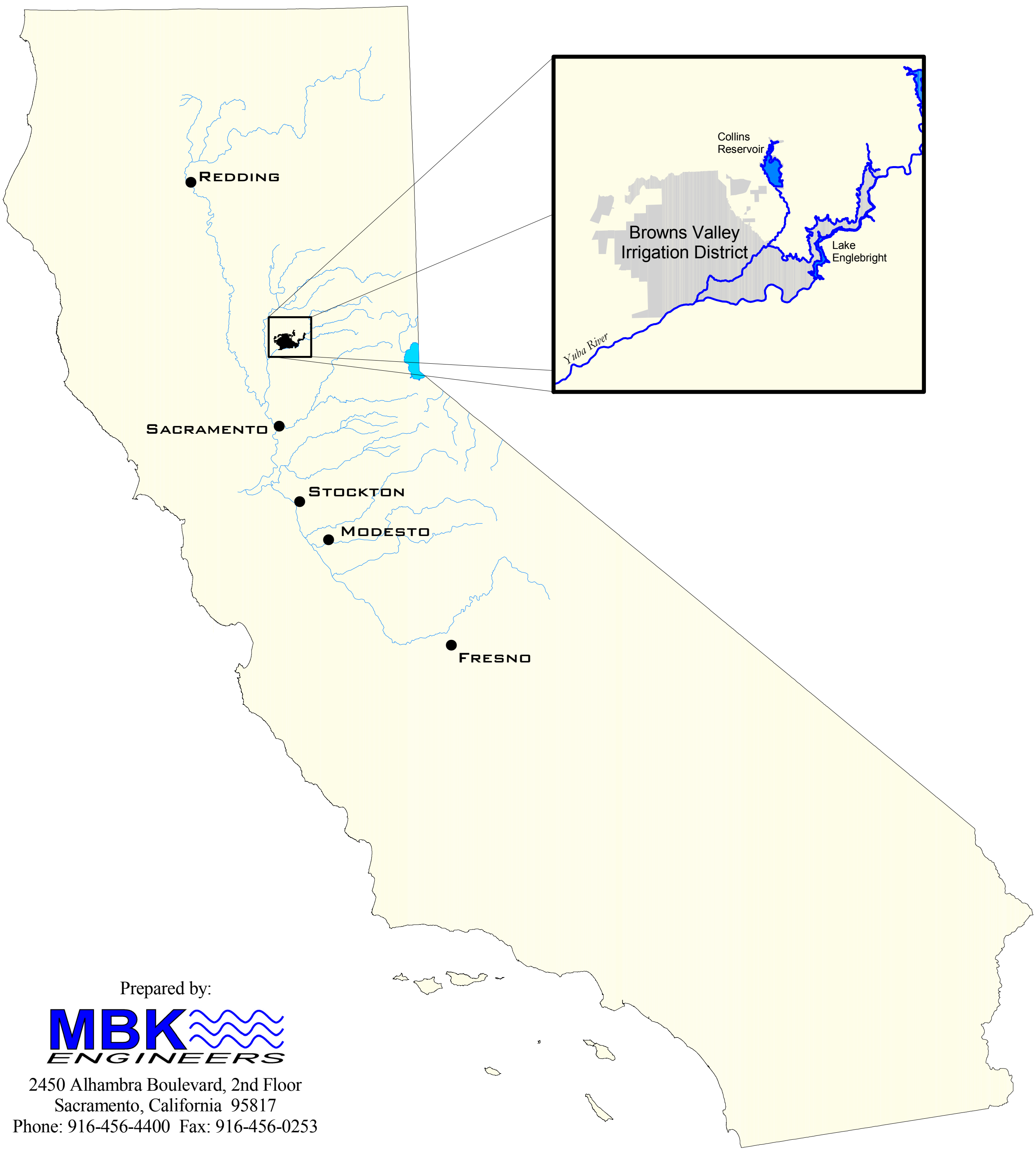
Browns Valley Irrigation District

Analysis of Water Conserved Under the Upper Main Water Conservation Project

May 2002



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OVERVIEW OF PROPOSAL OF BROWNS VALLEY IRRIGATION DISTRICT TO TRANSFER CONSERVED WATER

Background Information

Browns Valley Irrigation District ("BVID") is one of the oldest irrigation districts in California (formed in 1888), and includes approximately 40,000 acres in Yuba County, east of the City of Marysville. A general location map of BVID is displayed on the cover of this report and a more detailed map showing BVID's relation to the local water system is located in Figure 1. BVID has three sources of surface water rights and entitlements: (1) a pre-1914 direct diversion water right of 47.2 cfs from the North Yuba River with a priority date of March 21, 1890, which is the most senior water right on the North Yuba River (see section 10.3 of State Water Resources Control Board Water Right Decision 1644, March 1, 2001); (2) appropriative rights under water right permits issued by the State Water Resources Control Board at Collins Reservoir, a storage facility that is owned and operated by BVID on Dry Creek, a tributary to the Yuba River; and (3) a water supply contract with Yuba County Water Agency. BVID also pumps groundwater to supplement its surface water supplies.

From about 1890 to1963, BVID diverted about 20,000 acre feet annually under its pre-1914 water right from the North Yuba River at the head of the BVID's Upper Main Canal for irrigation use within BVID's service area. BVID's Upper Main Canal was constructed during the Gold Rush Era, and consists of about 20 miles of flumes and ditches. In 1963, when Collins Reservoir began operation, BVID diverted up to 5,500 acre feet per year of its pre-1914 water right at the Upper Main Canal, and diverted the balance of the pre-1914 water right from BVID's Pumpline Canal on the Yuba River, below the confluence with Dry Creek.

The Upper Main Water Conservation Project

Water losses on the Upper Main Canal were substantial, but typical of losses experienced by similar Gold Rush Era water conveyance facilities throughout the Sierra Nevada foothills. In 1990, BVID began a water conservation project to (1) construct a pipeline to deliver water from Collins Lake to serve the area that had previously been served from the Upper Main Canal (shown in Figure 1 and Figure 2), and (2) terminate the use of the Upper Main Canal for water deliveries. The water conservation project cost about $1.3 million. The water conservation project was funded by a water conservation loan to BVID under a program that was administered by the Department of Water Resources("DWR").

Prior to undertaking the water conservation project, the BVID Board of Directors adopted Resolution No. 3-7-90-1 on March 7, 1990 (Appendix G), which authorized proceeding with the water conservation project, and confirmed BVID's intention to retain control over the water conserved as a result of the project. The Board Resolution states in part: "Pursuant to California Water Code sections 1011 and 1706, the District intends to sell, lease, exchange or otherwise transfer for use within or outside the boundaries of the District the 5,500 acre-feet of water previously diverted for use from the Upper Main Canal, the use of which from the Upper Main Canal will henceforth cease as a result of its water conservation project."

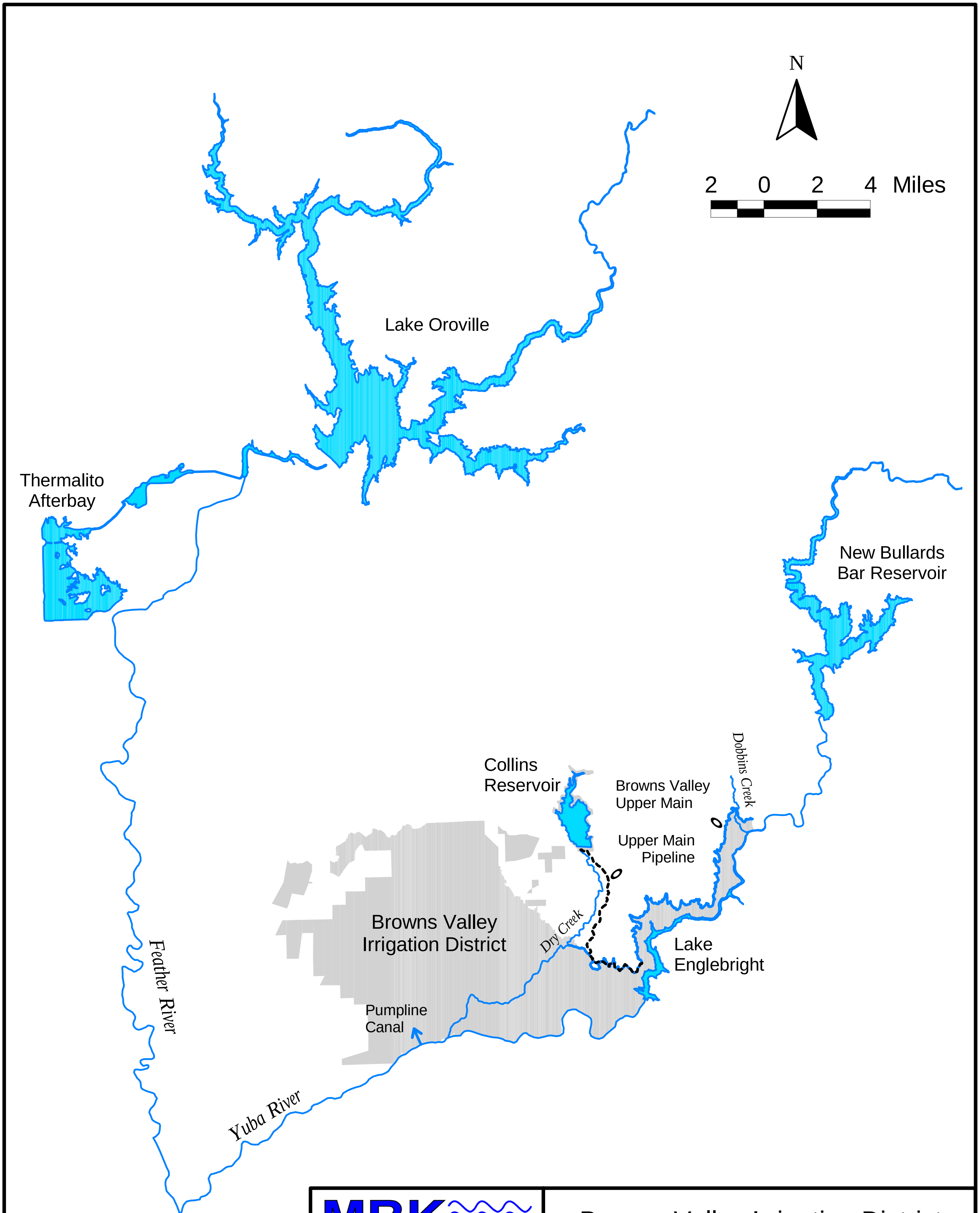

Figure 1

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Browns Valley Irrigation District

Area Map

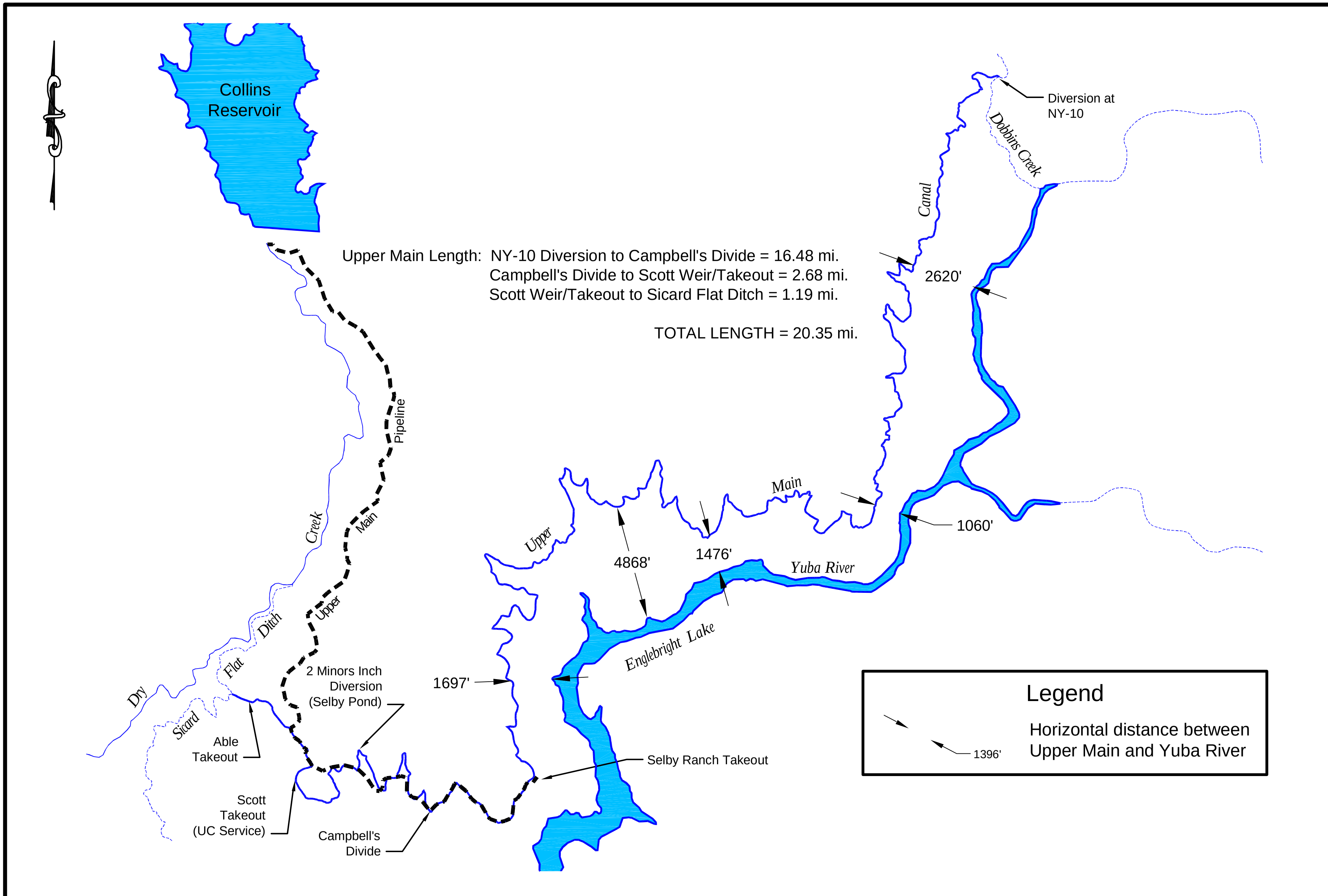

Figure 2

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Browns Valley Irrigation District

Browns Valley Upper Main Canal

The Right of BVID to Transfer Conserved Water

BVID relies on the provisions of various sections of the California Water Code as authority for the right to transfer the portion of the conserved water that would have been consumptively used in the absence of the BVID water conservation project.

Water Code section 1011 states in part:

"(a) When any person entitled to the use of water under an appropriative right fails to use all or any part of the water because of water conservation efforts, any cessation or reduction in the use of the appropriated water shall be deemed the equivalent to a reasonable beneficial use of water to the extent of the cessation or reduction in use. No forfeiture of the appropriative right to the water conserved shall occur upon the lapse of the forfeiture period applicable to water appropriated pursuant to the Water Commission Act or this code or the forfeiture period applicable to water appropriated prior to December 19, 1914."

Water Code 1706 states:

"The person entitled to the use of water by virtue of an appropriation other than under the Water Commission Act or this code may change the point of diversion, place of use, or purpose of use if others are not injured by such change, and may extend the ditch, flumes, pipe, or aqueduct by which the diversion is made to places beyond that where the first use was made."

Several sections of the California Water Code contain declarations of state policy favoring voluntary water transfers. For example, Water Code section 109 contains a declaration of state policy favoring voluntary water transfers, and directs DWR, the State Water Resources Control Board ("State Board") and all other state agencies to encourage voluntary water transfers. Water Code section 475 contains legislative findings and declarations favoring voluntary water transfers, states that the coordinated assistance of state agencies is required for voluntary transfers, and directs DWR to establish an ongoing program to facilitate voluntary water transfers.

Several statutory provisions declare that the act of transferring water shall not, by itself, result in a forfeiture of the underlying water right. For example, Water Code section 1244 states that a water transfer, in itself, shall not constitute evidence of waste or unreasonable use, and shall not affect any determination of forfeiture of an appropriative right. Water Code section 1745.07 states that no transfer of water pursuant to any provision of law shall cause a forfeiture, diminution or impairment of any water right, and that a transfer approved under any provision of law is deemed to be a beneficial use of water by the transferor. (See also, Water Code sections 1010, 1011,1011.5, 1014-1017, 1440, 1731 and 1737.)

Under Water Code section 1011, the right to the use of water under an appropriative right that has been reduced as result of water conservation efforts may be transferred pursuant to any provision of law relating to the transfer of water. For purposes of this section, "water conservation" means the use of less water to accomplish the same purpose of use allowed under an existing appropriative water right. In order to obtain the benefits of this section, the water right holder must file periodic reports with the State Board to describe the extent and amount of the reduction in water use due to the water conservation efforts. BVID has provided notice to the SWRCB regarding water conservation in letters dated September 19, 1990, August 2, 1991, and September 14, 1992. In addition BVID filed a Statement Of Water Diversion and Use on December 11,1988, which documents conserved water.

Methodology for Determining the Transferable Quantity of BVID's Conserved Water

An important element of any water transfer is determining what quantity if any, of the water is "transferable," as a result of the application of the provisions of the Water Code that are intended to protect other legal users of water and fish and wildlife from the possible adverse effects of a water transfer. The "no injury" rule is short-hand for Water Code provisions intended to protect legal users of water from injury from a water transfer. (See, e.g., Water Code sections 1702,1706 and 1725.) Under the no injury rule, a water transfer would not be approved to the extent that it reduced the availability of water for downstream users, regardless of the water priority of those users. Under the no injury rule, only "new water" is transferable, i.e., water that is added to the downstream water supply as a result of the transfer. The rationale for the "no injury" rule is as follows: "... California water law protects senior water users (those with the oldest water rights) from junior diverters while protecting junior water right holders from the expansion of senior water rights. Junior water right holders would be harmed if seniors could increase the amount of water they divert under their senior priority. Likewise, juniors could be hurt if seniors could change their point of diversion, place of use or purpose of use in a manner that reduces the quantity or quality of water relied upon by juniors for their diversion. The "no injury' rule protects junior right holders against this kind of harm from senior right holders." (See *A Guide to Water Transfers*, July 1999, pp. 3-7 - 3-8, published by the State Board, "State Board Guide.")

On December 28, 1999, the State Board issued Order WR 99-012, which involved a proposed transfer of conserved water under Water Code sections 1725 and 1011 involving licensed water rights of Natomas Central Mutual Water Company. The State Board determined that Natomas could transfer the right to use the amount of water that Natomas would have consumptively used but for Natomas' water conservation efforts, but that a reduction in diversion that did not reduce consumptive use cannot be transferred under Water Code section 1725. For example, the State Board said that conservation efforts that reduced diversions from the stream and return flows to the stream by equal amounts would not result in consumptive use savings that could be transferred.

State Board Water WR 99-012 describes the purpose of Water Code section 1011 as follows: "Section 1011 preserves an appropriative water right when less water is used under the right due to water conservation efforts. Essentially, section 1011 requires water to be treated as though it were used, when in actuality the water is conserved. Any reduction or cessation in the use due to conservation efforts is 'deemed equivalent to a reasonable beneficial use . . .' Thus, the right to use the amount of water conserved is not subject to forfeiture for nonuse. The right thereby protected from forfeiture may be used later if needed. The right to use the water conserved may also be transferred pursuant to the other provisions of law authorizing transfers."

The State Board Order also points out that, since 1980, the State Board has required licensees to document their conservation efforts in the Report of Licensee form that must be filed with the State Board every three years under 23 California Code of Regulations, sections 847 and 848, and that the failure to fill out the section of the form regarding water conservation would deprive the licensee of the benefits of section 1011. The State Board Order also states: "It also merits note that Natomas' failure to report conservation efforts in a timely manner called into question the credibility of its claim to have conserved water. Late reporting raises a question whether the nonuse of water was in fact due to conservation efforts, or if the water user is attempting to characterize nonuse that occurred for some other reason as water conservation in order to obtain the protections of section 1011. Conversely, reporting water conservation in a timely manner, while insufficient in itself to prove water conservation, would tend to support a claim that the nonuse of water was the result of water conservation efforts. For this reason, it is in every water users best interest to report water conservation efforts in a timely manner." As previously identified, BVID not only filed it's intent of maintaining control of the conserved water prior to undertaking the project, it has informed the State Board of the water conservation effors.

Once the source of transferable water is identified by the transferor, the quantity of water that would have been consumptively used in the absence of the transfer needs to be determined to confirm the quantity of transferable water due to a water conservation project. The State Board Guide states (at page 6-5):

"The consumptive use of water by crops is determined by calculating the evapotranspiration of applied water for the particular crop. Evapotranspiration (ET) is the combined process by which water is transferred from the soil surface and from the plant (from the leaf surface and through leaf pores) to the atmosphere (ambient air). Evapotranspiration of the applied water is a subset of the total crop evapotranspiration from all water sources including rainfall. Evapotranspiration of applied water is symbolized as ETAW and is a measure of the applied water transpired by plants, retained in the plant tissue, and evaporated from adjacent soil surfaces over a specific time period. ETAW is usually expressed in depth of water per unit area such as acre-feet per acre. . . ."

CONCLUSION OF WATER CONSERVATION ESTIMATE

This report quantifies the water that has been saved from consumptive losses as 3,100 acre-feet per year. This quantity is supported by alternative analysis of estimating vegetative consumptive use by grasses, bushes, trees and other vegetation within the vicinity of the Upper Main Canal.

DETERMINATION OF WATER CONSERVED

During the time of operation, there were significant water losses from the Upper Main. Figure 2 presents a map of the Upper Main showing the diversion point at NY10 and the location of points of delivery to customers. A majority of the water diverted at NY10 was lost before it got to the first delivery point at the Selby Ranch (Figure 2). The intent of this report is to describe the historical data of flows and water deliveries, present a water budget, describe losses along the Upper Main, and estimate consumptive use losses along the Upper Main that would meet criteria for transfer under Water Code Section 1011 as applied by the State Water Resources Control Board in Order WR 99-012 (Natomas Central Mutual Water Company).

The approach taken to evaluate and quantify losses associated with water deliveries through the Upper Main was to first perform a water budget with available data. This water budget would quantify losses from the Upper Main but would not determine the final destination of these water losses. The second step was to quantify the Upper Main losses being consumed by vegetation, returning to the surface system, or percolating underground. Quantifying these losses would provide support for the quantities of losses determined in the water balance approach.

WATER BUDGET FOR UPPER MAIN

A water budget is determined by accounting for all flow entering the Upper Main from NY10 and all flow diverted from or leaving the Upper Main. The following equation expresses the calculation of the water budget performed for the Upper Main for 1987 through 1989. The result of this equation is unaccounted water or losses from the Upper Main.

+ Flow diverted into Upper Main at NY10 (Table 1A)
- Deliveries to UC Field Station (Scott's Takeout)
- Deliveries to Selby Ranch
- Deliveries to UC Field Station (Campbell's Divide)
- Delivery of 2 miner's inches to Selby Ranch Pond
- Deliveries to Able
- Flow leaving the Upper Main at Sicard Flat Ditch

Losses, unaccounted water, may be in the form of evaporation from the water surface or seepage through the earth-lined Upper Main. There was a great deal of vegetative growth within the Upper Main and in the vicinity of the Upper Main. Water that seeped into the soil can be consumptively used by the large number of trees, shrubs, and grasses in the vicinity of the Upper Main. To complete the water budget, the consumptive use of losses determined by the above equation are addressed.

Diversion at NY10

Flow data was recorded at the head of the Upper Main at NY10 by Yuba County Water Agency. Monthly records are available from 1922 to 1990. The NY10 gauge facility consisted of a sharp crested weir together with a Steven's recorder.

Upper Main Flow

Flow in the Upper Main was not recorded by BVID. UC Field Station personnel recorded Upper Main flows and deliveries at Campbell's Divide and Scott Weir for 1987 through 1989 (see Figure 2). Daily records are available for flow at the Scott Weir during the entire 1987 through 1989 period. However, flow records for the Campbell's Divide are only partially available during this period.

Deliveries from the Upper Main

BVID did not record actual deliveries to each customer from the Upper Main. BVID charges its customers by the calibrated size of the takeout (i.e., 40 miner's inches), not based on a continuous measurement of delivery. The UC Field Station personnel recorded daily deliveries for 1987 through 1989 at its takeouts.

Historical delivery information is only available for the UC Field Station. Therefore, delivery for the other three water users, namely, Selby Ranch, Selby Ranch Pond, and Able are estimated. During the period from 1987 – 1989, the UC field Station took the entire flow of the Upper Main at its Scott takeout above Abel's delivery point. Therefore, Able received no water during this period. For the water budget calculation, the 2 miner's inches delivered to Selby Ranch Pond is assumed to be at the maximum possible (2 miner's inches). This results in a conservative estimate of system losses. Selby Ranch water deliveries are estimated based on deliveries to the UC Field Station. Recorded water deliveries to the UC Field Station and estimated deliveries to the Selby Ranch are presented in Appendix A. No deliveries were made at Campbell's Divide during the 1987 – 1989 period.

There was a high degree of coordination between the UC Field Station and the Selby Ranch. They worked cooperatively to share the available water supply on an equitable basis. Due to this cooperation, it is reasonable to assume that the deliveries to the Selby Ranch can be estimated based on deliveries to the UC Field Station. The maximum delivery capacity of the UC Field station is about 60 miner's inches, while the maximum delivery for the Selby Ranch is about 40 miner's inches. Historical deliveries to the Selby Ranch are estimated by multiplying the UC deliveries by 40/60 or 2/3.

The following Tables (Table 1A, 1B, 1C, and 1D) present the water budget for the Upper Main for 1987 – 1989. Table 1A contains monthly diversions at NY10 in acre feet. Table 1B contains the sum of water deliveries at the Upper Main. Tables 1C and 1D contain losses and percent of the diversion at NY10 that was lost, respectively. The average annual loss was about 3,100 acre feet, which is about 84% of the water diverted at NY10. Loss of this magnitude is typical for Gold Rush era (late 1800s) canals in the Sierra Nevada foothills.

BVID Upper Main Canal
Loss Calculations

Table 1A
NY10 Diversion - Flow at Head of BVID Upper Main
Acre Feet

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1987				359	778	504	612	615	251	270			3387
1988			38	406	804	400	850	570	900	300			4268
1989				194	615	575	545	587	536	420			3472
Average			38	320	732	493	669	591	562	330			3734

Table 1B
BVID Deliveries from Upper Main
Acre Feet

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1987				21	97	93	61	123	94				489
1988					75	120	126	120	95	72			608
1989				6	111	114	108	162	135	44			679
Average				13	94	109	98	135	108	58			616

Table 1C
Estimated Losses from BVID Upper Main
Acre Feet

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1987				338	681	410	551	492	156	270			2898
1988			38	406	729	280	725	450	805	228			3660
1989				189	504	461	437	425	401	376			2793
Average			38	306	638	384	571	455	454	272			3118

Table 1D
Estimated Percent Loss from BVID Upper Main

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1987				94%	88%	81%	90%	80%	62%	100%			86%
1988			100%	100%	91%	70%	85%	79%	89%	76%			86%
1989				97%	82%	80%	80%	72%	75%	90%			80%
Average			100%	96%	87%	78%	85%	77%	81%	82%			84%

Losses between Campbell's Divide and Scott Weir

In addition to performing a water budget for the entire Upper Main, a water budget was performed for the Upper Main reach from Campbell's Divide Weir to the Scott Weir. There were many days when UC Field Station personnel recorded flow at Campbell's Divide as well as the Scott Weir and takeout. Appendix B contains these flow records and loss calculations for the days when data are available. Losses for this reach of the Upper Main are calculated based on the following equation:

+ Upper Main flow at Campbell's Divide
- Deliveries to UC Field Station at Scott' Takeout (entire Upper Main flow)
- Delivery of 2 miner's inches to Selby Ranch Pond

Using available daily data for this period, average monthly percent loss (Table 2A), loss rate in cfs (Table 2B), estimated losses in acre feet per month (Table 2C), and the percent of total Upper Main loss occurring in this reach (Table 2D) have been determined. Approximately 40% of the water flowing past Campbell's Divide was lost by the time it reached the Scott Weir and takeout for the UC Field Station. The losses occurring in this reach of the Upper Main represent about 12% of the total canal loss. This reach of the Upper Main also represents about 13% (Table 2E) of the total length of the Upper Main from NY10 to Sicard Flat ditch. The fact that about 12% of the total loss occurs over about 13% of the ditch is an indicator that losses from the Upper Main were somewhat uniform throughout the length of the Upper Main.

Because the Upper Main has consistent characteristics throughout its length, similar loss calculations were to be expected. Therefore, the calculations made for the Campbell's Divide and Scott Weir reach support the assumptions made for the calculations of the entire Upper Main.

Campbell's Divide to Scott Weir
Loss Calculations

Table 2A - Campbell's Divide to Scott Weir
Average Monthly Percent Loss Using Available Data

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1987					46%	37%	42%	42%	28%				39%
1988					60%	40%	47%						49%
1989					50%								50%
Average					52%	39%	44%	42%	28%				41%

Table 2B - Campbell's Divide to Scott Weir
Average Loss Rate (cfs)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987					0.9	0.6	0.5	0.8	0.5			
1988					1.1	0.8	1.1					
1989					1.2							
Average					1.1	0.7	0.8	0.8	0.5			

Table 2C - Campbell's Divide to Scott Weir
Monthly Loss (acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1987					54.5	36.5	31.0	46.9	26.8				195.6
1988					70.3	48.8	64.8						183.9
1989					73.8								73.8
Average					66.2	42.6	47.9	46.9	26.8				230.4

Table 2D - Campbell's Divide to Scott Weir
Percent of Total Main Canal Loss

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1987					8%	9%	6%	10%	17%				10%
1988					10%	17%	9%						12%
1989					15%								15%
Average					11%	13%	7%	10%	17%				12%

Table 2E
Fraction of Total Upper Main Length Represented by Each Reach
(Campbell's to Scott)

	Length (Miles)	Percent of Total Length
NY10 to Campbell's	16.5	81%
Campbell's to Scott	2.68	**13%**
Scott to Sicard Flat Ditch	1.19	6%
Total Length	20.4	

DESCRIPTION OF UPPER MAIN LOSSES

Upper Main losses were calculated from the water budget previously described. The ultimate destination of the calculated Upper Main losses can be determined by estimating consumptive use by vegetation in the vicinity of the Upper Main, infiltration to the groundwater system, surface water returning to the Yuba River system, and evaporation.

Infiltration of Upper Main losses into the groundwater system is estimated using information in the *Soil Survey of Yuba County, California* report by the Natural Resources Conservation Service (NRCS). This is an extensive soil survey of Yuba County and was conducted by digging many holes throughout Yuba County. This report contains data on depth to bedrock, surface slope, and soil permeability. Appendix F contains soil maps in the vicinity of the Upper Main showing depth to bedrock and slope of the soil surface. Based on the soil survey, the average depth to bedrock or an impermeable layer in the vicinity of the Upper Main is generally less than 3 feet with relatively steep surface slopes. There is no groundwater aquifer in this region, and water entering the soil profile remains relatively close to the land surface.

Figure 3 is a characterization of the condition that existed when the Upper Main was in operation. Water would percolate into the ground from the Upper Main. Once water entered the ground, it was immediately available for use by grasses, trees, and shrubs along the Upper Main. Water could flow down steep hillsides below the soil surface and above the bedrock or impermeable layer. As water flowed through the ground, it was available to grasses, trees, and shrubs downhill from the Upper Main. In many places, the depth to groundwater was small enough that grass roots had access to losses. In most cases, only roots from shrubs and trees could reach water. There is evidence in the photographs discussed later in this report that groundwater did raise close enough to the surface on downhill slopes for grasses and shrubs to grow. The presence of growing grasses downhill from the Upper Main demonstrates that losses from the Upper Main remain close to the soil surface.

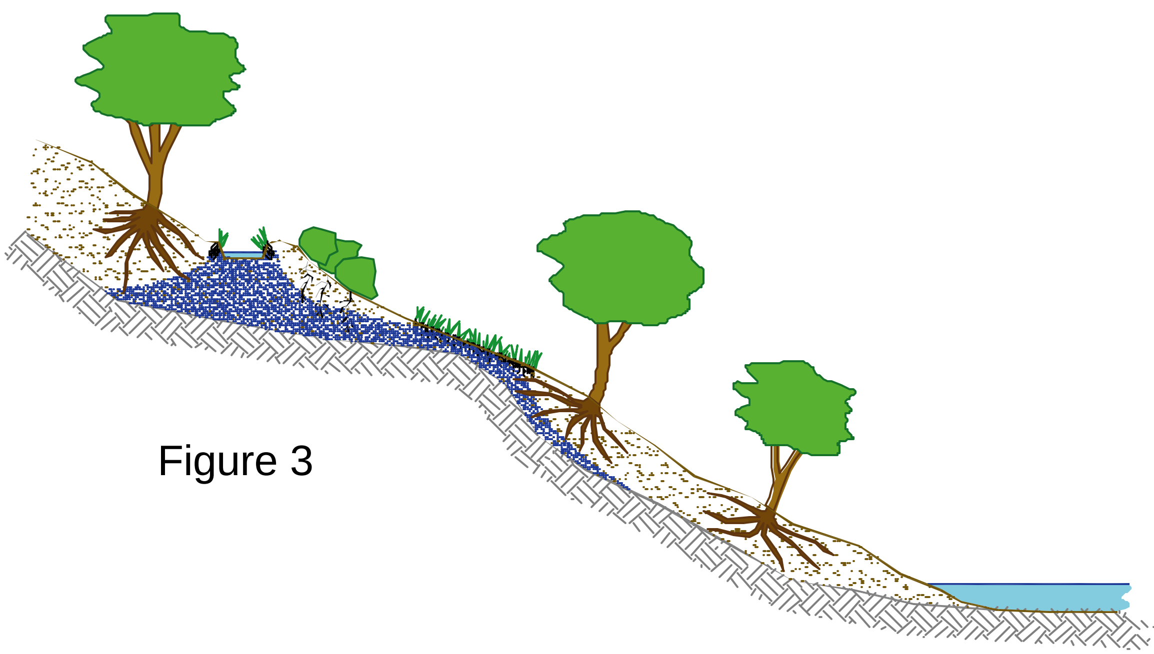

Figure 3

Based on permeability data from the NRCS report and soil surface slopes seepage velocities of losses from the Upper Main are estimated. Appendix F contains a table displaying permeability and slope ranges for each soil type in the vicinity of the Upper Main. Based on soil permeability, slope, and distance from the Yuba River (displayed in Figure 2), losses from the Upper Main would take years to travel through the soil to reach the Yuba River. Although this estimate is based on data with a wide range of variability, it is clear that water would be traveling slowly enough to be accessible to vegetation on downhill slopes from the Upper Main.

Historical Photographs

Upper Main losses supported a great deal of vegetative growth along and some distance away from the Upper Main. During the summer of 1984, the UC Field Station documented these ditch losses and vegetative growth with a series of photographs. Appendix C contains nine of the photographs (Photographs 1-9) taken by UC Field Station personnel along with descriptions of each photograph. The photographs clearly demonstrate the Upper Main losses and the consumptive use of these losses.

Recent Historical Photographs

MBK Engineers' staff conducted a field investigation of the Upper Main during July 2000. At the time of the MBK field investigation, the Upper Main had been out of operation for about 11 years. MBK documented this field investigation of the Upper Main with photographs. Four of these photographs are included in Appendix C (Photographs 10-13). The MBK photographs demonstrate a lack of vegetative growth when compared to the photographs taken by the UC Field Station in 1984 at the same locations.

Aerial Photographs

Comparing aerial photographs taken before and after operation of the Upper Main can provide insight on the magnitude of vegetative growth that relied on the losses that occurred along the Upper Main. Aerial photographs taken in 1984 are compared to aerial photographs taken in 1995 and 1996 to determine the area of vegetative growth that was consumptively using water from the Upper Main. Appendix D contains aerial photographs of the Upper Main from Campbell's Divide to the Scott Weir for 1984 and 1995. The photographs taken in 1984 show more vegetative growth along the Upper Main than the photographs taken after the operation ceased. Although the 1995 photographs show that there are still many oak trees in the area, oak trees can survive on seasonal rainfall. Oak trees will have high ET rates when they have access to water, and can have very low ET rates when there is minimal water available. In very dry conditions, oak trees will essentially shut down and possibly lose some of their leaves, resulting in very low ET rates (Griffin, 1973 Ecology, *Xylem Sap Tension in Three Woodland Oaks of Central California*).

ESTIMATE OF CONSUMPTIVE LOSSES

Losses estimated using the water budget analysis are supported by an analysis based on consumptive use in the vicinity of the Upper Main. Consumptive losses occurred through evaporation from the Upper Main surface, evaporation from wetted soils near the Upper Main, and evapotranspiration from vegetative growth near the Upper Main. Losses are estimated for evaporation and vegetative consumptive use. Although evaporation from wetted soil is documented (Appendix C, Photograph 6), the actual surface area for wetted soil is not possible to determine. Therefore, losses from wetted soils have not been calculated. In addition, the decrease in consumptive use of precipitation was not accounted for resulting in a conservative estimate of consumptive use savings.

Evaporation

Evaporation from the Upper Main was estimated by taking the entire length of the Upper Main and multiplying by its average width to calculate surface area. Surface area was then multiplied by the average annual evaporation rate to determine total evaporation. Average annual evaporation was determined by evaporation data recorded by the UC Field Station. Three feet of evaporation for the April through September period is several inches less than indicated from the UC Field Station. Therefore, this produces a conservative estimate of evaporation loss. Appendix E contains monthly evaporation data, and Table 3 contains the calculation for evaporative loss.

Table 3 Upper Main Evaporation Estimate

Length of Upper Main	20	Miles
Length of Upper Main	105600	Feet
Average width	10	Feet
Total surface area	1056000	square feet
Total surface area	24.2	Acres
Annual evaporation (April – September)	3	Feet
Loss to evaporation	72.7	Acre feet

Vegetative Consumptive Use

Consumptive use of water loss from the Upper Main was calculated by determining the type and acreage of growth that was supported by water from the Upper Main. The area of each type of vegetation was multiplied by the appropriate evapotranspiration rate to determine the volume of loss.

Area of Vegetative Growth

Area of vegetative growth was determined in AutoCAD, and the data are derived from aerial photographs. Aerial photographs of the entire Upper Main were analyzed to determine area and growth type. Appendix D contains two photographs that were used for this purpose. Polygons were drawn around areas of similar vegetation type and percent coverage. Attribute values were assigned to these polygons that represent the vegetation type and percent coverage. Attribute values for polygons are described in Appendix D. These data were collected for 1984, when the Upper Main was in service, and for 1995 and 1996, after the Upper Main was out of service.

In order to digitize the vegetation boundaries into AutoCAD, aerial photographs were overlaid on USGS maps. Color 35-mm aerial photograph slides were obtained from the California Department of Water Resources, Central District, and were scanned by MBK. These slides were made in 1984 and 1995 for DWR's land use surveys of Yuba County. Also, black-and-white 9"x9" aerial photographs were obtained from WAC Corporation in Eugene, Oregon, which were also scanned by MBK. Complete coverage of the study area was available for 1984 and 1996. Both the color slides and the black-and-white prints were of sufficient resolution to clearly show roads, the Upper Main, and individual trees. Both sets of photographs were used together and cross-referenced when necessary.

Before the vegetation boundaries were to be digitized, the photographs had to be properly referenced into a real geographic coordinate system. A base map of scanned, geo-referenced USGS 7.5-minute quadrangle maps was created in AutoCAD. The aerial photographs were then scaled, moved, and rotated to fit corresponding geographic features on the quad map, to a relative accuracy of +/-50 feet. After the photographs were properly referenced, vegetation boundaries could be digitized.

The vegetation boundaries were drawn to a relative accuracy of +/- 50 feet. The degree of accuracy varied according to how well defined the changes in vegetation were. Boundaries were drawn around vegetation that fit any of the following criteria:

a) Areas within a horizontal distance of 75 feet on the uphill side and 100 feet on the downhill side of the Upper Main.
b) Lush, green areas (ravines, meadows, etc.) obviously fed by leaks from the Upper Main.
c) Larger areas downhill from the Upper Main that were watered by seepage.

Much of the area of vegetative growth along the Upper Main was easily identified. It is difficult to estimate how far water traveled downhill from the Upper Main through the shallow soil profile to oak trees below. Oak tree roots can extend more than 80 feet below the surface (Lewis and Burgy, 1964 Journal of Geophysical Research, *The Relationship between Oak Tree Roots and Groundwater in Fractured Rock As Determined by Tritium Tracing*) and stretch over a wide area. The area around the Upper Main is very steep, with land slopes ranging from 10% to 50%. The soils are underlaid by rock, which prevent water from seeping deep into the ground. Given the steep slopes and geology of the area, water that has seeped into the ground could stay relatively close to the surface and be accessible to oak trees for some distance away from the Upper Main. The distance from the Upper Main that water could seep is dependent on the quantity and rate of use by vegetation downhill from the Upper Main. A conservative estimate was made when determining the area where subsurface flow was available to oak trees, this may result in an underestimation of consumptive use losses.

After the boundaries were digitized, the percentage of coverage of the vegetation type in each polygon was visually estimated and assigned to that polygon along with the vegetation type.

Digitized information was entered into ArcView for analysis. The integrity of the line work was checked as well as the existence of attribute labels within each polygon. The coverage percentages were then factored into the gross acreages for each polygon to yield the net acreage of vegetation. The polygons were then summarized, meaning the net acreages of each polygon of each unique vegetation type were added up. This resulted in a table of total net acreage values of each unique vegetation type in the study area.

Evapotranspiration (ET) Rates

Reference ET (ETo) and crop coefficients were used to estimate ET for vegetative growth along the Upper Main. The UC Field Station has a CIMIS station where it calculates and records ETo. CIMIS uses grass as the reference crop and a version of the Penman equation for determining ETo.   ETo is used with crop coefficients and methods contained in the *Cooperative Extension*

University of California Division of Agriculture and Natural Resources Leaflet 21428 to determine ET for vegetative growth along the Upper Main. There is little or no documentation on the ET rates or crop coefficients for oak trees. For the purpose of this analysis the crop coefficient for almond trees was used. This may be a conservative estimate because oak trees have a much larger canopy and therefore, more leaf surface area than almond trees potentially resulting in a greater ET rate.

To determine ET of the vegetative growth along the Upper Main, ETo was multiplied by a crop coefficient to determine the water use for each vegetation category. Once ET for the vegetation category was determined, available precipitation was used to satisfy the ET. The remaining ET is the amount of water used by vegetation without precipitation. Appendix E contains ETo, precipitation, and calculation of ET used to determine consumptive use.

After the operation of the Upper Main ceased, many trees, shrubs and grasses died. Since these plants and trees are no longer growing, not only has water been made available from lack of consumption of Upper Main loss, but there has been increased precipitation runoff. The water savings due to an increase in precipitation runoff can be significant, but have not been estimated in this report.

Consumptive Use Summary

Table 4 summarizes the total area of vegetative growth, effective ET rates, and consumptive use from vegetative growth along the Upper Main for the April through October period.

Table 4 Consumptive Use Summary

Type	Total Area (Acres)	Area with Growth (Acres)	Effective ETc (Acre-Feet per Acre)	Use (Acre Feet)
Oaks with cover crop, well watered	373	335	4.3	1437
Oaks without cover crop, well watered	494	345	3.3	1138
Trees with cover crop, well watered	17	15	4.0	62
Trees without cover crop, well watered	0	0	3.1	1
Tall grass and willows, well watered	7	6	3.1	19
Grasses, well watered	17	15	3.1	47
Low growth, unknown type	10	9	3.1	27
Total	918	726		**2731**

CONCLUSION

Based on the water budget calculation, there was approximately 3,100 acre feet of water lost annually from the Upper Main. This loss calculation is supported by estimates of consumptive use losses of 2,800 acre-feet annually (vegetative use plus evaporation). The water budget performed on the Upper Main is based on accurate and reliable flow measurements while supporting calculations of consumptive use are based on information that has a lower degree of accuracy. Variations in ET rates and the ability to estimate area of vegetative growth could significantly alter results therefore, conservative estimates of vegetative area were used in this report. Since there is no evidence that any water lost from the Upper Main reentered the water system, and that the water budget is a much more accurate estimation of losses, the consumptive losses are estimated to be 3,100 acre feet annually.