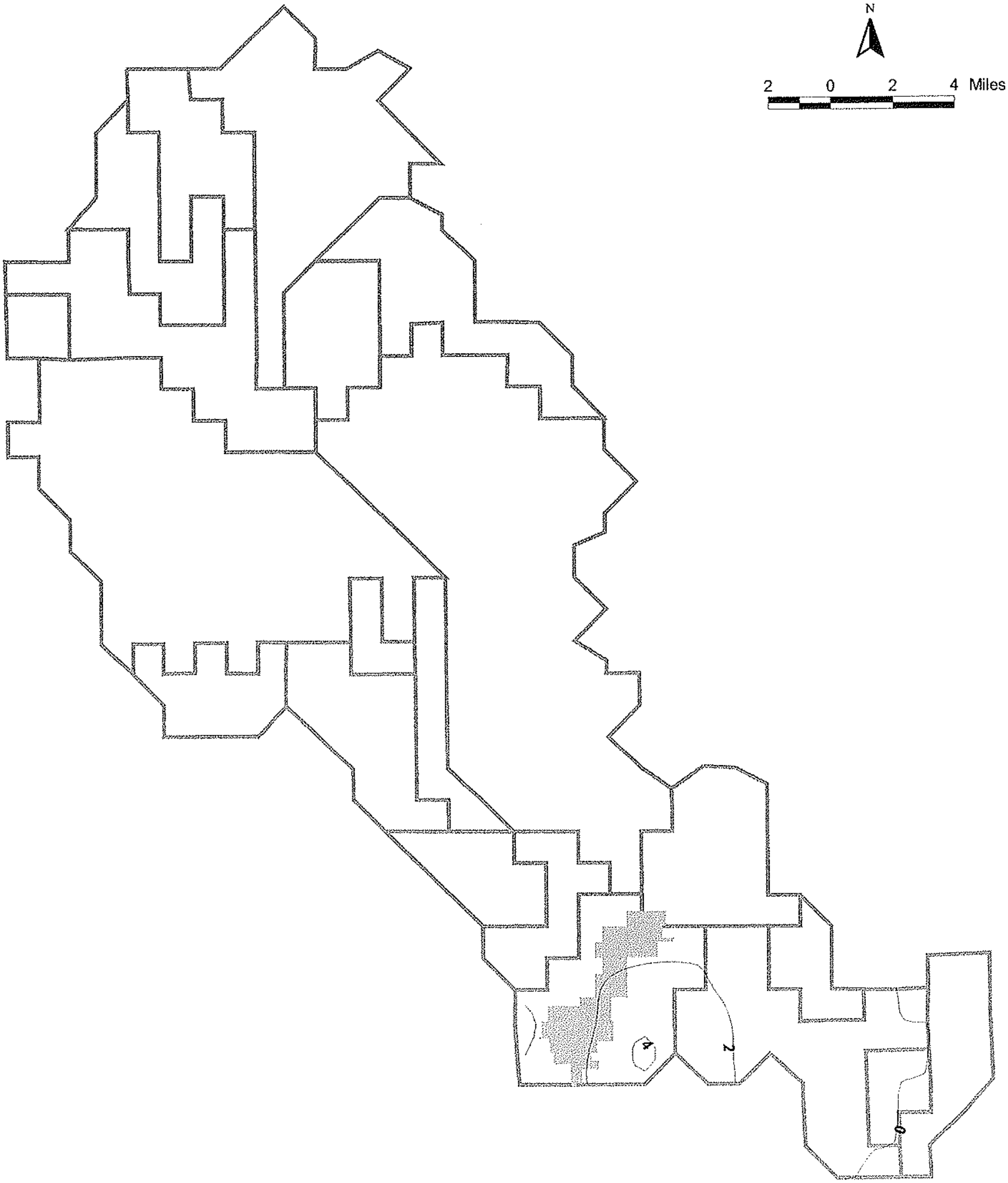
time periods represent respectively a dry and wet period. The resulting difference contours are shown in Figures 4.6 through 4.11.

The Fall 1977 contours for Alternatives 1 and 2 and Alternative 3 (Figures 4.6 and 4.8) show that there is some residual impact of the conjunctive use program but that its effects have greatly attenuated. Figure 4.7 and 4.9 (Spring 1983) show that the potential impacts from both alternatives are nearly the same. Figure 4.10 (Fall 1977) and Figure 4.11 (Spring 1983) shows the largest potential impact on groundwater levels are associated with Alternative 4. The increase in groundwater levels in Fall 1977 is in the order of 20 feet and that in Spring 1983 is in the order of 10 feet.



Note: Contour unit is feet.
Difference is calculated as alternative - baseline.

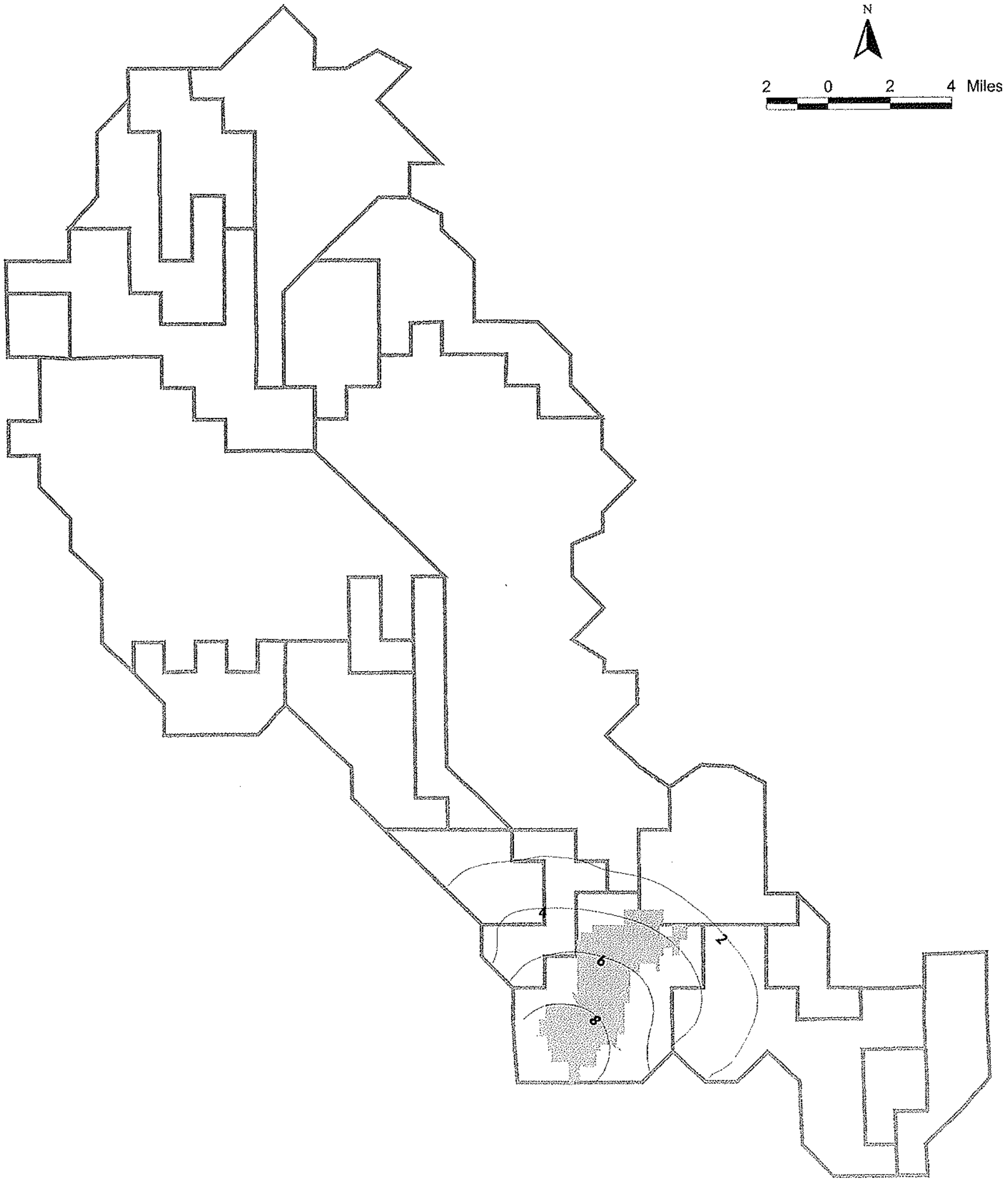
ωRIME

Analysis of Conjunctive Use Projects in the Yolo-Zamora Area

Difference Contours between Alternatives 1/2 and Baseline Conditions Fall 1977 Groundwater Levels

JULY 2003

FIGURE 4.6



Note: Contour unit is feet.
Difference is calculated as alternative - baseline.

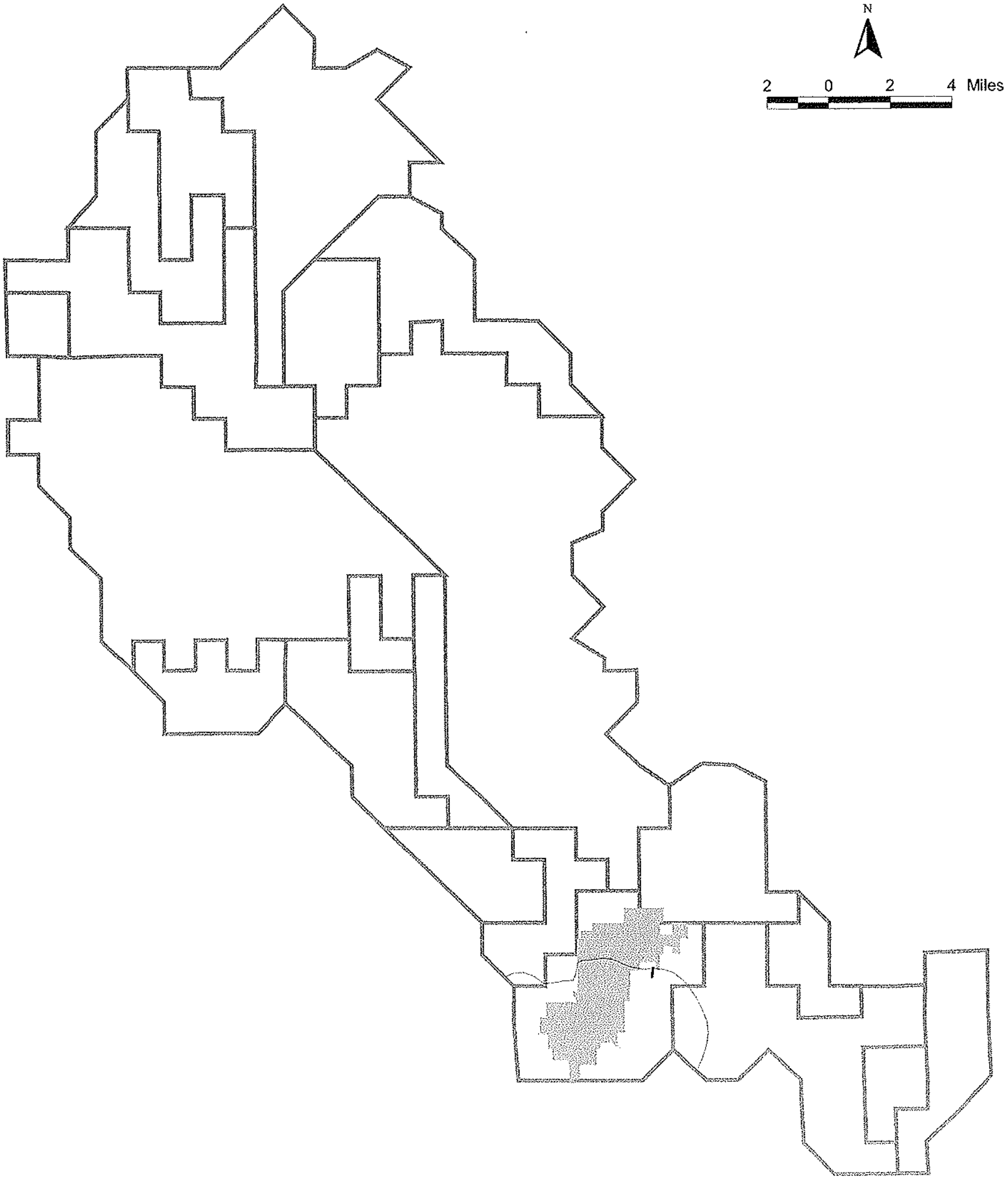
RIME

Analysis of Conjunctive Use Projects in the Yolo-Zamora Area

Difference Contours between Alternatives 1/2 and Baseline Conditions Spring 1983 Groundwater Levels

JULY 2003

FIGURE 4.7



Note: Contour unit is feet.
Difference is calculated as alternative - baseline.

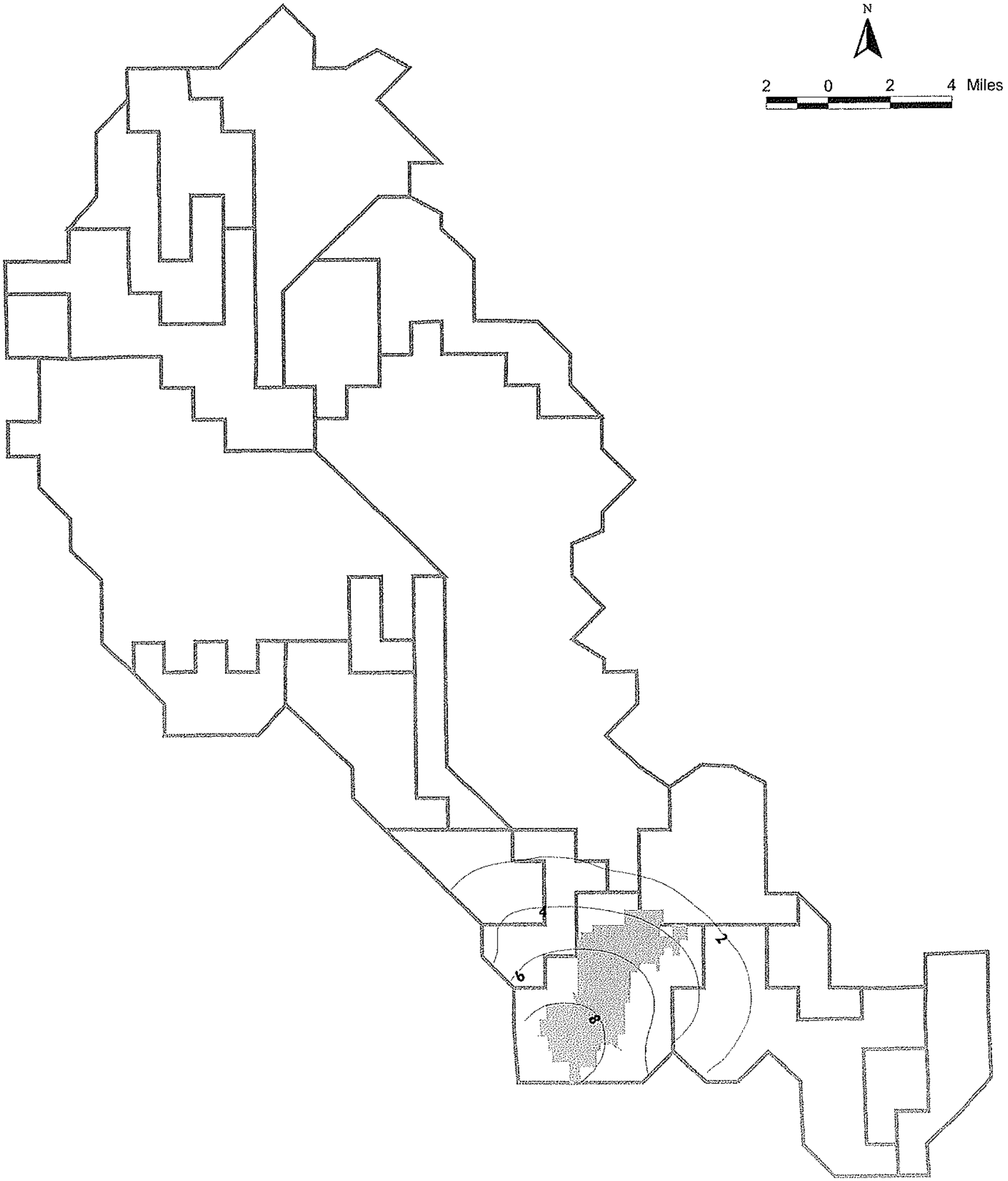
RIME

Analysis of Conjunctive Use Projects in the Yolo-Zamora Area

Difference Contours between Alternative 3 and Baseline Conditions Fall 1977 Groundwater Levels

JULY 2003

FIGURE 4.8



Note: Contour unit is feet.
Difference is calculated as alternative - baseline.

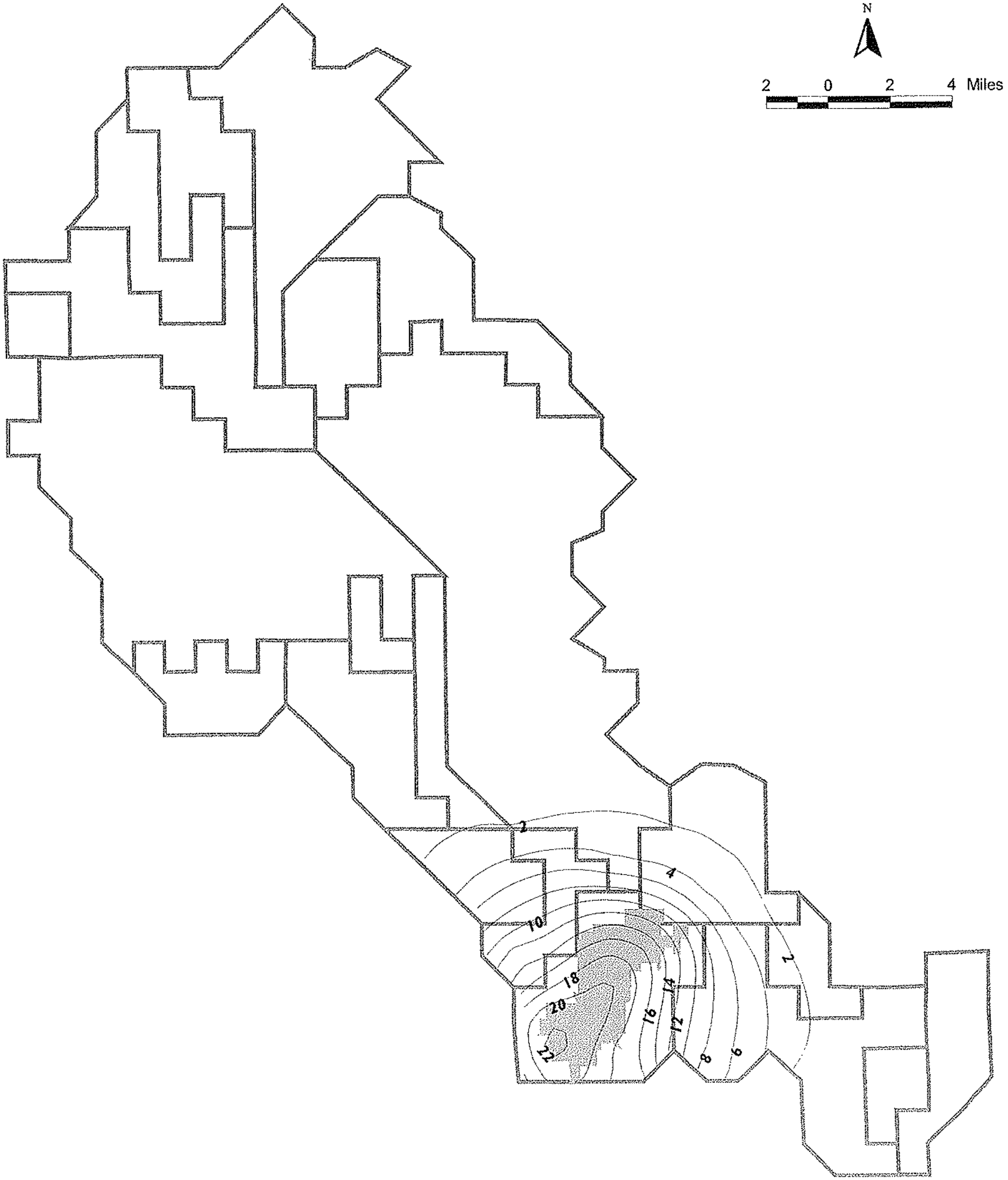
RIME

Analysis of Conjunctive Use Projects in the Yolo-Zamora Area

Difference Contours between Alternative 3 and Baseline Conditions Spring 1983 Groundwater Levels

JULY 2003

FIGURE 4.9



Note: Contour unit is feet.
Difference is calculated as alternative - baseline.

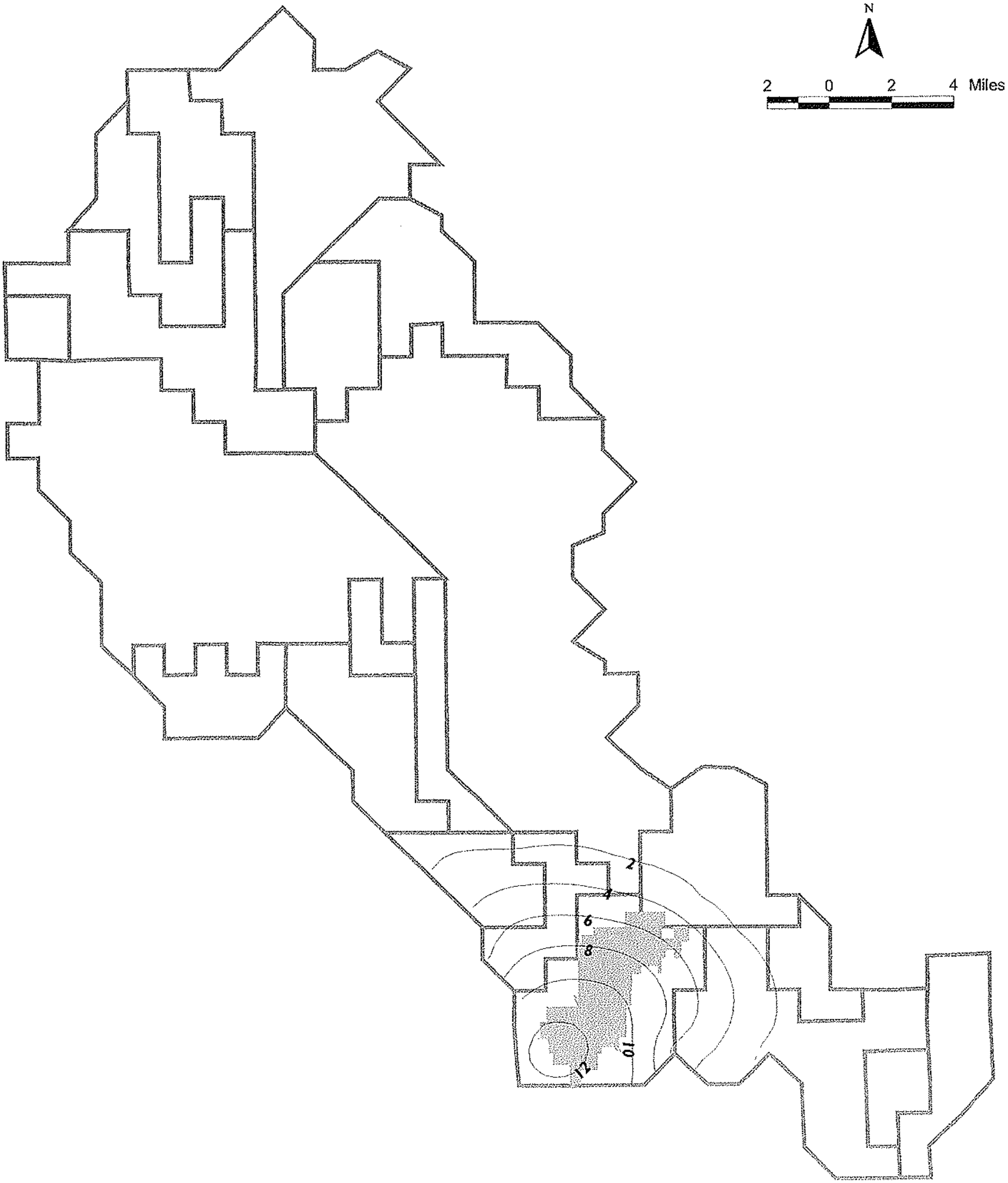
WRIME

Analysis of Conjunctive Use Projects in the Yolo-Zamora Area

Difference Contours between Alternative 4 and Baseline Conditions Fall 1977 Groundwater Levels

JULY 2003

FIGURE 4.10



Note: Contour unit is feet.
Difference is calculated as alternative - baseline.

WRIME

Analysis of Conjunctive Use Projects in the Yolo-Zamora Area

JULY 2003

Difference Contours between Alternative 4 and Baseline Conditions Spring 1983 Groundwater Levels

FIGURE 4.11

SECTION 5 SUMMARY

The LCBIGSM was used to evaluate from conjunctive use alternatives in the Yolo-Zamora area. The alternatives consist of using surface water instead of groundwater to meet agricultural demand. The Baseline condition was developed and alternative analysis were conducted to determine the impacts on groundwater levels.

The following provides a summary of the results of the Alternatives Analysis:

1. Groundwater levels, on average in the Yolo-Zamora area, increase 5 to 13 feet depending on the conjunctive use project alternative;
2. The reduction in groundwater pumping reduces the stress on the aquifer system. This, in turn, diminishes the amount of groundwater recharge the Yolo-Zamora area receives from surrounding areas and from Cache Creek;
3. Groundwater levels attenuate to near Baseline condition levels at the end surface water supply cycle for Alternatives 1 and 2; and
4. Continuous surface water supply of 14,400 acre-feet per year (Alternative 4) will increase the average groundwater level between 10 and 20 feet, in different location of the Yolo-Zamora area, without much variation over time.

WRIME, Inc. 2003. Lower Colusa Basin Integrated Ground and Surface water Model (LCBIGSM). Data Update and Model Recalibration.

WOOD RODGERS

ENGINEERING ▪ PLANNING ▪ MAPPING ▪ SURVEYING

“The Yolo County GPS Subsidence Network,” 2002 Survey, February 26, 2003

Appendix G

The Yolo County GPS Subsidence Network

Recommendations and Continued Monitoring

(Photo: Larry Hatch, City of Woodland, at station HERSHEY)

Submitted by:

Don D'Onofrio, GeodeticConsultant
7228 Willowbank Way, Carmichael, CA 95608
(916) 944-7879
dondonofrio@attbi.com

Jim Frame, Frame Surveying & Mapping
609 A Street, Davis, CA 95616
(530) 756-8584
jhframe@dcn.davis.ca.us

February 26, 2003

Executive Summary

In July and August, 2002, the first re-observation of the Yolo County GPS subsidence network was accomplished. The intent of the survey, following recommendations made after the initial 1999 survey, was to determine the amount of subsidence over the intervening three years. Again, the City of Davis served as the lead agency for the project. Participating agencies were the same as those in 1999. The U.S. Corps of Engineers did not participate in the 2002 project. A complete list of agencies and personnel is included in **Appendix C**.

The most significant area of subsidence occurred near the cities of Davis and Zamora, and in the north and western portion of the county. Subsidence in the vicinity of Davis was about five centimeters (two inches) and in the vicinity of Zamora about seven centimeters (almost three inches). A complete station-by-station listing of subsidence is included in **Appendix B**. A listing of all station coordinates and elevations is included in **Appendix A**.

Seven additional Yolo County stations were added to the 2002 survey. The stations are in the southern portion of the county. These stations had been observed in 1997 as part of a cooperative GPS survey of the Sacramento/San Joaquin Delta, but a decision was made to leave them out of the 1999 survey. A project map depicting all local stations is found in **Appendix D.** Also in Appendix D is a contour map indicating subsidence trends in the county.

The City of Sacramento, through the National Geodetic Survey, asked to cooperate in the Yolo County project. Eight stations in the vicinity of Sacramento were incorporated into the project. The results of these stations are also included in Appendix A. The primary interest of the city was horizontal coordinates: however, their stations were observed to obtain high-accuracy vertical values.

There was a series of ten recommendations in the 1999 report (The Yolo County Subsidence Network: Recommendations for Future Monitoring, Frame and D'Onofrio, 1999). A complete listing of these recommendations and comments is included in Section IV of this report. A review of the results of the 2002 survey and a comparison with the results of the 1999 effort suggests two additional recommendations. These are:

Recommendation 11. Incorporate measurements to relate the two DWR extensometers (at Zamora and Conaway Ranch) and the Yolo County Subsidence network.

Recommendation 12. Seek cooperation with the County of Solano to determine the magnitude and extent of the subsidence in the vicinity of Davis.

These recommendations are further discussed in this report in Section V.

I. INTRODUCTION

This report outlines the results of the 2002 Yolo County Subsidence network observations and compares them to the results of the 1999 network survey. It includes a listing of the recommendations made in 1999 with updated comments. It also includes two new recommendations and the rationale behind them. Detailed information about the origins of the project can be found in the 1999 report: The Yolo County Subsidence Network: Recommendations for Future Monitoring, Frame and D'Onofrio, 1999.

As with the 1999 survey, the 2002 survey was accomplished with observation personnel and GPS equipment from participating public agencies and the University of California, Davis. Personnel and equipment were supplied by the California Department of Transportation and the U.S. Bureau of Reclamation. Personnel were supplied by the Yolo County Planning & Public Works Department, City of Davis Public Works Department, City of Woodland Public Works Department and the California Department of Water Resources. Equipment was supplied by the Department of Geology, University of California, Davis and the California Department of Water Resources. The City of Sacramento also participated by providing personnel and equipment for observing the stations in the city.

II. BACKGROUND

In 1999 the first GPS observations were obtained for the Yolo County Subsidence network stations. The small portion of the county south of Interstate Highway 80 was not included in the survey although seven stations there had been observed as part of the 1997 Sacramento/San Joaquin Delta GPS project. These seven stations were included in the 2002 re-observation of the Yolo County Subsidence Network.

The results of the 1999 GPS observations corroborated subsidence observations previously made by means of other technologies in certain areas of the county. Several stations included in the network indicated subsidence when compared to previous terrestrial elevation data. The most significant was station DUFOUR which indicated subsidence of about 1.4 meters (greater than four feet) from its last known published elevation in 1967. Between the 1999 and 2002 surveys stations along the I-5 corridor and vicinity, from Dunnigan to Woodland, exhibited subsidence. Subsidence was also noted along the Highway 113 corridor and vicinity, from Woodland to Davis. Subsidence in these areas from pre-1999 terrestrial and GPS surveys was also noted.

The utility and accuracy of the GPS technology for monitoring subsidence was demonstrated shortly after completion of the 1999 survey when Andregg, Inc. surveyors performed terrestrial level ties between four station pairs in the network. The terrestrial observations and GPS results agreed to within about one centimeter or better in all instances. GPS observations are significantly more cost effective than conventional terrestrial leveling.

Results of the 1999 survey accompanied by a project map, station descriptions and the series of recommendations may be found at the web site dedicated to the project. The web site address is: www.yarn.org/subsidence/about.html.

The NGS web site has a complete listing of all station data with additional values and metadata. The data can be obtained at the web site address: www.ngs.noaa.gov/cgi-bin/ds_project.prl. Enter the GPS project identifier, **GPS1790,** to obtain data for all stations used in the Yolo County project.

III. PROJECT ISSUES

All but one station in the original 1999 network were recovered in good condition and still suitable for GPS observations. Station PHILLIPS was found to be unsuitable for continued GPS monitoring due to the growth of trees in the vicinity. A new station, VINCOR, was established nearby. A terrestrial level tie was accomplished between stations PHILLIPS and VINCOR so the continuity of subsidence records history would remain intact. (See **Recommendation 3.**) The Yolo County Planning & Public Works Department requested the addition of a station at the Yolo County Airport. An existing monument was located on the airport and was added to the network as station YCAP. Please note that network stations already exist at the Davis and Woodland airports.

The seven additional stations added to the network in the southern portion of the county had been observed in 1997. The procedures employed in the 1997 survey were the same as those employed in the Yolo County project; thus direct measures of potential subsidence were determined over the five year period between observations. These stations indicated relative stability (no subsidence).

Two of the eight stations added to the project at the request of the City of Sacramento indicated significant subsidence. Station J 1414 subsided five centimeters (two inches) since its 1994 GPS observation. Station RIEGO RM 4 subsided six centimeters (about 2 ½ inches) since its 1994 GPS observation. These two stations were part of the California Department of Transportation HPGN Densification network. Note, however, that the 1994 observations were not conducted according to the same height modernization specifications as were the observations made in 2002.

All other activities associated with the 2002 network re-observation were routine.

IV. 1999 RECOMMENDATIONS AND UPDATED COMMENTS

The original ten recommendations from the 1999 report are included here with updated comments, as appropriate. Two new recommendations are suggested in the following section (**V. NEW RECOMMENDATIONS**).

Recommendation 1. Inform public and private agencies involved in construction, utilities management, public works and related activities in the county about the network and the location of all stations. Information about the project's web site should be included in this information.

There have been numerous indications that the network stations and their related coordinates and elevations are being regularly used. The land surveying community, in particular, relies heavily upon the network stations for positioning activities.

Recommendation 2. Task a single county entity with visiting each monument in the network annually to assess the integrity of the individual monuments. Any discrepancies in monument description or condition should be brought to the attention of interested county parties and to the National Geodetic Survey (NGS). Follow proper reports for reporting such discrepancies.

It is unclear if any agency has accepted this responsibility. This has not yet been a problem since all but one station in the network were recovered in 2002 in good condition and suitable for GPS observations. The only station found unsuitable was station PHILLIPS, which is still in good condition but is under tree canopy. That makes it unsuitable for GPS observations since clear access to the GPS satellites has been compromised. The recommendation is still valid and should be followed.

Recommendation 3. Identify stations in imminent danger of destruction and replace them in advance, following National Geodetic Survey guidelines. (A copy of these guidelines may be obtained from the NGS California State Geodetic Advisor, Marti Ikehara - marti_ikehara@dot.ca.gov.) A station destroyed before replacement represents a permanent break in the subsidence history of that station.

Although station PHILLIPS has been rendered unsuitable for GPS observations the physical station has not been disturbed. After the new station VINCOR was established about 20 meters from station Phillips, Frame Surveying & Mapping performed a terrestrial level tie between the two stations. This helps to retain the subsidence history at the site. The potential for station destruction increases over time, especially as development encroaches in the vicinity if the stations.

Note: The cost of these first three recommendations is relatively minor, less than about two person-weeks of effort per year.

Recommendation 4. Re-observe the entire network in three years (2002). Depending on the results of this re-observation the county can better determine the time period for subsequent re-observations.

This recommendation was accomplished with the re-observation in 2002. We recommend another re-observation in 2005. Subsidence is not uniform over time, but is correlated with groundwater withdrawal. Another re-observation in 2005 should provide further information about subsidence and subsidence patterns, especially in areas of more significant subsidence. The network should be re-observed at about the same time of year as the 1999 and 2002 surveys as some seasonal variation in ground elevation is known to occur. Observations made at a different time of year might compromise the results. The cost of the re-observation should be similar to the cost of the 2002 survey, allowing for inflationary increases.

Recommendation 5. Investigate the benefits of more frequent re-observation of particular areas of the county.

This recommendation was suggested without knowledge of the actual amount of subsidence that might be discovered. A comparison of the 1999 and 2002 surveys indicated a maximum subsidence of about seven centimeters. It is unlikely that this level of subsidence over three years would indicate a need for further re-observations at a lesser time interval. Three-year observations seem to be satisfactory, pending a review of the 2005 proposed re-observation results.

Recommendation 6. Investigate densification of the network in areas of particular interest.

The existing network provides a series of stations at about seven kilometer spacing. These discrete stations may prove unsatisfactory for finer-level understanding of subsidence and subsidence patterns. Differential subsidence over relatively small areas-on the order of one kilometer - have been observed in other subsiding areas in California. The City of Davis has indicated an interest in developing a dense network consisting of one north-south and one east-west transect through the city, intersecting near central Davis. The cost of installing and observing this denser network is estimated at about $37,000. The project would most likely incorporate GPS and terrestrial leveling, and would involve the establishment of additional survey monuments. New monuments suitable for monitoring subsidence add significant costs to a project. The GPS observations would include ties to stability to ensure accurate determinations of subsidence.

Recommendation 7. Provide continuing non-financial support for the Continuously Operating reference Station (CORS) at the University of California, Davis. This site can be of significant value in ongoing subsidence measurement operations.

The UCD CORS site is monitored continuously and can be related to other CORS sites such as those in Fairfield and the Sutter Buttes. These latter two stations have been found to be stable in the vertical component. Because of the amount of continuous data it is possible to relate the UCD site to the other sites at the sub-centimeter level. At any time the elevation of the UCD site can be determined relative to these other sites. It is the ongoing observations of the UCD site that provides information about the seasonal changes in surface elevation.

Recommendation 8. Investigate the establishment of a CORS site in the north county area.

The California Spatial Reference Center (CSRC) has developed a plan to include a CORS in the north county subject to funding and priorities. A willingness on the part of the county and its cooperating partners to share the cost with CSRC might influence CSRC priorities. Costs were included in the 1999 report. Annual maintenance costs for a CORS site is about $6,000 per year which can be reduced by cooperative efforts.

Recommendation 9. Consider the merits of encouraging the Federal Emergency Management Agency (FEMA) to adopt the results of the project in its flood plain mapping efforts.

The 2002 revision of the FEMA Flood Insurance Rate Map (FIRM) for the City of Woodland was based upon vertical control established by the 1999 subsidence network. The revision includes flood elevation contours published in both NGVD29 (a superseded datum) and NAVD88 (the current national datum and the datum to which the subsidence network is referenced). As future re-observations are accomplished and subsidence in the county becomes more thoroughly documented, FEMA is likely to increase reliance upon the network in its flood plain analysis, and may ultimately convert all Yolo County FIRMs to NAVD88.

Recommendation 10. Investigate other supporting technologies as an adjunct to the GPS Subsidence Network within Yolo County.

The 1999 report suggested investigating Synthetic Aperture Radar (SAR) and Light Detection and Radar (LIDAR) technologies for providing a denser look at subsidence and subsidence patterns in the county. It now appears that LIDAR is a significantly more expensive technology. But perhaps more importantly, the accuracies of LIDAR are at about the 15 centimeter level. Given the level of subsidence disclosed by the 2002 subsidence, it appears that this technology offers no significant benefits.

There is perhaps a better chance for use of SAR technology, however, this technology does not work as well in agricultural areas. It is based upon change detection over time, which requires land areas that do not change over time. Agricultural areas change with the conditions of the ground (level versus furrows) and agricultural growth. For example, SAR cannot distinguish between a barren field and one with a full growth of crops and would give a false interpretation of ground surface change under those conditions. There is some potential for SAR, but it would probably cost about $15,000 for a test project, with no guarantee that the results would be beneficial.

V. 2002 ADDITIONAL RECOMMENDATIONS

After the results of the project had been determined a meeting was held with the staff of the California Department of Water Resources responsible for maintaining the two extensometers in the county. The extensometers are in the vicinity of Zamora and on the Conaway Ranch. Network station ZAMX, near the Zamora extensometer, reflected subsidence of seven centimeters. Station EX-1, near the Conaway Ranch extensometer, subsided only two centimeters. In each case the extensometer records indicated subsidence about one-half that of the GPS measurements.

The extensometers are significantly more responsive to ground level fluctuation on an almost daily basis. GPS measurements, on the other hand, are obtained over a several day period and meaned to a common date. The extensometer fluctuations do not account for the difference between the two types of measurements. Conversations with representatives at the U.S. Geological Survey indicate that extensometers, even those established to a depth of as much as 1,000 feet, may not truly reflect the full amount of ground subsidence. We believe that each of the technologies provides accurate measurements, but that GPS more accurately measures total ground subsidence.

Recommendation 11. Incorporate measurements to relate the two DWR extensometers (at Zamora and Conaway Ranch) and the Yolo County Subsidence network.

As a result of these results and our discussions with DWR, we believe that more direct measurements between the two extensometers and their respective nearby network stations be taken at the time of the GPS measurements. Since GPS observations are made over a several-day period a series of these measurements may be desirable. GPS accuracy is mostly a function of the length of time the GPS satellite constellation is tracked. Observation time at network stations ZAMX and EX-1 might be extended to provide a greater level of accuracy. This could provide sub-centimeter results for the two stations and allow a more accurate measurement of the differences between the technologies.

The cost for these additional observations is estimated at about $6,000.

Recommendation 12. Seek cooperation with the County of Solano to determine the magnitude and extent of the subsidence in the vicinity of Davis.

A review of the subsidence contour map in Appendix D indicates significant subsidence in the vicinity of Davis. The extent of the subsidence is unknown south of Davis since this area is in Solano County and is not part of the Yolo County network. There are several existing stations in Solano County that are part of earlier GPS surveys, specifically the Sacramento/San Joaquin Delta projects. These stations could be added at an additional cost of about $2,000. This assumes Solano County would be willing and able to provide personnel and equipment to occupy these stations. Alternatively, DWR might be willing to underwrite this extension of the Yolo project, since these stations are part of the Delta network.

VI. CONCLUSION

The completion of the 2002 Yolo County GPS subsidence project provides the first modern review of subsidence in the county. The comparison of the 1999 and 2002 projects indicates areas of the county that, when related to older terrestrial surveys, continue to exhibit subsidence. Most of the county experienced some subsidence. The Interstate Highway 5 corridor from Dunnigan to Woodland and the Highway 113 corridor from Woodland to Davis are affected most by this subsidence. Another pocket of subsidence is in the northwestern portion of the project area. The largest subsidence between the two GPS surveys is in the vicinity of Zamora which subsided seven centimeters. The 2002 results are included in Appendix A and the elevation differences (subsidence = negative, uplift = positive) between the two surveys are included in Appendix B. Continued monitoring of the network is recommended. Continued monitoring of the primary factor causing subsidence, groundwater withdrawal, is also recommended.

It should be noted that the horizontal coordinates (latitude and longitude) also changed for all stations in the network. The county is in the area of horizontal motion caused by being located in the zone affected by the North American and Pacific tectonic plates. All stations in the project move northwesterly a few centimeters per year with minor variation in movement among the stations.

Respectfully submitted:

Jim Frame	Don D'Onofrio
Frame Surveying & Mapping	Geodetic Consultant

Appendix A: Final Station List and Coordinates

(Includes City of Sacramento stations)

(Photo: Station CHURCH in the City of Woodland)

Appendix A: Final Station List and Coordinates

STATION DESIGNATION	FINAL ADJUSTED LATITUDE (epoch 2002.53)	FINAL ADJUSTED LONGITUDE (epoch 2002.53)	FINAL ADJUSTED NAVD88 Orthometric HEIGHT, meters (2002 elevations)	PID
169	38 44 12.69568N	121 57 15.85660W	52.50	JS2170
ABUT	38 38 05.70584N	121 57 06.70255W	53.01	AI5050
ALHAMBRA	38 33 31.09757N	121 42 26.68762W	12.97	AI5051
ANDREW	38 23 12.17743N	121 38 18.71969W	3.68	AE9864
B 849	38 32 01.29090N	121 58 15.18331W	39.68	JS2151
BIRD	38 50 54.73498N	122 02 37.47696W	94.11	AI5052
BRIDGE	38 42 41.39518N	122 02 50.18340W	64.20	AI5053
CALDWELL	38 27 33.51280N	121 39 24.21307W	5.42	AE9863
CANAL	38 37 02.05407N	121 51 30.11560W	29.79	AI5054
CASTRO AZ MK RESET	38 33 50.77536N	121 38 37.80288W	5.27	JS4556
CHURCH	38 39 48.00509N	121 48 09.05752W	24.12	AI5055
CODY	38 47 30.59722N	121 46 29.01978W	12.75	AI5056
CONAWAY	38 37 05.49414N	121 38 40.42822W	7.71	AI5057
COTTON	38 38 20.24426N	122 02 08.12167W	91.52	AI5058
COURTLAND	38 20 24.75925N	121 33 40.05033W	8.06	JS4311
COY DUMP	38 35 28.05097N	121 41 31.83411W	8.55	AI5059
CVAP 02	38 50 19.76338N	121 50 39.17593W	8.01	AI5060
DAVEPORT	38 31 59.46429N	121 47 14.17621W	19.39	JS4617
DRAIN	38 55 31.04473N	121 54 52.46219W	12.97	AI5061
DUFOUR	38 45 48.09569N	121 50 39.06776W	20.25	JS2238
F 859 RESET	38 47 34.20043N	121 43 36.01698W	14.21	AI5062
FERRY	38 40 32.00674N	121 37 49.18003W	12.13	JS2338
FORD RM 2	38 43 33.23507N	121 43 47.39158W	17.53	AI5046
FREMONT	38 45 52.89327N	121 38 08.00521W	12.56	AI5063
G 1200	38 47 09.87346N	121 14 32.09509W	77.38	JS0755
GAFFNEY	38 24 25.68438N	121 34 56.13556W	1.00	AE9851
GWM 17	38 46 52.25771N	122 02 38.10735W	84.79	JT0105
GWM 32	38 44 21.97065N	122 09 59.02755W	112.58	JT0026
HERSHEY	38 52 28.84718N	121 54 51.96511W	13.97	AI5064
HPGN CA 03 08	38 43 01.99778N	121 48 07.54090W	23.73	JS4668
HPGN D CA 03 BG	38 30 20.00860N	121 34 55.09118W	9.91	AC9219
HPGN D CA 03 DG	38 38 27.43690N	121 45 39.59540W	24.09	AC9223
HPGN D CA 03 EH	38 51 59.61225N	121 32 32.95659W	10.73	JS4847
JIMENO RM 4	38 55 39.86130N	121 50 35.87435W	12.30	AI5047
KEATON	38 42 33.52245N	121 53 11.08244W	35.83	AI5065
LIBRARY	38 40 44.18419N	121 46 28.10008W	19.90	AI5066
MADISON	38 41 00.22740N	121 58 36.36010W	47.00	JS2364
P 1031	38 40 38.14441N	121 42 34.07731W	10.26	JS2344
P 1075	38 50 51.29489N	121 56 00.25761W	14.87	JS2130
VINCOR **(new station)**	38 48 08.11883N	121 59 00.32187W	48.28	DE9127

PLAINFIELD	38 35 05.49717N	121 48 11.62107W	19.96	AI5068
RIVER	38 38 50.46071N	121 34 20.06216W	12.02	AI5069
RUSSELL RANCH 2	38 32 38.06502N	121 52 33.83768W	29.37	AC9893
SM NO 15	38 43 51.60375N	121 37 59.39187W	7.33	AI5070
SUTTER BUTTES CORS POINT	39 12 20.99452N	121 49 14.10152W	645.89	AF9711
SYCAMORE	38 50 19.12265N	121 45 06.38892W	7.66	AI5071
T 1069	38 35 09.99936N	121 58 17.45546W	54.71	JS2157
T 462	38 26 25.99174N	121 30 17.76157W	9.14	JS1556
T 849	38 47 24.93233N	121 54 56.34425W	36.17	JS2177
TYNDALL	38 52 26.17670N	121 49 03.81149W	9.08	AI5072
UCD1 UC DAVIS GEOL 1 CORS ARP	38 32 10.44759N	121 45 04.37720W	31.44	AI4467
WILSON	38 29 41.85081N	121 41 31.51403W	9.60	AE9857
WOODPORT	38 40 17.76114N	121 52 20.38066W	39.74	JS3886
X 200 RESET	38 54 20.73108N	121 58 59.79141W	29.88	JS2144
YOLO CO AP BASE LINE PT 6 **(new station)**	38 34 20.34417N	121 51 18.37282W	29.61	DE9129
Z 585 RESET	38 34 15.79628N	121 31 49.55488W	6.30	JS2248
ZAMX	38 46 45.78460N	121 48 44.62949W	13.03	AI5074
EX-1	38 38 46.40916N	121 40 03.02450W	7.86	AI5073
POTRERO HILL GRM	38 12 09.43671N	121 56 07.33702W	62.1	AJ1919
STOCKTON CORS ARP	37 53 47.04380N	121 16 42.53064W	11.7	AH8914

City of Sacramento Stations

HPGN D CA CSUS	38 33 14.56994N	121 25 23.72262W	13.31	AC9246
J 1414	38 29 47.62917N	121 23 49.73609W	11.84	JS3901
AP STA A2	38 30 18.05576N	121 30 01.31353W	5.01	JS4839
G 1414	38 27 10.89635N	121 22 51.46942W	11.77	JS3899
CNTRL MON LR 208	38 39 18.54189N	121 23 14.17731W	23.39	AC9237
CAPITOL RESERVOIR	38 39 02.32747N	121 30 26.67360W	4.79	DE9128
HPGN D CA 03 AA	38 36 52.10322N	121 30 52.07406W	6.08	AC9226
RIEGO RM 4	38 45 05.18885N	121 29 05.74989W	14.34	AC9218

NOTE: The epoch date for stations STOCKTON CORS ARP (AH8914)and SUTTER BUTTES CORS POINT (AF9711) IS **2002.00**. All other stations are as indicated, 2002.53.

Appendix B: Table of Station Subsidence

(Photo: Don Stackhouse, USBR, at station CVAP 02.)

Appendix B: Station List
A Comparison of 1999 and 2002 Project Results

STATION DESIGNATION	*Published* Orthometric Height, meters (1999 elevations)	*Adjusted* Orthometric Height, meters (2002 elevations)	*Adjusted minus Published* Ortho Height (2002-1999) Subsidence (-) Uplift (+)
169 USGS	52.52	52.50	-0.02
ABUT	53.03	53.01	-0.02
ALHAMBRA	12.99	12.97	-0.02
ANDREW[1]	3.68	3.68	-0.01
B 849	39.68	39.68	0.00
BIRD	94.13	94.11	-0.02
BRIDGE	64.21	64.20	-0.01
CALDWELL[1]	5.42	5.42	0.00
CANAL	29.80	29.79	-0.01
CASTRO AZ RESET	5.27	5.27	0.00
CHURCH	24.13	24.12	-0.01
CODY	12.80	12.75	-0.05
CONAWAY	7.72	7.71	-0.01
COTTON	91.51	91.52	+0.01
COURTLAND[1]	8.06	8.06	0.00
COY DUMP	8.56	8.55	-0.01
CVAP 02 USGS	8.05	8.01	-0.04
DAVEPORT	19.44	19.39	-0.05
DRAIN	12.99	12.97	-0.02
DUFOUR	20.31	20.25	-0.06
F 859 RESET	14.23	14.21	-0.03
FERRY	12.12	12.13	+0.01
FORD RM NO 2	17.55	17.53	-0.03
FREMONT	12.54	12.56	0.02
G 1200	77.38	77.38	0.00
GAFFNEY[1]	0.99	1.00	+0.01
GWM 17 USGS	84.85	84.79	-0.06
GWM 32 USGS	112.58	112.58	0.00
HERSHEY	13.99	13.97	-0.02
HPGN CA 03 08	23.78	23.73	-0.05
HPGN D CA 03 BG[1]	9.91	9.91	0.00
HPGN D CA 03 DG	24.13	24.09	-0.04
HPGN D CA 03 EH	10.75	10.73	-0.02
JIMENO NO 4	12.30	12.30	0.00
KEATON	35.84	35.83	-0.01
LIBRARY	19.93	19.90	-0.03
MADISON	47.03	47.00	-0.03
P 1031	10.26	10.26	0.00
P 1075	14.90	14.87	-0.03
VINCOR (new station)[2]	48.32	48.28	-0.04
PLAINFIELD	19.99	19.96	-0.03
RIVER	12.03	12.02	-0.01

Appendix B: Station List
A Comparison of 1999 and 2002 Project Results

RUSSELL RANCH 2	29.38	29.37	-0.01
SM NO 15	7.30	7.33	+0.03
SUTTER BUTTES CORS POINT	645.89	645.89	0.00
SYCAMORE	7.67	7.66	-0.01
T 1069	54.73	54.71	-0.02
T 462 [1]	9.14	9.14	0.00
T 849	36.20	36.17	-0.03
TYNDALL	9.10	9.08	-0.02
UCD1 UC DAVIS GEOL 1 CORS ARP	31.50	31.44	-0.06
WILSON (1)	9.61	9.60	-0.01
WOODPORT	39.75	39.74	-0.01
X 200 RESET	29.91	29.88	-0.03
YOLO CO AP BASE LINE PT 6 (new station)		29.61	
Z 585 RESET	6.35	6.30	-0.05
ZAMX	13.10	13.03	-0.07
EX-1	7.88	7.86	-0.02

City of Sacramento Stations

HPGN D CA CSUS [1]	13.31	13.31	0.00
J 1414 [1]	11.79	11.84	+0.05
AP STA A2 [1]	5.00	5.01	+0.01
G 1414 [1]	11.75	11.77	+0.02
CNTRL MON LR 208 [1]	23.38	23.39	+0.01
CRES (new station)		4.79	
HPGN D CA 03 AA [1]	6.09	6.08	-0.01
RIEGO RM 4 [1]	14.40	14.34	-0.06

[1] These stations were observed as part of the 1997 Sacramento/San Joaquin Delta project.

[2] Station VINCOR is a replacement for nearby station PHILLIPS, which was not suitable for GPS observations in 2002 due to tree growth. The 1999 height and "adjusted minus published" values shown are theoretical and were determined from a leveling tie made to PHILLIPS in 2002.

Appendix C: Personnel Listing

C-1: Agency Personnel

C-2: Observation Personnel

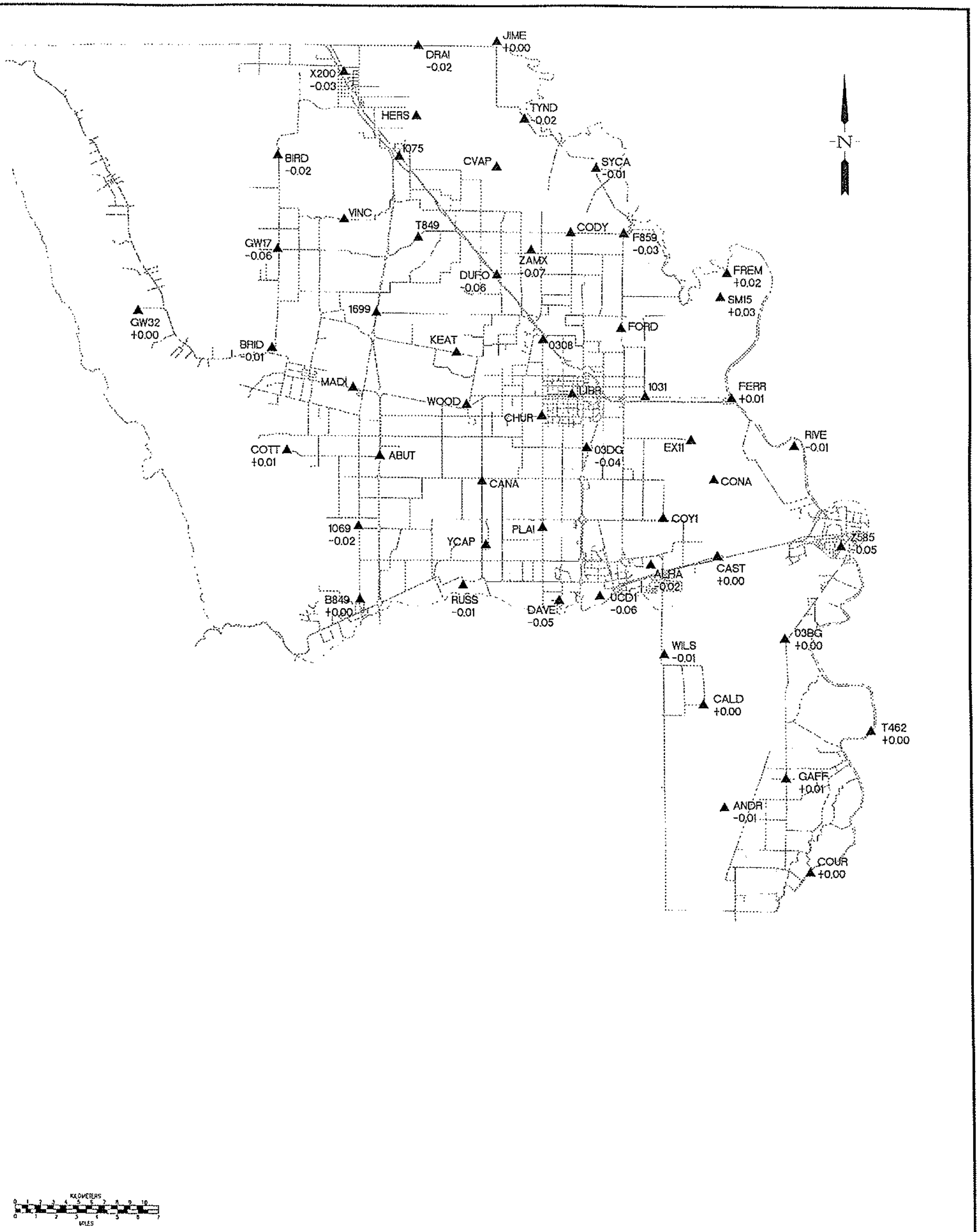
(Photo: GPS Equipment at station ZAMX at the Zamora extensometer)

Appendix C-1: Agency Personnel

Personnel	**Agency**
Jacques DeBra	Utilities Program Specialist Planning and Public Works Department City of Davis
John Fielden	Hydrogeologist California Department of Water Resources, Sacramento
Christy Barton	Asst. General Manager Yolo County Flood Control and Water Conservation District, Woodland
Ken Misner	County Surveyor Yolo County Planning & Public Works Department, Woodland
Ron Scott	City of Woodland
John Adam	California Department of Transportation North Region, Marysville
Terri Reaves	Surveys & Photogrammetry U.S. Bureau of Reclamation, Sacramento
Louise Kellogg	Associate Professor Department of Geology University of California, Davis
Deborah Braver	Water Resource Association of Yolo County, Woodland
Marti Ikehara	National Geodetic Survey, Sacramento
Jim Frame	Frame Surveying & Mapping, Davis
Don D'Onofrio	Geodetic Consultant, Carmichael

Appendix C-2: Yolo County Observing Personnel

Personnel	**Agency**
Ken Misner	Yolo County Planning & Public Works Department
Ron Scott	City of Woodland
Larry Hatch	City of Woodland
Marie Graham	City of Davis
Ingdean "Indy" Yan	California Department of Water Resources
Isela Ortiz	California Department of Water Resources
Sal Batmanghilich	California Department of Water Resources
Don Stackhouse	U.S. Bureau of Reclamation
Robert Keller	U.S. Bureau of Reclamation
Ireck Hernandez	California Department of Transportation
Tim Dowell	California Department of Transportation
Jim Frame	Frame Surveying & Mapping
Don D'Onofrio	Geodetic Consultant



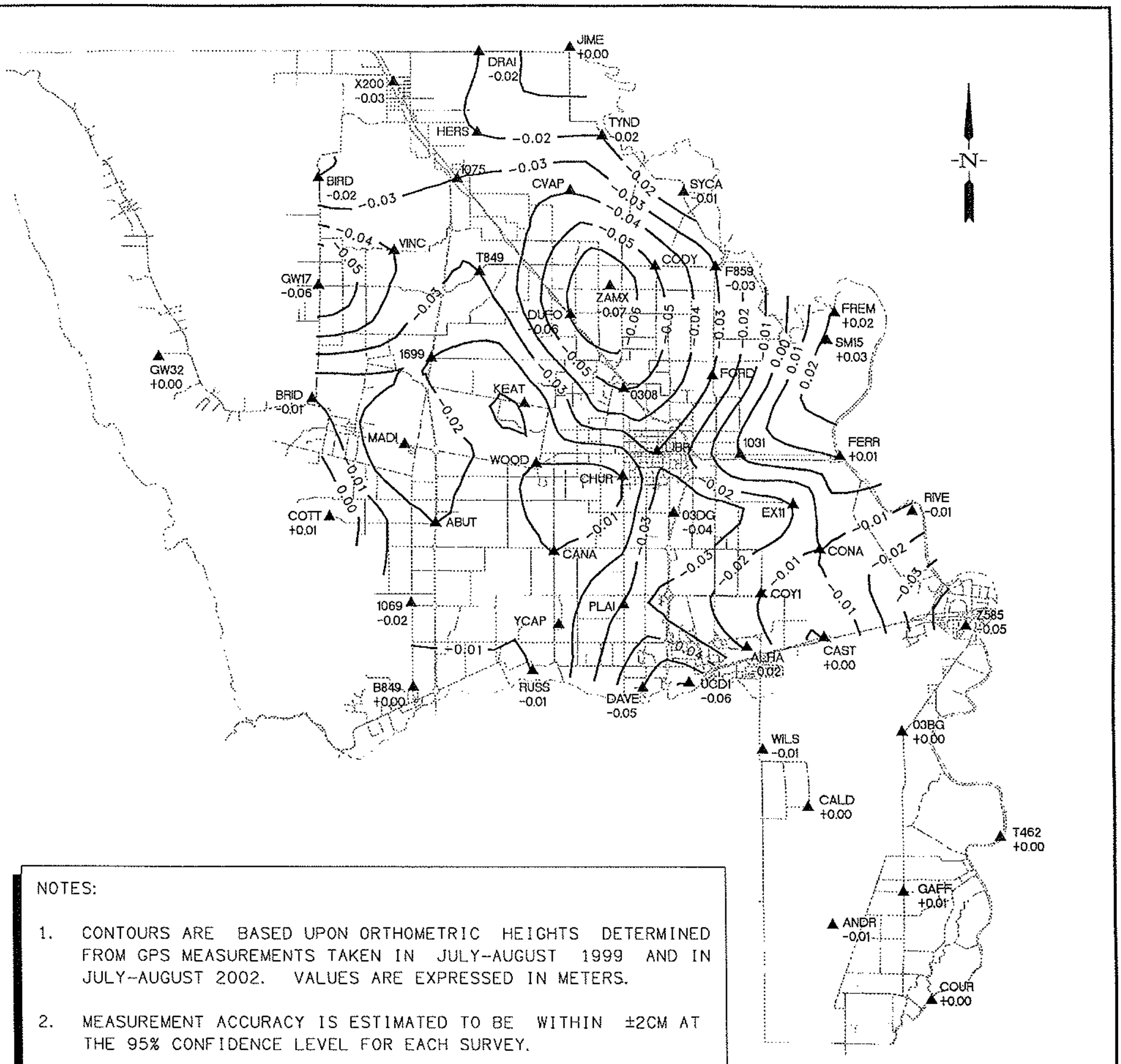
FRAME SURVEYING & MAPPING

609 A Street Davis, CA 95616
(530) 756-8584 (TEL) (530) 756-8201 (FAX)

1280-039C

YOLO SUBSIDENCE NETWORK

1999 - 2002 SUBSIDENCE CONTOURS
YOLO COUNTY, CALIFORNIA
FEBRUARY, 2003 SCALE: 1"= 10KM



NOTES:

1. CONTOURS ARE BASED UPON ORTHOMETRIC HEIGHTS DETERMINED FROM GPS MEASUREMENTS TAKEN IN JULY-AUGUST 1999 AND IN JULY-AUGUST 2002. VALUES ARE EXPRESSED IN METERS.
2. MEASUREMENT ACCURACY IS ESTIMATED TO BE WITHIN ±2CM AT THE 95% CONFIDENCE LEVEL FOR EACH SURVEY.
3. THE COMBINATION OF MEASUREMENT ERROR AND THE AVAILABILITY OF ONLY TWO DATA POINTS AT EACH STATION MAY RESULT IN UNRELIABLE SUBSIDENCE RATE CALCULATIONS.
4. CONTOUR LOCATIONS ARE APPROXIMATE DUE TO THE SPARSE DISTRIBUTION OF THE DATA POINTS.
5. STATIONS IN THE SOUTHEASTERN PORTION OF THE COUNTY WERE NOT OBSERVED IN 1999. SUBSIDENCE INFORMATION FOR THESE STATIONS IS BASED UPON 1997 OBSERVATIONS.

JAMES H. FRAME III
No. 5435

LICENSE EXPIRES
SEPTEMBER 30, 2004

FSM **FRAME** SURVEYING & MAPPING
609 A Street Davis, CA 95616
(530) 756-8584 (TEL) (530) 756-8201 (FAX)
1280-039C

YOLO SUBSIDENCE NETWORK

1999 - 2002 SUBSIDENCE CONTOURS
YOLO COUNTY, CALIFORNIA
FEBRUARY, 2003 SCALE: 1"= 10KM

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Letter From the YZWD Board of Directors to YCFCWCD

Appendix H

YOLO-ZAMORA WATER DISTRICT
P.O. Box 355
Yolo, CA 95697

April 28, 2003

Mr. Bruce Rominger, Chairman
Yolo County Flood Control & Water Conservation District
34274 State Highway 16
Woodland, CA

Subject: YCFCWCD/YZWD Conjunctive Water Use Feasibility Study, Conclusion of Study.

Dear Mr. Rominger and Members of the Board:

On behalf of the Board of Directors of the Yolo-Zamora Water District (YZWD), thank you for the leadership and effort of the Yolo County Flood Control & Water Conservation District (District) to investigate opportunities to provide supplemental surface water to the YZWD for an effective conjunctive water use project.

At the conclusion of the Project Advisory Group Meeting on March 12, 2003, it was agreed among the group members present that the four water supply and delivery alternatives investigated during the study were not financially feasible. Also, preliminary information on a project to service a much smaller area was reviewed. It was agreed the smaller project was not feasible for the landowners that could potentially be involved.

The YZWD Board, at its meeting on Monday, April 28, 2003, reviewed the findings of the Project Advisory Group and concurs with its findings.

The alternatives identified during the course of the investigation have technical merit from the standpoint of water management. Accordingly, the alternatives may warrant reconsideration in the future.

Although a project is not feasible at this time, the Board would like the District to know that individual farmers within the YZWD continue to be interested in receiving supplemental surface water from the District. This Board is hopeful that the District will work with interested individuals to provide supplemental surface water to the extent it is compatible with the District's operation. Any supplemental surface water delivered to the YZWD service area will be beneficial.

In closing, please know that this Board, in representing the Yolo-Zamora Water District, is truly grateful for the District's leadership and efforts aimed at furthering the management of water resources not only within the District, but within Yolo County generally.

Sincerely,

Twyla Thompson

Twyla Thompson, President
Yolo-Zamora Water District

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ENGINEERING • PLANNING • MAPPING • SURVEYING
3301 C Street, Bldg 100-B
Sacramento, CA 95816
Tel: 916.341.7760
Fax: 916.341.7767