Santa Rosa Subregional Long-Term Wastewater Project

BASELINE HYDROLOGY AND IRRIGATION DRAINAGE EVALUATION FOR WEST AND SOUTH COUNTY RECLAMATION ALTERNATIVES

SANTA ROSA SUBREGIONAL LONG-TERM WASTEWATER PROJECT

Prepared for

City of Santa Rosa
and
U.S. Army Corps of Engineers

FEBRUARY 1996

Prepared by

QUESTA ENGINEERING CORPORATION
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For

HARLAND BARTHOLOMEW & ASSOCIATES, INC.

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1 INTRODUCTION

1.1 PURPOSE AND OBJECTIVE

The West County and South County Reclamation Alternatives under study by the City of Santa Rosa have the potential to affect local hydrology in the areas receiving the irrigation water. In particular, questions have been raised in the past and during the scoping phase of the present studies regarding possible changes in base streamflow due to the drainage of excess irrigation waters from farm fields. Such drainage waters (also termed "irrigation return flow") may increase the summer flow of freshwater into the West County Esteros, and may also carry salts, nutrients, metals and pesticides into the local streams from the areas irrigated with reclaimed water. The increased flow can arise from inadvertent surface runoff or as subsurface flow intercepted by stream channels. Irrigation return flow also can serve to replenish soil moisture in stream side areas, thereby enhancing the growth of riparian vegetation.

This technical memorandum presents an analysis of the existing hydrology of the major streams and watersheds in the West and South County project areas, along with an assessment of potential changes in hydrology associated with the imported/reclaimed irrigation water. The specific focus of the hydrological study was on runoff or streamflow conditions, and was analyzed on the basis of monthly averages for existing baseline conditions for normal, dry and wet rainfall years, and for various irrigation and climatic scenarios that may result from a reclamation project. Specifically, the objective of the study was to determine the likely changes in total watershed runoff and seasonal stream discharges that can be anticipated when potentially large land areas in the West and South County areas are brought under irrigation. The results of this study are intended to provide the basis for the environmental impact analysis in regard to the potential irrigation drainage effects of the West and South County Reclamation Alternatives. The environmental significance of the hydrologic changes identified in this study will be assessed as part of the EIR. An evaluation of salts, nutrients, metals and pesticides is presented in separate but related technical memoranda.

1.2 SCOPE AND METHODOLOGY

The scope of the hydrology investigation was limited to an analysis of selected key watersheds in the West and South County project areas; it did not cover every stream reach where irrigation may occur. A general analysis first was made of the major watershed areas where irrigation is planned in order to determine the likelihood of summer baseflow impacts occurring. The watersheds selected for detailed analysis were those considered most representative of typical conditions where irrigation with reclaimed water is planned, where concerns over hydrologic impacts have been raised, and where the general analysis indicates the greatest chance for irrigation drainage effects on streamflow. The detailed watershed analysis included Stemple Creek and Americano Creek in the West County and Tolay Creek in the South County. Other South County watersheds evaluated at a general level included Copeland Creek, Lichau Creek, Willow Brook and the Upper Petaluma River area.

The following flow impact criteria were used in qualitatively evaluating hydrologic (flow) impacts on creeks and determining the need to perform further quantitative assessments.

Negligible: Not observable/measurable in field; expected summer flow increase of less than 0.1 cfs.

Very Slight: Observable/measurable in field with great difficulty; expected summer flow increase of 0.1 to 0.9 cfs.

Slight: Observable/measurable with care in field, but still less than one inch of water in summer; expected summer flow increase of 1.0 to 1.9 cfs.

Moderate: Readily observable/measurable in field; flow 1 to 4 inches of water; expected summer flow increase of 2.0 to 3.9 cfs.

Severe: Easily observable/measurable in field, flow greater than 4 inches of water; expected summer flow increase of more than 4.0 cfs.

The results of the qualitative analysis are summarized in Table 1 below:

Table 1

Qualitative Watershed Analysis

	Effect Quantified	Rationale for Not Quantifying	Expected Flow Impact *
West County			
Americano Creek	Yes		V. slight
Stemple Creek	Yes		V. slight
Sebastapol			
Blucher Creek	No	Irrigation acreage small part of watershed	Negligible
Green Valley	No	Irrigation area small part of watershed and soils/hydrology not susceptible to subflow phenomena.	Negligible
Atascadero Creek	No	Irrigation area small part of watershed and soils/hydrology not susceptible to subflow phenomena.	Negligible
South County East of Rohnert Park			
Crane Creek	No	Irrigation small part of watershed. Spring-fed headwaters become loosing streams in irrigation area. Irrigation area primarily lowlands without restrictive layers.	Negligible
Copeland Creek	No	Same as above.	Negligible
Hinebaugh Creek	No	Same as above.	Negligible
Penngrove-Upper Petaluma River			
Lichau Creek	No	Same as above.	Negligible
Willow Brook	No	Same as above.	Negligible
Corona Creek	No	Irrigation small part of watershed. Creek is very ephemeral/flashy	Negligible
Lower Petaluma River			
Stage Gulch Creek	No	Irrigation small part of watershed. Creek is very ephemeral/flashy	Negligible
Wheat Creek	No	Irrigation small part of watershed. Creek is very ephemeral/flashy	Negligible
Oak Creek	No	Irrigation small part of watershed. Creek is very ephemeral/flashy	Negligible
Tolay Creek	Yes		Negligible

The specific work completed for the hydrology study included:

1. Compilation, review and analysis of available streamflow and climatic data for the West and South County project areas;

2. Review and mapping of soils, geology, vegetation and land use conditions in the specific watersheds selected for analysis;

3. Field reconnaissance survey and spot measurements of summer streamflow conditions in June 1995;

4. Review of prior hydrologic studies of the streams and watersheds included in the study;

5. Development of a water balance model for estimation of monthly discharges for existing conditions and for projection of changes associated with the reclamation alternatives; and,

6. Performance of model runs for dry, normal and wet year scenarios.

The key tool used in the detailed analysis to estimate stream flows and assess potential irrigation return flow impacts was a water balance analysis, also referred to as an inflow-outflow or root zone model. This approach is essentially a water accounting procedure, which takes into account all significant water inputs (i.e., rainfall, irrigation) and outflow components (i.e., runoff, evapotranspiration, groundwater recharge). It sequentially tracks these water volumes from month to month through the system (i.e., the watershed). This approach was chosen because it allows the estimation of runoff volumes on a monthly basis for any given climatic (i.e., rainfall, evapotranspiration) condition, and also can be used to estimate hydrologic responses from changes in land use or the introduction of additional water sources, namely irrigation.

Alternative approaches to developing streamflow estimates that were considered but not utilized for this study include:

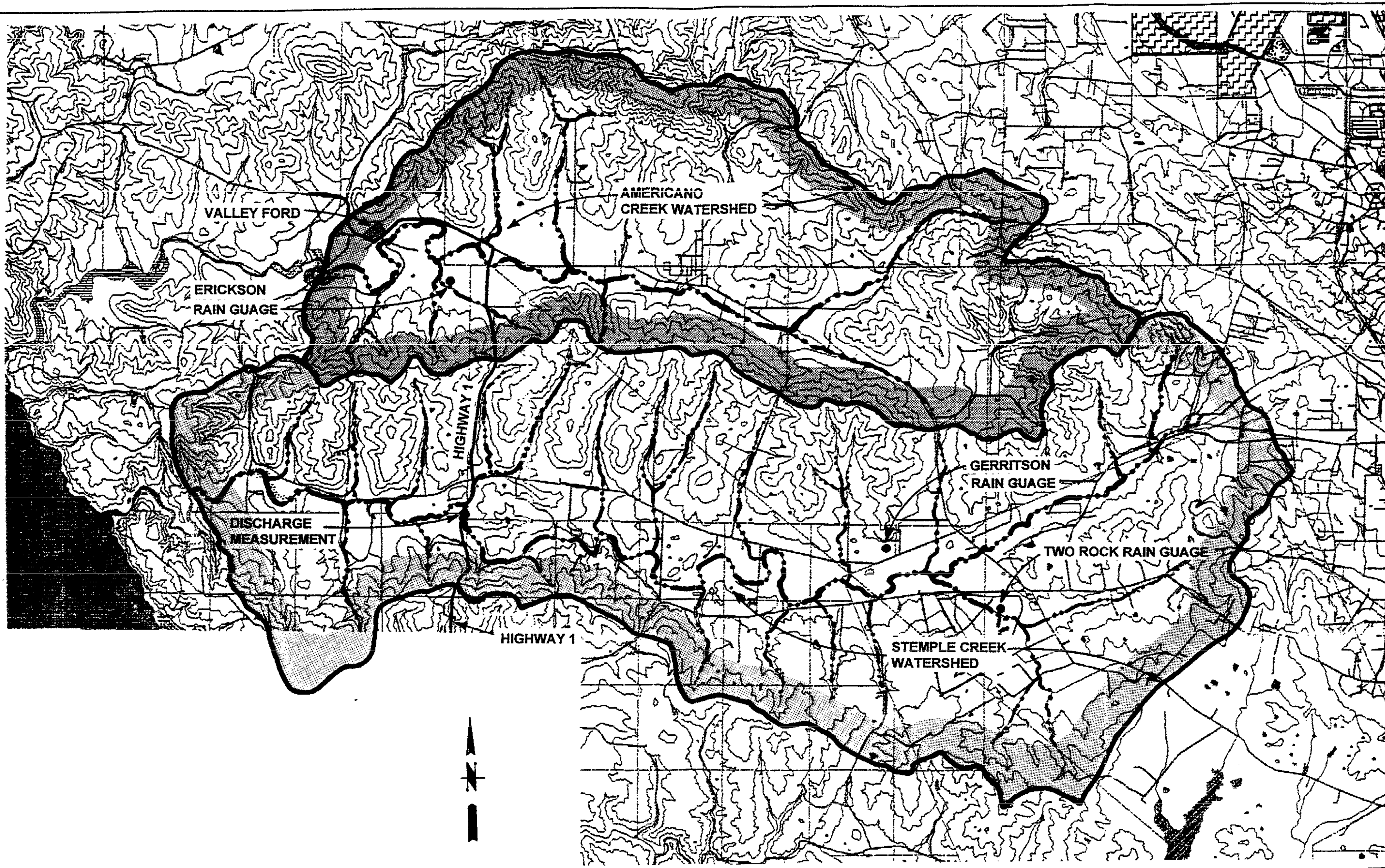
1. Streamflow gauging over several years to establish "flow duration-frequency" curves;

2. Extrapolation and statistical application of streamflow data for similar nearby watersheds (a regression analysis); and,

3. Application of available watershed runoff models (e.g., U.S. Army Corps of Engineers' HEC-1).

These alternative approaches were not utilized for a variety of reasons. Streamflow records are not available for watersheds in the West and South County areas; and, it was not considered feasible or appropriate to undertake a multi-year streamflow program for the purposes of this study. A comparative study of flows for a nearby watershed (Salmon Creek) was completed by Dearth, et al. (1988), in connection with the prior studies of the West County Alternative. This analysis yielded good results for projection of winter runoff flows; but, due to significant watershed differences, the model poorly predicted summer base flows, which are important for the study of the West and South County Reclamation Alternatives.

Watershed runoff models also are ill-equipped to yield reliable estimates of base flow during non-rainfall periods. Finally, all of these other possible hydrologic methods lack the ability to consider the effect of irrigation practices and return flow, which is of paramount interest for the Santa Rosa reclaimed water study. The water balance methodology was determined to be best suited for the needs of this study and consistent with other traditional means of examining chemical and salt loading water quality changes and groundwater effects associated with irrigation (and wastewater) applications to land. However, the run-off regression results developed by Dearth were partially used to verify and calibrate our water balance model.



SCALE: 1" = 6000'

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Point Richmond, California

SANTA ROSA PROJECT
WEST COUNTY WATERSHEDS

Figure
1

2 GENERAL WATERSHED CHARACTERISTICS

2.1 OVERVIEW

The West County Reclamation Alternative would bring lands into irrigation that are concentrated within two major watersheds -- Americano Creek and Stemple Creek. These two watersheds border each other and are quite similar in topography, soils, geology, land use and climate. In contrast, the South County Reclamation Alternative includes potential irrigation areas spread over many smaller watersheds of diverse characteristics. The main South County watershed areas affected by the reclamation activities include: a) Tolay Creek; b) the Baylands areas bordering the Petaluma River and San Pablo Bay; c) tributaries to the Upper Petaluma River including Willow Brook, Lichau Creek and Denman Flat; and, d) tributaries to the Laguna de Santa Rosa such as Copeland and Crane Creeks.

A list of the main watershed areas, and the relative amount of land that may be irrigated in the West and South County Reclamation Alternatives, is provided below:

Watershed	Watershed Area (Acres)	Potential Maximum Irrigated Area (Acres)	% Irrigation
West County			
Americano Creek at Valley Ford	14,175	5,470	39
Stemple Creek at Highway 1	26,570	6,200	23
South County			
Copeland Creek at Petaluma Hill Road	4,688	132	3
Petaluma River at Lynch Creek	26,112	2,175	8
Tolay Creek	6,980	1,540	22

As indicated by the above, Tolay, Americano and Stemple Creeks will have the greatest proportion of watershed area affected by irrigation. Accordingly, these watersheds are described and analyzed in this section (and in the remainder of this report), and are the major focus of this hydrologic-irrigation drainage study. The other South County watersheds are described and reviewed independently and in less detail within this section.

2.2 AMERICANO, STEMPLE AND TOLAY CREEK WATERSHEDS

These three watersheds are characterized by moderate to steep hills with fairly broad flat bottom valleys (Figures 1 and 2). Topography ranges within the watersheds from mean tide level to 650 feet NGVD. The drainage area for Americano Creek near Valley Ford is approximately 14,200 acres, or 22.2 square miles. The watershed area for Stemple Creek at Highway 1 is about 26,600 acres, or 41.5 square miles. The watershed area for Tolay Creek at Highway 121 is roughly 7,000 acres, or 10.9 square miles.

The lower sections of Americano and Stemple Creeks are tidally influenced lagoons. Tidal inundation of the lower lagoons are dependent upon the channel and beach depositional dynamics of the creek mouths. The mouths Stemple and Americano Creeks are typical of California coastal stream estuaries. The system experiences dynamic changes from season to season. In the winter when stream flows are high, the river mouth is open to full tidal inundation as river water discharges to the ocean. The force of the streamflow perpetually keeps the mouth open from beach sand littoral sedimentation. As the spring progresses, flows in the river are reduced and it becomes increasingly difficult for the river to maintain a constant opening and connection to the ocean. The creek may break through during moderate to high rainfall events but soon beach sand will be deposited and the mouth can be closed as flows begin to diminish. By late spring/early summer the flows drop significantly and the river mouth may be closed by a large wind event during neap tides. When stream flows increase in the late fall, the beach sand barrier may be breached again. Throughout the summer, watershed outflow can be impounded, filling the river channel and raising the elevation of the lagoon. Salinities increase as the impounded water evaporates through the summer months. The results of these processes can be fresh to brackish conditions at low tide during the spring and hyper-saline conditions in the late summer and fall.

The Tolay Creek watershed is located just north of San Pablo Bay. The watershed is elongated in a north-south direction. The creek below Highway 121 meanders through fresh and brackish water wetlands prior to discharge into San Pablo Bay. The creek can be generally characterized as ephemeral California coastal. All three watersheds respond quickly to storm precipitation. Storm hydrographs tend to peak during storms and quickly recede as the storm passes. Baseflow remains small during the winter months and the creeks are usually dry or have very minor baseflow by early summer.

- **Climate**. The climate of western Sonoma and Marin Counties is characterized by moderate temperatures and precipitation. The lower portions of the Americano and Stemple Creek watersheds, nearest the ocean, remain cool throughout the summer and remain above freezing in the winter. However, just inland a few miles, temperatures can exceed 100 degrees in the summer and drop below freezing in the winter. Precipitation is concentrated in six months of the winter with only light amounts reported throughout the rest of the year. The average annual rainfall is 31.7 inches for Americano Creek and 29.4 inches for Stemple

Creek. Along the immediate coast line summer fog may provide enough moisture to keep pastures green. Inland, however, the summer dry period is long and hot enough that stored moisture in the soil is depleted and range lands dry up by late June or early July. The climatic conditions in the Tolay Creek area are similar to the West County, except that the area is influenced to a lesser degree by the coastal fog, and the average annual rainfall is substantially lower at about 24 inches.

- **Soil Hydrologic Properties**. Soil surveys have been completed for Sonoma and Marin Counties by the Natural Resources Conservation Service (NRCS). Numerous types of soils have been identified in the West County watersheds including the Novato, Pajaro, Blucher, Rincon, Diablo and Cole soils. Upland soils identified in the area include the Sobega, Los Osos, and Tomales series. The Tolay Creek watershed is dominated by Clear Lake clay and Rincon soils. These soils are described in greater detail in other technical memoranda. For irrigation management purposes and for estimating runoff relationships the NRCS has assigned hydrologic soil groups (HSGs) to the individual soil series found in the area. The hydrologic soil group classification is used to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting. The HSGs are one element used in computing the amount of rainfall runoff and hence infiltration of the different soils. The HSG also indicates the transmission rate - the rate at which the water moves within the soil. This rate may be highly variable depending on the local soil profile conditions. The hydrologic soil groups are divided into four categories: Group A soils have low runoff potential and high infiltration rates (0.30 in/hr); Group B soils have moderate runoff potential and infiltration rates (0.15-0.30 in/hr); Group C soils are usually moderately fine to fine textured soils that have low infiltration rates (0.05-0.15 in/hr); and, Group D soils have high runoff potential and very low infiltration rates (0-0.05 in/hr). The soils in both Stemple and Americano creek drainages are predominately type C soils with small areas of the B and D soils. The soils in the Tolay Creek watershed are rated mainly as C and D soils.
- **Land Use and Vegetation Characteristics**. The watersheds in the West and South County study areas are predominately open space range land. Some dry farming of oat hay and other type of crops occurs in the valley bottoms but the predominate land usage on a watershed-wide perspective is range land for cattle. The vegetation type is wild oat grass, an exotic annual grass brought to California in the early 1700s and 1800s by the Spanish to improve the range land. There are some isolated areas of native California coastal scrub in the Americano and Stemple Creek watersheds.

- **Groundwater Resources**. Groundwater interaction can be very important to the maintenance of base streamflow in the dry season. Little data are available on the groundwater within the Stemple, Americano and Tolay Creek watersheds. Groundwater resources are generally known to be sparse, due to the geologic condition of the areas. There is little or no irrigation occurring in the Stemple, Americano or Tolay Creek drainages indicating that the aquifers in the area are small and likely cannot sustain agricultural irrigation pump rates. Wells in the area are usually shallow dug wells within the stream alluvium immediately adjacent to the drainages that provide minimum needs for domestic and nominal farm uses. The predominant aquifer is the Quaternary alluvium in the valley bottoms. Its water holding capacity and yield is dependent locally on the thickness and lateral extent of these water bearing facies.

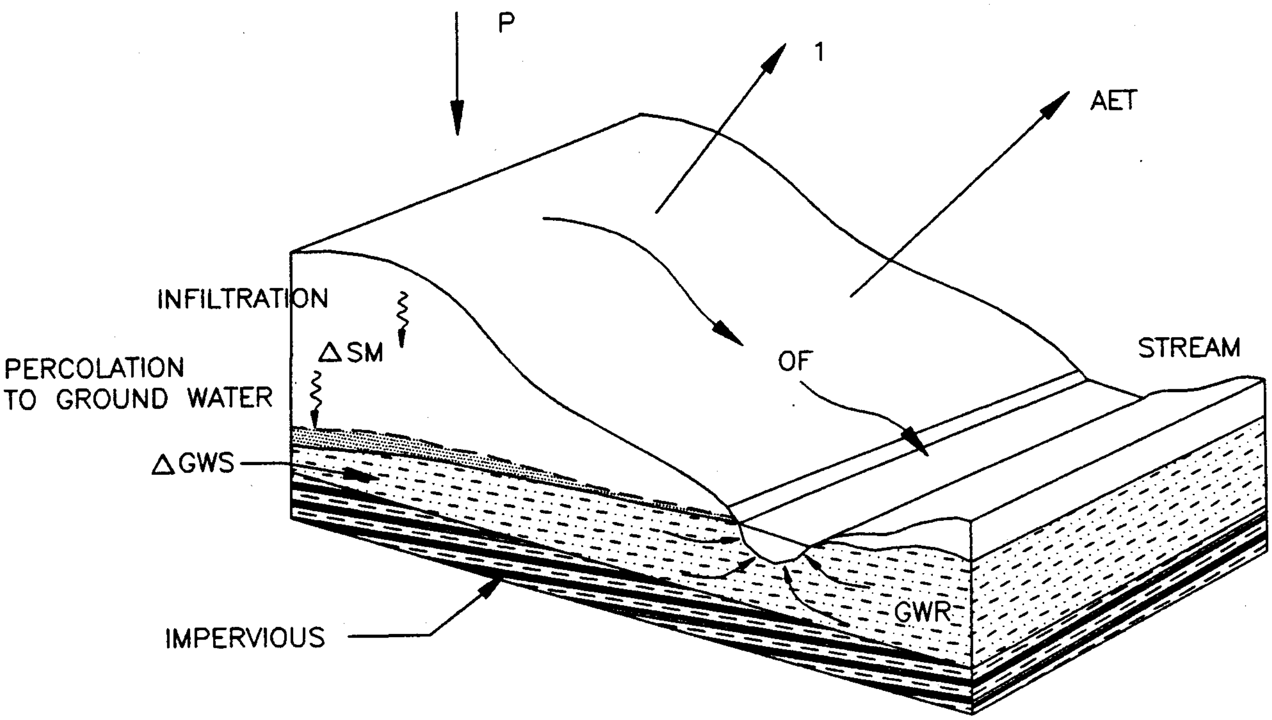
- **Groundwater Return Flow**. Because of the lack of large contributing groundwater aquifers, ground influences on streamflow are limited to seasonal discharges from perched and shallow groundwater zones. These local shallow aquifers function as seasonal reservoirs that slowly release any available water to the creek channels. Because of the presence of restrictive layers (clay pans or bedrock) within five or six feet of the surface in the West County and Tolay watersheds, most of the groundwater flow is throught to be preferential flow through the soil at the contact with these restrictive layers, or through animal burrows and localized, more permeable zones. As a result of these preferential flow paths, groundwater is discharged more rapidly to the adjacent streamways than would occur from a system dominated by inter-pore flow following Darcy's Law. Groundwater levels in the near surface vary considerably from winter to summer. In the winter groundwater levels raise with the addition of infiltrating rainfall, and discharge throughout the winter. As the rainy season subsides groundwater continues to flow laterally and discharge into the stream channel. Eventually, the groundwater levels decline and outflow diminishes. By late spring/early summer, groundwater elevations drop below the stream bottom and stream baseflow largely stops. Flows may be limited to interground flow in the stream bed, emerging here and there in pools. In the summer, outflow within the basin is limited mainly to scattered springs and areas of standing water within the creek beds where the water table is intercepted by the channel. It is likely that the areas of standing summer time water in either Stemple, Americano or Tolay Creeks is caused by variations in the alluvium water holding capacity, base stream elevations, and localized water table variations.

- **Existing Water Use and Diversions within the Watershed**. Though the groundwater resources are not extensive they are used wherever possible to provide water for domestic and livestock use. There are numerous small diversions and stock ponds within each of the watersheds. Usually these ponds are located in the tributary valleys and trap small amounts of runoff that is later used for livestock watering or in dairy operations. There are some in-stream ponds in the valley bottom, but, these are small in size. There are also several areas within the watersheds that have natural springs or seeps. Many of these areas have been developed for water supply or livestock watering purposes. Because of the small amount of diversions in the watershed, these are not considered in the water balance model.

2.3 OTHER SOUTH COUNTY WATERSHEDS

As compared with Tolay Creek and the West County, the other watersheds in the South County will be affected to a lesser degree by the reclamation project. This is due to the relatively small amount of irrigated areas in any watershed, the tight management control over irrigation imposed by the Irrigation Management Plan and the inherent soil and hydrologic conditions which differ considerably from Tolay, Americano and Stemple Creeks. These differences are noted here and summarized in the Table 1 above.

- **Baylands**. The Bayland areas along the lower Petaluma River and San Pablo Bay do not drain and discharge naturally to local streams or the Bay. The baylands are intersected by a number of drainage ditches culminating at pump stations along the Petaluma River. These near-tidal areas require groundwater pumping to maintain the water table at a suitable depth. The addition of irrigation water may contribute to a rise in groundwater and increased pumping requirements in these areas. A separate technical memorandum discusses hydrologic and water quality issues associated with irrigation of Baylands.
- **Upper Petaluma River**. Potential irrigation areas in the Upper Petaluma River include Denman Flat, Willow Brook and Lichau Creek. All of these areas differ from the West County and Tolay Creek watersheds in that the soils are generally much deeper and lack the restrictive soil or bedrock zones that contribute to lateral flow from irrigation areas to drainage ways. In these areas, the addition of irrigation water may contribute to greater groundwater recharge and potentially a slight rise in the water table; but, the effect on base streamflow would be negligible and considerably less than for the watershed situations in the West County and Tolay Creek.
- **Crane Creek and Copeland Creek**. These Creeks are numerous tributaries to the Laguna de Santa Rosa where a small amount of irrigation may occur. Field measurements in June 1995 (see Appendix A) showed Copeland Creek to be a "losing" stream in the vicinity of the Petaluma Hill Road. This means that streamflow declines in the downstream direction due to the permeable alluvium. The surplus water that may infiltrate from irrigation lands can also be expected to percolate into the deeper groundwater, and not move laterally to affect streamflow. Crane Creek is expected to be similar.
- **Lower Petaluma River**. Several small, unnamed creeks drain the watershed lands alongside Lakeville Highway in the southern part of the project area. Irrigation would also typically constitute a small portion of these watersheds. The creeks discharge man made drainage ditches passing through the Baylands. The clayey soil conditions in these areas are also not conducive to the preferential groundwater flow paths of the West County and Tolay Creek areas.



$$P = I + AET + OF + \Delta SM + \Delta GWS + GWR$$

LEGEND

COMPONENTS OF THE WATER BALANCE ON A HILLSIDE OR A SMALL CATCHMENT:

- P = PRECIPITATION
- I = INTERCEPTION
- AET = ACTUAL EVAPOTRANSPIRATION
- OF = OVERLAND FLOW
- ΔSM = CHANGE IN SOIL MOISTURE
- ΔGWS = CHANGE IN GROUNDWATER STORAGE
- GWR = GROUNDWATER RUNOFF

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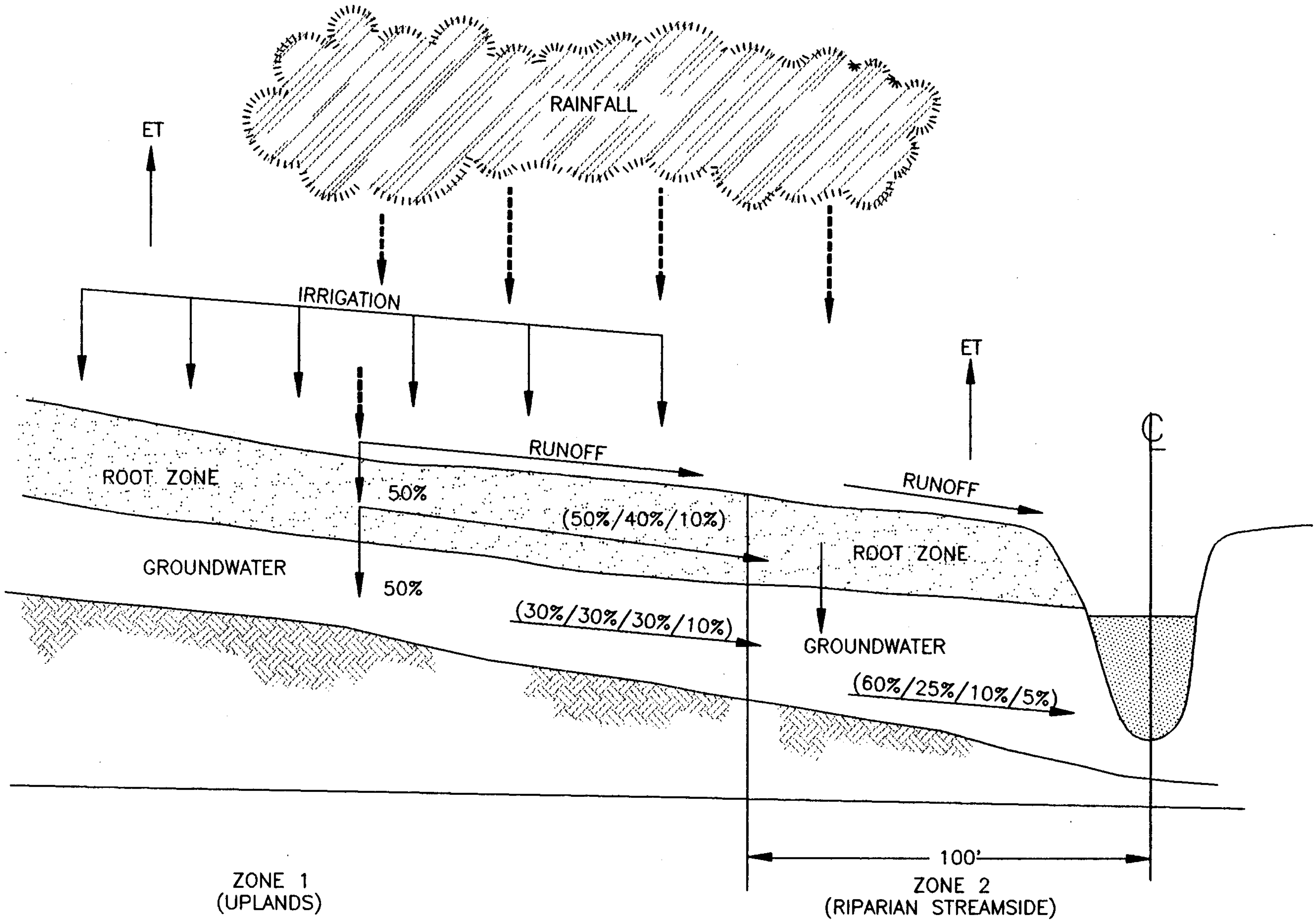
Questa Engineering Corporation Point Richmond, California	**SANTA ROSA WASTEWATER PROJECT** **WATER BALANCE SCHEMATIC**	Figure **3**



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SANTA ROSA WASTEWATER PROJECT
WATER BALANCE ROUTING SCHEDULE

Figure
4

3 WATER BALANCE - HYDROGRAPH ANALYSIS FOR EXISTING CONDITIONS

A water balance analysis was completed for selected watersheds in the West County and South County project areas to help understand the hydrology and to develop quantitative estimates of stream discharge under a variety of climatic and irrigation scenarios. The water balance is essentially an input-output model that accounts for all of the inflow to and outflow from a particular watershed area. The water balance can be constructed for the soil profile, an isolated farm field or for an entire drainage basin. It takes into account the rainfall-runoff relationships, groundwater recharge, agricultural irrigation and return flows, and evapotranspiration losses. This section describes the methodology and assumptions used to develop the water balance, followed by a presentation and discussion of the hydrographs developed for existing conditions in the West and South County areas. Section 4 of the report presents the predicted effects associated with irrigation.

3.1 METHODOLOGY AND ASSUMPTIONS

The water balance was constructed using monthly time steps. This is consistent with traditional water balance approaches, allows for convenient use of available monthly hydrologic data, and provides the best illustration of seasonal changes in streamflow. Peak discharges associated with individual large storm events are not addressed by the water balance; such flows, which occur in the winter months, are not of particular relevance in evaluating the West or South County Reclamation Alternatives.

A generalized schematic flow chart illustrating the various hydrologic parameters and their interrelationships is provided in Figure 3. A detailed schematic of the water balance developed for this study is shown in Figure 4. A fundamental aspect of the water balance is the assumed routing or partitioning of water in the watershed. The aim is to represent the physical processes as closely as possible, while still keeping the assumptions and data requirements sufficiently general or simplified so that the model and calculations remain manageable. Following is a description of the data, assumptions and calculations for each element of the water balance, along with the supporting rationale and general workings of the model.

- **Watershed Zones**. As indicated in Figure 4, the watershed was divided into two specific zones: 1) Zone 1 represents the upland areas, away from the streams, and includes all lands which may come under irrigation as well as other non-irrigated uplands; and 2) Zone 2 represents the stream corridor, assumed to be 200-feet (100 feet each side of the stream) wide and includes the stream channel and bordering riparian areas; no irrigation is assumed to take place in the Zone 2 stream corridor under existing or proposed project conditions.

- **Routing Assumptions**. Zones 1 and 2 both receive precipitation, generate runoff and are subject to losses of water due to evapotranspiration (i.e., plant uptake and evaporation from the soil surface) and due to percolation into the soil and shallow groundwater zone. Runoff from Zone 1 and Zone 2 is assumed to enter drainages directly and become streamflow during the same rainfall period (i.e., the monthly time step). Routing of water between Zone 1, Zone 2 and the stream shown in Figure 4 is as follows:

  a. Water that infiltrates in Zone 1 becomes a source of lateral inflow to Zone 2, partially as groundwater flow (50 percent), and partially as near-surface root zone flow (50 percent). The root zone flow is then treated as soil moisture replenishment in Zone 2, in the same manner as infiltrating rainfall or irrigation water. Groundwater flow from Zone 1 becomes groundwater in Zone 2.

  b. The root zone flow is assumed to move from Zone 1 to Zone 2 over a three-month period as follows: 50 percent in month one (the rainfall month); and 40 percent in month two and 10 percent in month three.

  c. The Zone 1 water reaching the groundwater is assumed to flow laterally into the Zone 2 groundwater over a four-month period as follows: 30 percent in month one (the rainfall month); 30 percent in month two; 30 percent in month three; and, 10 percent in month four.

  d. Infiltrating water in Zone 2 (plus lateral groundwater inflow from Zone 1) is assumed to discharge to the stream over a four-month period as follows: 60 percent in month one; 25 percent in month two; 10 percent in month three; and 5 percent in month four.

  The above described routing procedures and percentages were arrived at through general field observations, trial application of Darcey's Law for lateral saturated flow, calibration with the previous regressional analysis by Dearth, and comparison with spot flow measurements and summer observations as part of the model calibration process.

- **Rainfall**. Rainfall is the driving force in the hydrology and water balance. Average monthly rainfall was determined for each of the study areas based on available rainfall records from the following Sonoma County Water Agency stations: Two Rock, Erickson, Gerritson and Sears Point. The Two Rock station was used to represent Stemple Creek rainfall. The Erickson and Gerritson gauges were weighted equally to represent Americano Creek rainfall. The Sears Point station was used for Tolay Creek. The monthly rainfall averages for each of the watersheds are listed in Table 2. Individual rainfall data for the Sonma County Water Agency Stations are presented in Appendix B. The locations of the rainfall stations are shown in Figures 1 and 2.

"Average," "dry" and "wet" year rainfall conditions were used in the water balance analysis to examine the sensitivity of streamflow to climatic variations. Average rainfall was taken directly from the established monthly averages for the respective rain gauge station in each watershed. For the purposes of this analysis, "dry" and "wet" year rainfall was estimated on the basis of historical records for the lowest 30 percent and highest 30 percent rainfall totals, respectively. The monthly averages of the lowest 30 percent rainfall years was calculated. The same procedure was followed to establish annual and monthly rainfall for "wet" year conditions.

- **Runoff**. Rainfall runoff into creeks and local drainages can vary greatly depending on numerous factors such as rainfall amount, rainfall intensity, frequency, duration, antecedent soil moisture conditions, soil type, and condition of the soil-vegetation surface. In order to develop the general runoff relationships for the various watersheds, the curve number method was utilized. The curve number method was developed by the U.S. Department of Agriculture, Soil Conservation Service (now the Natural Resources Conservation Service, or NRCS) and was designed for analyzing agricultural and mixed land-used watersheds.

  A key term in connection with the NRCS method is the "Curve Number" (CN). The runoff curve number is a rainfall runoff rating set by the NRCS for use in determining the expected runoff rate from a watershed, based on surface conditions. The larger the curve number, the greater the percentage of runoff for a given rainfall event. The curve number for a particular site is based on vegetative cover, cropping technique, soil properties, and the amount of impervious surface area.

  In this study, the soils and associated hydrologic soil groups were evaluated for the selected watersheds and, from this, a composite CN value was established for: a) existing conditions; and, b) project (i.e., irrigated) conditions. The CN value was adjusted for irrigated conditions since the project would have the effect of decreasing the runoff rate (and the CN value) by virtue of the improved vegetative cover and overall hydrologic condition of the land. This is discussed further in Section 4 of this report.

  For existing conditions a CN value of 78 was used for Stemple Creek and Americano Creek (West County) and a CN value of 83 was used for Tolay Creek in the South County. The CN value for the West County watersheds was based on the NRCS guidelines for grazing lands, a predominant Hydrologic Soil Group rating of C, and "fair" watershed conditions. Also taken into account in selecting this CN value was the presence of some areas of Hydrologic Soil Group B, some undisturbed brush areas and some bottom land hay farming. For the Tolay Creek watershed, the CN value of 83 was selected on the basis of a weighted average of the percentage of Group C and Group D soils in the watershed, with the assumption that the lands are used for grazing and that the watershed is in “fair” condition.

Excerpts from NRCS guidelines pertaining to the selection of CN values are included in Appendix A at the end of this Technical Memorandum.

- **Evapotranspiration Losses**. Rainfall not lost to direct runoff, as well as applied irrigation water, is subject to loss by evapotranspiration. Evapotranspiration (ET) refers to the absorption and use of water by plants to respire and photosynthesize, as well as evaporation from the soil surface. This process is handled in the water balance as follows:

    A. **Rainfall > ET**. If the net rainfall (after adjusting for runoff losses) in a given month exceeds the potential ET of the vegetation or crop, then the excess rainfall is assumed to percolate into the root zone; here it replenishes soil moisture, until the soil moisture reaches field or water holding capacity; any excess water is assumed to percolate into the groundwater or leave as lateral root zone flow. The water holding capacity is assumed to be 4.2 inches.

    B. **Rainfall < ET**. If the net rainfall in a given month is less than the potential ET, then the assumption is made that all of the infiltrating rainfall is used by the vegetation (i.e., lost to ET) and that no water percolates to the water table or contributes to lateral root zone flow. Under these conditions water stored as soil moisture from the prior month is assumed to also be available to the vegetation for ET, and is reduced by an amount related to the ET deficit and the amount of soil moisture in storage. The equation used to calculate the depletion of soil moisture is not a straight-line relationship; rather, it takes into account the fact that as soil moisture diminishes, the ability of plants to draw water from the soil also declines. This is in contrast to water available to plants at the surface (i.e., from rainfall or irrigation) which goes immediately to ET on a one-to-one basis.

  The above described ET-soil moisture procedure is based directly on the methodology developed by C. Warren Thornwaite (1955). For non-irrigated conditions, it produces an estimation of the “actual ET” for a given set of climatic conditions. The actual ET will change from year to year in accordance with variations in the amount and distribution of rainfall.

  The “potential ET” used in the water balance model is the maximum amount of water evaporation and uptake from a vegetated field, assuming ample supply of water to the root zone (i.e., from rainfall or irrigation). Under non-irrigated conditions the potential ET is achieved (i.e., actual ET = potential ET) during wet months, usually through March or April. The actual ET is substantially less than potential ET for the drier months. This situation changes with the application of irrigation water, when sufficient water is available to meet the potential ET throughout the irrigation season. The monthly data for potential ET used in the water balance were taken from published maps of equal evapotranspiration lines based on DWR Bulletin 113-3 (1975).

3.2 MODEL RUNS AND CALIBRATION

Using the above described assumptions and data, the model was set-up and run for detailed analysis for Stemple, Americano and Tolay Creeks. This involved the following additional steps:

1. **Zone 2 Riparian Area Estimate**. Measurement of stream channel lengths for each watershed was made, from which the Zone 2 riparian area was estimated - equal to 200 feet wide times the channel length. All blue line streams and other drainage channels apparent from inspection of U.S.G.S. topographic maps were included in the overall estimate of stream channel length. As outlined in the Irrigation Management Plan, blue-line streams will be subject to irrigation setback requirements and include establishment of vegetated filter strips and riparian restoration.

2. **Zone 1 Upland Area Estimate**. All watershed area not in Zone 2 was considered to be an upland area, i.e., Zone 1. This was computed for each of the three watersheds by determining the total watershed area and subtracting the estimated Zone 2 riparian area, from Step 1 above.

The model for each watershed was set-up and run for average, dry and wet rainfall scenarios as part of the calibration process. Additionally, the actual monthly rainfall data for the 1994-95 water year was entered; and the results of this model run were checked against spot streamflow measurements made in mid-June 1995 at several locations in the West and South County areas. A summary of the stream discharge measurements is provided in Appendix A. By iteration, the model was adjusted to achieve close correspondence between the predicted flows and the base streamflow conditions observed in June 1995. The adjustments made were in regard to the assumed lag time and distribution of lateral root zone flow and groundwater movement between Zone 1 and Zone 2, and between Zone 2 and the stream channel. The initial estimates of these flow rates were based on slope and permeability factors per Darcy's Law; the final, adjusted estimates (reflected in the discussion in Section 3.1) were the result of the calibration process.

As another point of comparison, the water balance hydrograph prediction for Stemple Creek was compared with the regression model of Dearth et. al (1988). The comparison was made for the 1978-89 water year by running the water balance for the actual 1978-79 rainfall data. The results are plotted in Figure 5. The shape of the hydrographs by the two methods is very similar. The notable difference is that the Questa water balance shows a slightly higher discharges for the rainfall conditions in January, February and March. This may be explained because Dearth used a comparison watershed which had more forested areas making runoff response to rainfall slower. The Dearth model also shows an unexplained rise in streamflow in May when a corresponding rise in rainfall was not apparent. Slightly larger late spring/early summer flows are also predicted by the Dearth model, again more typical of a forested watershed than a grassland watershed. This comparison indicates that the Questa water balance provides a better representation of base streamflow conditions.

3.3 RESULTS

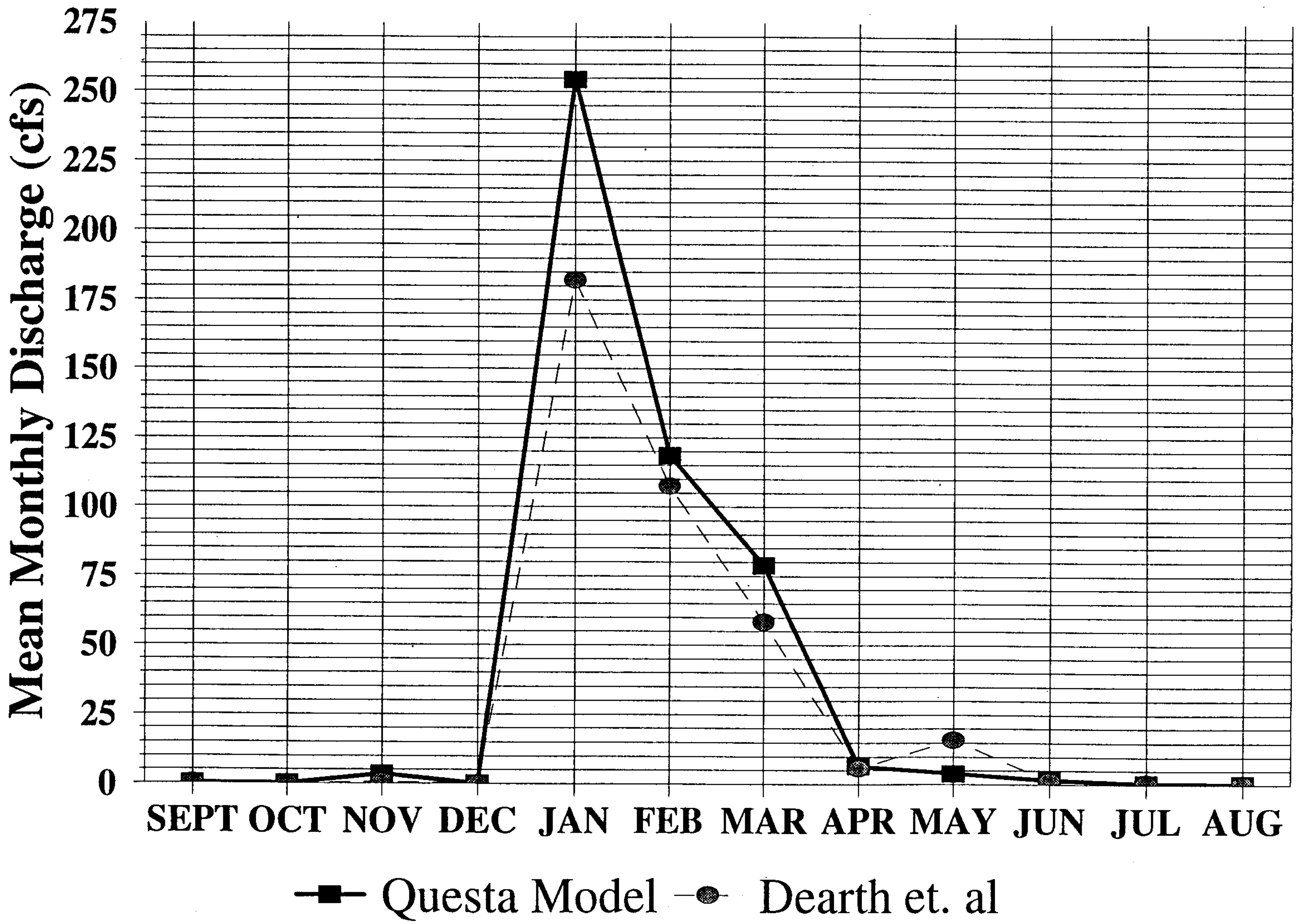
The results of the water balance analysis for existing watershed conditions for average, dry and wet rainfall years are displayed in Tables 3 through 9 for Stemple, Americano and Tolay Creeks. As noted, the calculations reflect the monthly outflow (in acre-feet) near the bottom of each watershed: Highway 1 for Stemple Creek; Valley Ford for Americano Creek; and, Highway 121 for Tolay Creek. Appendix B presents the detailed water balance calculation sheets for each of the watersheds, which also contain the computed average streamflow for each month under the different rainfall scenarios.

The water balance analysis, supported by spot field observations, shows the following:

- The major effects on streamflow due to rainfall variation are exhibited in the winter rainfall season and do not extend very far into the spring or summer.
- For Americano Creek and Stemple Creek in the West County, streamflows decline to about 1.5 cfs or less by June and below 0.6 cfs by July in all rainfall scenarios (average, dry and wet) examined. Flows in Tolay Creek, a much smaller watershed, decline more sharply in the springtime, dropping to less than 1.2 cfs by May in all rainfall scenarios.

All three of the creeks are very seasonal in nature and all are essentially dry by mid-July in most years. This is because the ET rates are typically greater than rainfall from April through October. This is generally true even in wet or above average years. Hence, any water that appears as late spring baseflow comes from rainfall infiltration during the winter months of January, February and March. March rainfall is the most important determinant of the amount and length of flow into the late spring and summer. In addition, Americano, Stemple and Tolay Creek watersheds are characterized by shallow soil mantles and restrictive or impermeable bedrock; they are not underlain by extensive regional groundwater basins that would contribute to year-round flow.

Figure 5. STEMPLE CREEK HYDROGRAPH COMPARISON
Questa and Dearth, et al for the 1978-79 Rainfall Year



4 IRRIGATION EFFECTS

Following the development and calibration of the basic water balance model, the potential effects of the West County and South County Reclamation Alternatives were analyzed. This was done by adjusting the rainfall-runoff characteristics to reflect land use changes and by adding an applied irrigation water factor to the calibrated water balance model for each of the three study area watersheds. The resulting output of the model gives the predicted streamflow for irrigated conditions, for comparison with the "Existing Conditions" results presented in Section 3.

4.1 IRRIGATION ASSUMPTIONS

The following assumptions were made regarding input data to reflect changes due to the irrigation-reclamation activities.

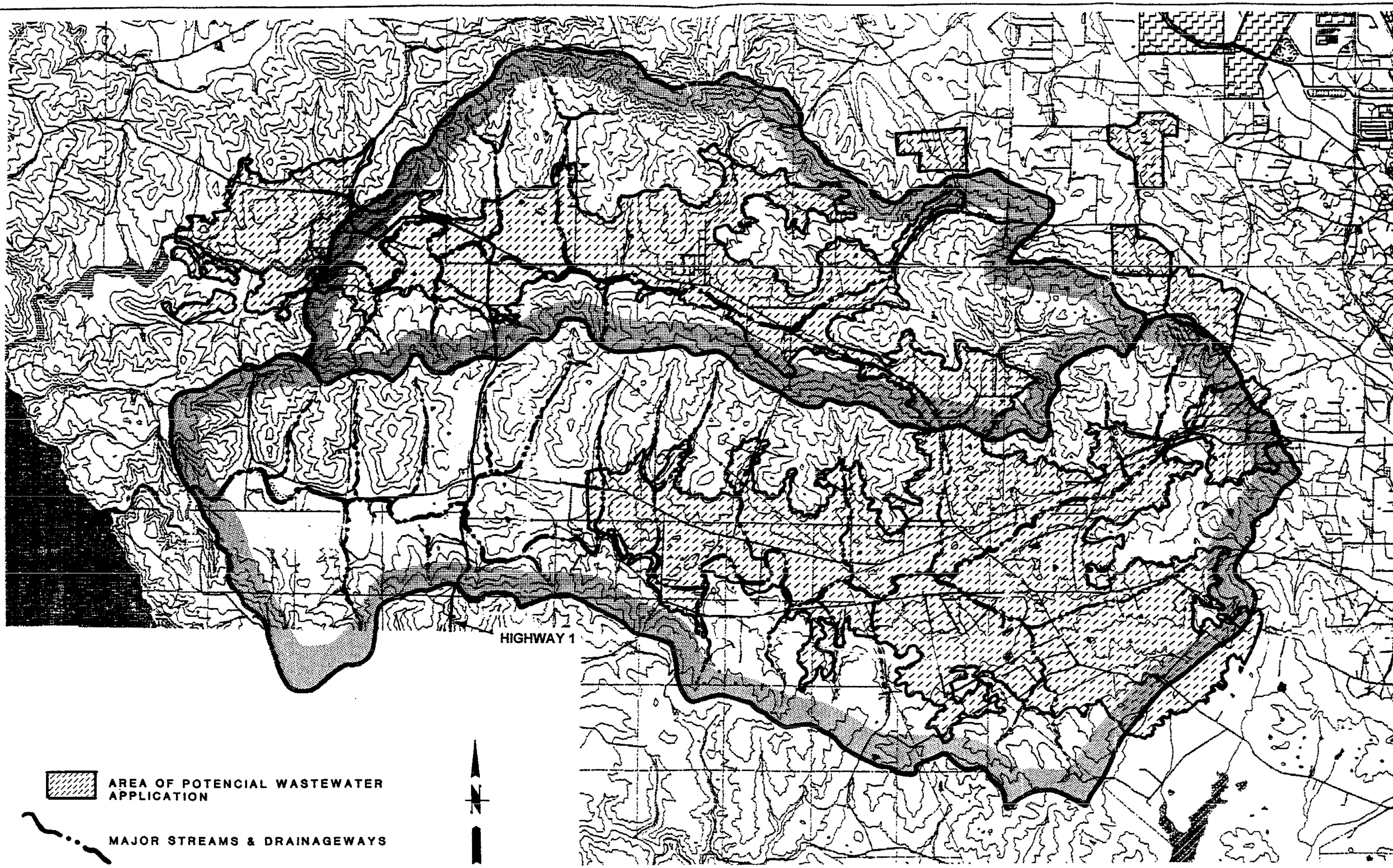
- **Irrigation Area**. The lands potentially to be used for irrigation with reclaimed water were identified on maps prepared as part of the irrigation suitability studies for this project. The total irrigation acreage for each of the three watersheds was determined from available irrigation suitability maps (Figures 6 and 7). It was also assumed, as a worst case scenario, that the maximum amount of land that would be brought under irrigation in any single watershed is 6,200 acres. The total irrigation area assumed for each of the three watersheds was:

    - Stemple Creek - 6,200 acres (i.e., maximum required irrigation area).
    - Americano Creek - 5,470 acres.
    - Tolay Creek - 1,540 acres.

  The assumption was also made that, by project design, all irrigation would be confined to Zone 1, the upland areas, with no irrigation within the 200-foot wide riparian stream buffer zone (Zone 2).

- **Crop Type**. Irrigated pasture is projected to be the dominant use of reclaimed water under the reclamation alternatives as well as having the greatest irrigation water requirement. Accordingly, to construct a worst-case scenario, it was assumed that all lands receiving irrigation would be irrigated pasture. This crop use has one of the greatest water demand and most applications of the different cropping scenarios.

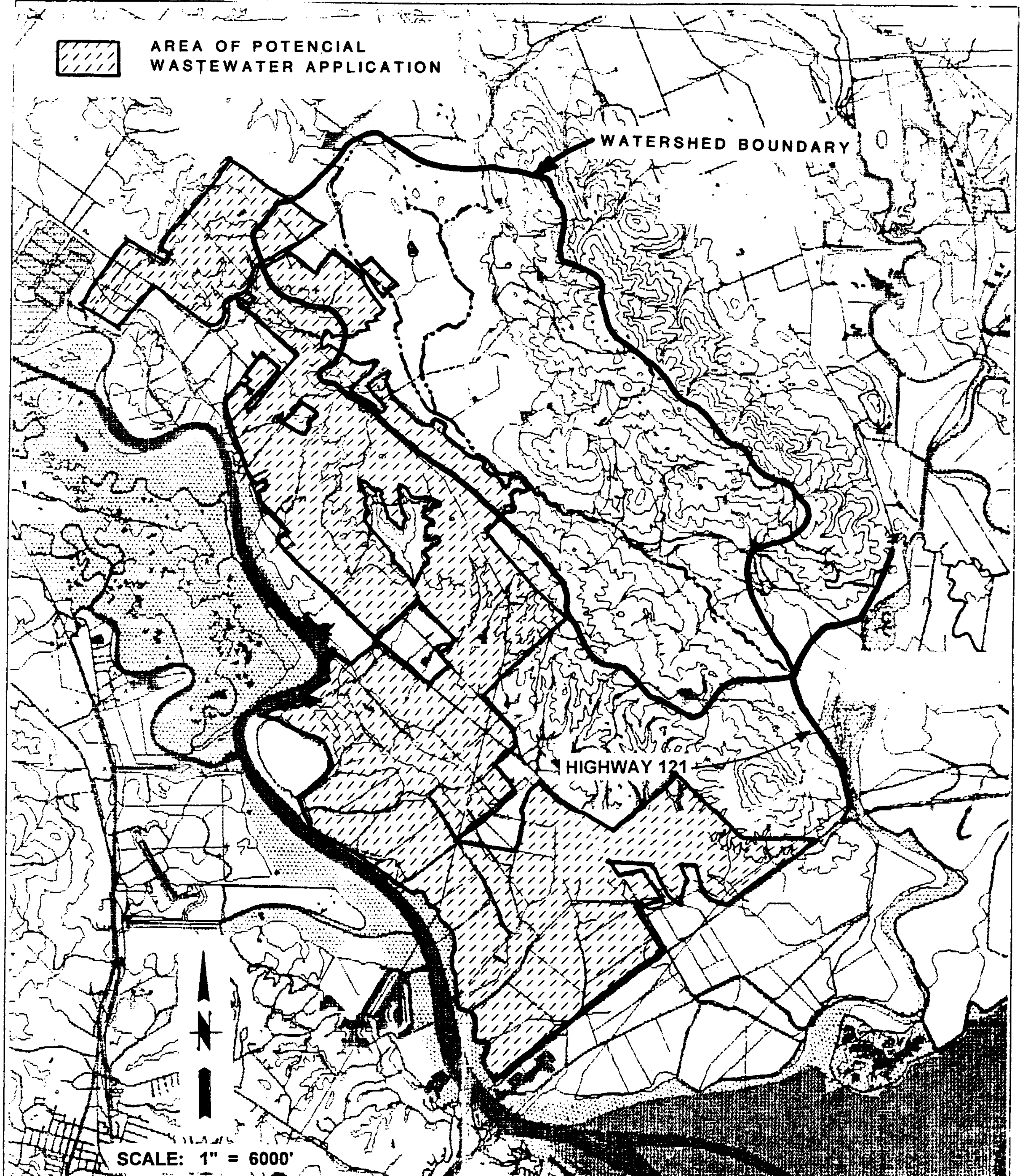
- **Irrigation Rates**. Irrigation rates used in the water balance were taken directly from the recommendations of accompanying irrigation suitability studies for



Questa Engineering Corporation
Point Richmond, California

SANTA ROSA PROJECT
WEST COUNTY
AREAS OF WASTEWATER APPLICATION

Figure 6



QUESTA ENGINEERING CORPORATION POINT RICHMOND, CALIFORNIA	**SANTA ROSA PROJECT** **TOLAY CREEK** **AREAS OF WASTEWATER APPLICATION**	FIGURE 7

pasture irrigation. The applied irrigation rates assume 80 percent irrigation efficiency, meaning that 80 percent of the applied water goes to satisfy the crop's potential ET. The remaining 20 percent is assumed for the water balance analysis to be lost entirely to percolation into the root zone and groundwater, with no direct runoff. This is a very conservative assumption since the 20 percent irrigation water inefficiency is normally considered to include water lost by wind drift and ET on non-target areas. The total water applied for the irrigation season was assumed to be 23.4 inches for the West County areas (Stemple and Americano Creek) and 24.7 inches for the South County (Tolay Creek).

- **Rainfall-Runoff Relationship**. As noted in the water balance discussion in Section 3, the conversion of watershed lands from grazing to irrigated pasture will have the effect of improving the soil-hydrologic conditions, thereby reducing the rainfall-runoff rate. This can be attributed to the improved vegetative cover and related farm field improvements (i.e., mitigation of gullying and erosion) with the reclamation alternative. In the water balance model, the change in the rainfall-runoff relationship was made by adjusting the CN value to reflect irrigated pasture land uses in "good" hydrologic condition. This resulted in lower CN values of 68 for the West County watersheds and 78 for Tolay Creek for the irrigated areas only. The net effect of improvement in watershed soil conditions is that rainfall runoff will be reduced, with more of the incident precipitation entering the soil profile and eventually reaching the stream course as baseflow. Watershed improvements therefore extend the natural baseflow later into the summer, more reminiscent of historic conditions. The CN value guidelines are provided in Appendix A for reference. The rest of the watersheds were assumed to remain unchanged.

4.2 MODELING SCENARIOS

Several different scenarios were modeled using the water balance in order to examine the sensitivity of streamflow to climatic variations and different irrigation management situations that may arise under the reclamation alternatives. In addition to the three scenarios (average, dry and wet) presented in Section 3 for the existing (non-irrigated) conditions, the following five reclamation project scenarios were modeled:

- Normal summer irrigation - average rainfall year
- Normal summer irrigation - dry rainfall year
- Normal summer irrigation - wet rainfall year
- Normal summer irrigation - average rainfall year, with cool summer conditions (i.e., reduced potential ET by 20 percent)
- Winter and summer irrigation - dry rainfall year.

Two of these scenario represent the "Cool Summer" and "Dry Winter" contingencies discussed in the Irrigation Management Plan and allow for an evaluation of the impacts associated with them.

4.3 MODEL RESULTS AND DISCUSSION

The calculation tables for each of the model runs are included in Appendix B. Table 3 summarizes July results since the greatest concern may come from summer flow increases. For further in-depth comparison, a summary of the results for each of the eight scenarios (three existing conditions, five project conditions) is provided in Tables 4 through 9. Tables 4, 6 and 8 show the results in terms of total monthly streamflow discharge in acre-feet; Tables 5, 7 and 9 show the results converted to average streamflow, in cubic feet per second (cfs).

The following highlight the main findings and conclusions from the water balance analysis regarding the type and magnitude of hydrology changes that can be expected from the reclamation alternatives.

- **Normal Irrigation Effects**. The effects of irrigation during average, dry and wet rainfall years are indicated by scenarios 4, 5 and 6 in each of the summary tables. There are two principal results.

    1. Reduced Winter Discharges. The water balances show a reduction in winter flows by about 10 to 15 percent for all three streams, for average, dry and wet rainfall conditions. This is a result of greater infiltration and less direct runoff during the winter months (November to April) due to the improved hydrologic condition of the watershed, which is reflected by a lower CN value in the models.

    2. Increased Summer Discharges. Slight increases in summer (May to October) stream discharges are indicated by the water balance for all three streams, for average, dry and wet rainfall conditions. The projected normal rainfall year summer (July) streamflow increases are: 1) 0.26 to 0.40 cfs for Americano Creek (Table 5); b) 0.5 to .66 cfs for Stemple Creek (Table 7); and, c) 0.07 to 0.07 cfs (no change) for Tolay Creek (Table 9). As a point of reference, for channels of these dimensions streamflows of less than 0.2 typically occur as intergravel flow with some flow detectable in pools. Flows of less than 0.1 cfs are not ordinarily observable. Flows in the range of 0.5 to 1.2 CFS would be observable with an average flow depth of about one inch. The flow would likely be confined to the low flow portion of the channel, with some intergravel flow. We estimate that about 25 percent of the increased flow would be attributable to the improved watershed conditions. This amount of summer base flow is probably reminiscent of pre-1900 conditions.

Additionally, it should be noted that the water balance analysis does not account for increased uptake (i.e., ET) of streamflow due to enhanced vegetation plantings in the riparian zone which is a proposed feature of the reclamation alternative. These riparian plantings would have the effect of further lessening the summer streamflow changes by virtue of increased consumptive water use within and along the stream corridor.

The model also does not partition any of the irrigation water applied in excess of crop ET to storage in a deeper aquifer. It assumes that all groundwater inputs from irrigation are eventually discharged to the stream. In this respect, the model portrays a worst-case condition. Factoring in the enhanced riparian plant community consumptive water use, the net effect of the irrigation project would likely be slightly lesser flows than what the model currently predicts. These decreased flows would probably not be observable and measurable in dry years. Early summer base flow amounts in normal water years would be similar to conditions presently occurring in wetter than normal years and within the range of conditions historically occurring in the watersheds.

- **Direct Irrigation Runoff Effects**. The Irrigation Management Plan includes a number of provisions that would greatly reduce the possibility of excessive irrigation applications (over irrigation) in amounts that could produce runoff directly entering stream courses. Consequently, irrigation runoff was not factored into the water balance model. Nonetheless, occassional over-irrigation or spills in amounts that produce local stream runoff could occur due to system failures such as pipeline breaks or operator error. In an averagely managed irrigation system with typical application efficiencies of 75 to 90 percent, such events (irrigation runoff) may consist of two to five percent of the total flow; in a well managed system runoff would be less than one percent. However, the proposed system would have additional measures including field border berms and vegetated filter strips to absorb and detain any such runoff. Although it is difficult to anticipate and quantify system failures and operator error, we estimate less than one percent of the total irrigation flow may be occasionally lost directly to stream courses. We do not anticipate such incidents occurring on a daily basis. For purposes of evaluating such consequences on stream flow, we will assume runoff producing incidents occur three days per month, or ten percent of the time. Increases in summer base flows of about .04 to .05 cfs are estimated to result from irrigation runoff totaling one percent of flows that occur ten percent of the time.

- **Cool Summer Irrigation**. As compared with the normal irrigation scenario, irrigation during cool summer conditions (i.e., reduced ET) results in increases in stream discharge during the late summer irrigation period, as well as in the winter months. The increases reflected in the water balance results are due to the fact that more irrigation water passes through the root zone to groundwater and to the streamside riparian zone. This flow ultimately discharges as streamflow; but this occurs over a delayed two to four-month period extending into the fall. The magnitude of these flow increases are 0.09 to 0.32 cfs for each of the streams. Reduced irrigation application amounts during cool summers, with some contingency lands brought under temporary irrigation as called for in the IMP, can be used to reduce the effects of cool summers on stream base flow.

In the winter, small increases in stream discharge are also predicted by the water balance; this is due to the increased amount of soil moisture at the beginning of the rainy season. Normally, the soils would be dry until the first significant rains.

- **Winter Irrigation in Dry Year**. Modeling of the winter irrigation scenario showed a consistently small increase in winter and spring stream discharge for all three streams, as compared with normal summer irrigation for comparable dry year conditions. This is attributable to the addition of water to the root zone during the winter at levels that exceed the water holding capacity of the soil; this adds to the lateral root zone flow into the riparian streamside area, as well groundwater flow and ultimate stream discharge. For Americano Creek and Stemple creek, increased stream discharges are indicated for the period of December through July; the magnitude of the projected streamflow increases varies from 0.01 to 0.09 cfs for Americano Creek, and from 0.01 to 0.05 cfs for Stemple Creek. For Tolay Creek, winter irrigation results in a maximum projected streamflow increase of 0.01 or less; and, this is limited more narrowly to the period of January through May due to the smaller size of the watershed. These increases are at levels that would not be observable or measureable in the field and should not be considered significant.

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Table 2 Rainfall Data

	Americano			Stemple			Tolay		
Month	Dry	Average	Wet	Dry	Average	Wet	Dry	Average	Wet
October	1.24	2.12	2.72	0.88	2.06	3.15	0.92	1.4	1.86
November	2.0	4.79	7.24	1.94	3.95	4.92	2.09	3.16	4.2
December	2.54	5.38	7.66	2.69	4.55	6.44	2.86	4.33	5.76
January	4.91	7.29	10.47	3.57	6.6	9.53	3.93	5.95	7.91
February	3.63	4.84	6.30	3.11	5.0	7.17	2.62	3.97	5.28
March	3.29	4.28	5.96	3.22	4.42	6.07	1.74	2.64	3.51
April	0.95	1.68	2.53	0.75	1.68	2.71	1.13	1.71	2.27
May	0.54	0.34	0.13	0.66	0.44	0.45	0.2	0.31	0.41
June	0.10	0.11	0.20	0.11	0.23	0.23	0.11	0.17	0.23
July	0.08	0.03	0.00	0.00	0.0	0.0	0.03	0.05	0.07
August	0.1	0.08	0.12	0.07	0.07	0.09	0.05	0.08	0.11
September	0.41	0.71	0.67	0.26	0.39	0.66	0.17	0.25	0.33
Total	19.81	31.65	43.98	17.27	29.4	41.41	15.9	24.0	31.9

1. Rainfall data derived from Sonoma County Water Agency rainfall gauges at Two Rock (TR 8014), Gerritson (TR 0903), Erickson (VF 9051) and Sears Point.
2. Gerritson and Erickson gauges were weighed equally to determine Americano Creek rainfall.
3. Two Rock was used to determine Stemple Creek rainfall.

Ref.: 93012HYD.T2

TABLE 3 SUMMARY OF JULY FLOW INCREASES (CFS)*

	Normal Year	Dry Year	Wet Year	Cool Summer Contingency	Dry Winter Contingency
Americano Creek	.26 to .40	.19 to .35	.35 to .49	.26 to .38	.19 to .57
Stemple Creek	.50 to .66	.32 to .50	.66 to .83	.50 to .79	.32 to .74
Tolay Creek	.07 to .07	.05 to .06	.08 to .08	.07 to .07	.05 to .08

* First number is existing conditions, second number is projected flow with irrigation.

Ref.: 93012HYD.T3

TABLE 4

MONTHLY OUTFLOW COMPARISONS FOR AMERICANO CREEK

IN ACRE-FEET (ac-ft)

Watershed Scenario	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sept.
Existing Conditions												
1. Average Rainfall - No Irrigation	23.7	2,993.7	3,812.5	6,072.5	3,807.1	3,236.7	729.1	200.0	74.9	16.8	6.0	0.8
2. Dry Year - No Irrigation	0.8	559.8	1,099.7	3,445.3	2,677.3	2,155.1	340.5	165.7	57.5	12.3	4.4	0.0
3. Wet Year - No Irrigation	20.9	5,497.1	6,234.8	9,636.9	5,405.5	5,052.0	1,366.3	235.2	96.1	22.0	7.9	1.2
Project Conditions												
4. Average Rainfall - Normal Irrigation	27.6	2,611.4	3,446.5	5,668.2	3,597.0	3,094.2	726.1	251.8	103.5	25.7	17.9	17.2
5. Dry Year - Normal Irrigation	18.3	445.4	953.9	3,141.9	2,296.2	2,030.4	383.6	199.5	77	22.6	16.4	16.8
6. Wet Year - Normal Irrigation	36.8	5,088.0	5,778.0	9,155.3	5,147.5	4,849.1	1,294.3	293.3	130.4	31.3	11.2	14.0
7. Cool Summer - Normal Irrigation	45.8	2,630.0	3,454.0	5,670.9	3,597.9	3,094.2	726.1	251.8	103.5	24.1	26.9	33.7
8. Dry Year - Winter Irrigation	18.3	445.4	1,015.8	3,291.9	2,544.2	2,340.1	531.4	275.0	126.6	36.3	21.5	18.5

93012HRT.AC2

TABLE 5

MONTHLY STREAMFLOW COMPARISONS FOR AMERICANO CREEK

AVERAGE DISCHARGE (cfs)

Watershed Scenario	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sept.
Existing Conditions												
1. Average Rainfall- No Irrigation	0.37	48.25	59.47	94.71	65.74	50.48	11.75	3.12	1.21	0.26	0.09	0.01
2. Dry Year - No Irrigation	0.01	9.02	17.15	53.74	42.71	33.61	5.49	2.58	0.93	0.19	0.07	0.00
3. Wet Year - No Irrigation	33	88.6	97.3	150.3	93.3	78.8	22.02	3.67	1.55	0.34	0.12	0.02
Project Conditions												
4. Average Rainfall - Normal Irrigation	43	42.09	53.76	88.41	62.1	48.26	11.7	3.93	1.67	0.40	0.28	0.28
5. Dry Year - Normal Irrigation	0.28	7.18	14.88	49.0	39.65	31.67	6.18	3.11	1.24	0.35	0.26	0.27
6. Wet Year - Normal Irrigation	57	80.71	90.13	142.8	88.9	75.6	20.9	4.5	2.1	0.49	0.18	0.23
7. Cool Summer - Normal Irrigation	0.71	43.29	53.87	88.45	62.13	48.26	11.7	3.93	1.67	0.38	0.42	0.54
8. Dry Year - Winter Irrigation	0.28	7.18	15.84	51.34	43.93	36.50	8.56	4.34	2.04	0.57	0.34	0.30

93012HRT.AC

TABLE 6

MONTHLY OUTFLOW COMPARISONS FOR STEMPLE CREEK

IN ACRE-FEET (ac-ft)

Watershed Scenario	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sept.
Existing Conditions												
1. Average Rainfall - No Irrigation	42.3	4089.3	5,559.6	9,944.7	7,382.8	6,288.1	1,349.8	370.5	141.1	32.1	11.6	1.0
2. Dry Year - No Irrigation	2.6	998.7	2,308.1	4,029.6	3,683.9	3,348.3	289.0	200.1	54.5	20.4	7.5	0.0
3. Wet Year - No Irrigation	100.8	5,853.2	9,243.2	16,066.2	11,835.0	9,670.0	2,819.6	432.9	179.0	42.3	15.5	2.5
Project Conditions												
4. Average Rainfall - Normal Irrigation	37.2	3,706.7	5,191.7	9,504.1	7,119.5	6,108.4	1,345.9	432	174.9	42.2	24.8	19.5
5. Dry Year - Normal Irrigation	20.0	853.8	2,118.6	3,77.3	3,516.7	3,656.2	553.8	314.0	114.6	31.8	20.8	18.9
6. Wet Year - Normal Irrigation	75.4	5,381.6	8,761.0	15,526.7	11,489.7	9,435.9	2,714.0	511.8	22.5	53.0	19.3	16.8
7. Cool Summer - Irrigation	157.8	3,727.2	5,199.9	9,507.1	7,120.5	6,108.4	1,345.9	432	174.9	51.0	39.7	39.2
8. Dry Year - Winter Irrigation	20.1	853.8	2,188.9	3,947.5	3,797.9	4,007.4	721.4	403.5	170.9	47.4	26.6	20.9

TABLE 7

MONTHLY STREAMFLOW COMPARISONS FOR STEMPLE CREEK

AVERAGE DISCHARGE (cfs)

Watershed Scenario	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sept.
Existing Conditions												
1. Average Rainfall - No Irrigation	0.66	65.91	86.71	155.11	127.49	98.09	21.75	5.78	2.27	0.5	0.18	0.02
2. Dry Year - No Irrigation	0.04	16.10	36.0	62.82	63.62	52.22	4.66	3.12	0.88	0.32	0.12	0.0
3. Wet Year - No Irrigation	1.57	94.34	144.17	250.59	204.37	150.83	45.44	6.75	2.89	0.66	0.24	0.04
Project Conditions												
4. Average Rainfall - Normal Irrigation	0.58	59.74	80.98	148.24	122.9	95.3	21.7	6.7	2.82	0.66	0.39	0.31
5. Dry Year - Normal Irrigation	0.31	13.8	33.04	58.92	60.73	57.03	8.93	4.90	1.85	0.50	0.32	0.30
6. Wet Year - Normal Irrigation	1.18	86.74	136.65	242.17	198.41	147.17	43.74	7.98	3.59	0.83	0.30	0.27
7. Cool Summer - Normal irrigation	0.80	60.07	81.10	148.3	122.96	95.3	21.7	6.7	2.8	0.79	0.62	0.63
8. Dry Year - Winter Irrigation	0.31	13.8	34.1	61.6	65.6	62.5	11.6	6.3	2.8	0.74	0.42	0.34

TABLE 8

MONTHLY OUTFLOW COMPARISONS FOR TOLAY CREEK

IN ACRE-FEET (ac-ft)

Watershed Scenario	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sept.
Existing Conditions												
1. Average Rainfall - No Irrigation	1.4	828.8	1,413.3	2,255.5	1,401.0	717.6	321.9	41.0	11.7	4.3	1.6	0.0
2. Dry Year - No Irrigation	0.3	397.8	748.5	1,271.0	771.6	359.8	143.1	32.7	9.3	3.4	1.3	0.0
3. Wet Year - No Irrigation	2.9	1,294.2	2,101.8	3,243.4	2,1041.7	1,212.1	575.1	64.4	22.3	4.8	1.8	0.0
Project Conditions												
4. Average Rainfall - Normal Irrigation	5.8	790.9	1,368.3	2,204.5	1,371.4	691.8	305.6	44.9	12.8	4.7	1.7	3.3
5. Dry Year - Normal Irrigation	5.2	374.4	720.0	1,233.7	752.4	345.1	135.8	35.5	10.1	3.7	3.9	4.4
6. Wet Year - Normal Irrigation	7.3	1,245.9	2,047.4	3,185.1	2,005.4	1,190.2	556.2	71.1	24.7	5.3	1.9	3.3
7. Cool Summer - Normal Irrigation	11	796.2	1,370.3	2,205.2	1,371.6	69.18	305.6	44.9	12.8	4.7	6.7	8.9
8. Dry Year - Winter Irrigation	5.3	374.4	736.9	1,275.7	822.0	379.9	155.6	49.0	17.4	7.5	5.3	4.9

93012HRT.TC2

TABLE 9

MONTHLY STREAMFLOW COMPARISONS FOR TOLAY CREEK

AVERAGE DISCHARGE (cfs)

Watershed Scenario	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sept.
Existing Conditions												
1. Average Rainfall - No Irrigation	0.02	13.35	22.04	35.2	24.2	11.2	5.2	0.64	0.19	0.07	0.02	0.00
2. Dry Year - No Irrigation	0.01	6.41	11.68	19.82	13.32	5.61	231	0.51	0.15	0.05	0.02	0.00
3. Wet Year - No Irrigation	0.04	20.8	32.8	50.6	35.3	18.9	9.3	1.0	0.36	0.08	0.03	0.00
Project Conditions												
4. Average Rainfall - Normal Irrigation	0.09	12.7	21.3	34.4	23.7	10.8	4.9	0.7	0.20	0.07	0.03	0.05
5. Dry Year - Normal Irrigation	0.08	6.03	11.23	19.24	12.99	5.38	2.19	0.55	0.16	0.06	0.06	0.07
6. Wet Year - Normal Irrigation	0.11	20.08	31.93	49.68	34.63	18.56	8.96	1.11	0.40	0.08	0.03	0.05
7. Cool Summer - Normal Irrigation	0.17	12.83	21.4	34.4	23.7	10.8	4.9	0.7	0.21	0.07	0.10	0.14
8. Dry Year - Winter Irrigation	0.08	6.03	11.5	19.9	14.2	5.9	2.5	0.76	0.28	0.12	0.08	0.08

93012HRT.TC

APPENDIX A

TABLE A1

DISCHARGE MEASUREMENTS FOR SANTA ROSA PROJECT STREAMS*

JUNE 20, 1995

Creek Name	Location	Discharge (CFS)
Green Valley	near Russian River confluence	5.87
Green Valley	at Graton Road	1.17
Stemple	at Highway 1	0.27
Lichau	at Railroad Avenue	0.23
Copeland	at Pressley Road	0.72
Copeland	at Lichau Road	1.29
Adobe	at Manor Lane	1.22
Adobe	at Casa Grande Road	0.77
Tolay	at Highway 121	0.28

* Discharge measurements made by Questa Engineering using area-velocity and bucket-step watch methods.

Ref.: 93012HYD.A1

WEST COUNTY HYDROLOGY AND IRRIGATION

DRAINAGE ASSUMPTIONS

0 to 5 Percent Slopes

Rainfall	27.3"
PET	30.5"
Water holding capacity in root zone	4.2"
Thickness of shallow groundwater	4 ft
Water holding capacity/shallow groundwater	4.2"
Available water	2"/ft
Existing N in root zone groundwater	2.0 mg/l
Exisitng TDS root zone groundwater	500 mg/l
TDS irrigation water	480 mg/l
NO_3-N irrigation water	5.5 mg/l
Existing NO_3-N shallow groundwater	2.0 mg/l
Existing NO_3-N stream water	2.0 mg/l
Gypsum	<1%
Initial soil/water salinity	500 mg/l

5 To 10 Percent Slopes And 10 To 15 Percent Slopes

same as above *except:*

Thickness of shallow groundwater	3 ft

Lettuce (0 To 5 Percent Slope)

Rooting depth	9"
Irrigation application	15" (sprinkler)
Irrigation efficiency	80%
wind loss	7%
pipe leaks, movement loss	3%
runoff	4%
deep percolation	6%
Fertilizer N application	120 lbs/acre
No manure	
Assume over-winter oat hay cover crop	

Potatoes (0 To 5 Percent Slope)

Rooting depth	18"
Irrigation application	11"
Irrigation efficiency	80%
wind loss	7%
pipe leaks, movement loss	3%
runoff	4%
deep percolation	6%
No manure	
Assume over-winter oat hay cover crop	

Strawberries (0 To 5 Percent Slopes)

Rooting depth	6"
Irrigation application 2/3's ET-drip	15.3"
Irrigation efficiency	90%
pipe leaks	3%
runoff	1%
deep percolation	6%
N fertilizer application	50 lbs/acre

No manure

Assume over-winter oat hay cover crop

Sudan Grass (6 To 10 Percent Slopes)

Rooting depth	18"
Irrigation application	22.8" (19" x 1.2)
Irrigation efficiency	80%
pipe leaks	3%
runoff	7%
deep percolation	10%

Manure application:

10 tons/acre - 3% N - 25% volitalization in 1st year

1/3 mineralization per year over 3 years so N annual = 150 lbs N

Sudan N requirement 50-200 lbs/acre

Sudan grass also has winter oat-hay cover crop

Permanent Irrigated Pasture (10 To 15 Percent Slopes)

Rooting depth	24"
Irrigation application	23" (20" x 1.15%)
Irrigation efficiency	85%
wind loss	7%
pipe leaks, movement losses	3%
deep percolation	3%
runoff	2%
N requirement	80-100 lbs N acre
N fertilizer	none
Manure	6 tons/acre=(90 lbs N)

APPENDIX B

Table B7A. AMERICANO CREEK - OVERALL WATER BUDGET FOR STEMPLE CREEK FOR AN AVERAGE RAINFALL YEAR AT VALLEY FO] (WITH 80% IRRIGATION EFFECIENCY) (COOL SUMMER)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.71	3.3	3.5	4.9	33.7	33.7	0.54
OCT	2.12	0.2	2.3	10.1	35.6	45.8	0.71
NOV	4.79	0.0	1.1	2593.5	36.5	2630.0	42.39
DEC	5.38	0.0	0.6	3147.7	306.3	3454.0	53.87
JAN	7.29	0.0	1.0	5053.0	618.0	5670.9	88.45
FEB	4.84	0.0	1.2	2639.6	958.3	3597.9	62.13
MAR	4.28	0.0	2.0	2133.0	961.2	3094.2	48.26
APR	1.68	0.6	2.2	265.9	460.2	726.1	11.70
MAY	0.34	3.8	2.8	0.0	251.8	251.8	3.93
JUN	0.11	5.3	3.6	0.0	103.5	103.5	1.67
JUL	0.03	4.8	3.2	0.0	24.1	24.1	0.38
AUG	0.08	4.7	3.2	0.0	26.9	26.9	0.42
TOTAL	**31.65**	**22.79**	**26.7**	**15847.8**	**3816.01**	**19658.9**	

Table B8A. AMERICANO CREEK - OVERALL WATER BUDGET FOR STEMPLE CREEK FOR A DRY RAINFALL YEAR AT VALLEY FORD (WITH 80% IRRIGATION EFFECIENCY) (WINTER IRRIGATION)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.41	3.7	3.5	0.0	18.5	18.5	0.30
OCT	1.24	1.3	2.3	0.8	17.5	18.3	0.28
NOV	2	1.5	1.1	427.6	17.7	445.4	7.18
DEC	2.54	1.5	0.6	757.8	258.0	1015.8	15.84
JAN	4.91	1.5	1.0	2704.5	587.4	3291.9	51.34
FEB	3.63	1.5	1.2	1577.6	966.6	2544.2	43.93
MAR	3.29	1.5	2.0	1304.5	1035.6	2340.1	36.50
APR	0.95	2.2	2.8	31.7	499.6	531.4	8.56
MAY	0.54	3.6	3.5	0.0	278.5	278.5	4.34
JUN	0.1	5.3	4.5	0.0	126.6	126.6	2.04
JUL	0.08	4.7	4.0	0.0	36.3	36.3	0.57
AUG	0.12	4.7	4.0	0.0	21.5	21.5	0.34
TOTAL	**19.81**	**32.89**	**30.5**	**6804.5**	**3863.88**	**10668.4**	

Table B1S. STEMPLE CREEK - OVERALL WATER BUDGET FOR STEMPLE CREEK FOR AN AVERAGE RAINFALL YEAR AT HIGHWAY 1 (EXISTING CONDITIONS)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.39	0.0	3.5	0.0	1.0	1.0	0.02
OCT	2.06	0.0	2.3	42.3	0.0	42.3	0.66
NOV	3.95	0.0	1.1	4089.3	0.0	4089.3	65.91
DEC	4.55	0.0	0.6	5167.5	392.0	5559.6	86.71
JAN	6.6	0.0	1.0	9107.0	837.7	9944.7	155.11
FEB	5	0.0	1.2	6003.3	1379.5	7382.8	127.49
MAR	4.42	0.0	2.0	4930.1	1358.0	6288.1	98.08
APR	1.68	0.0	2.8	700.3	649.5	1349.8	21.75
MAY	0.44	0.0	3.5	0.0	370.5	370.5	5.78
JUN	0.23	0.0	4.5	0.0	141.1	141.1	2.27
JUL	0	0.0	4.0	0.0	32.1	32.1	0.50
AUG	0.07	0.0	4.0	0.0	11.6	11.6	0.18
TOTAL	**29.39**	**0**	**30.5**	**30039.7**	**5172.98**	**35212.7**	

Table B2S. STEMPLE CREEK - OVERALL WATER BUDGET FOR STEMPLE CREEK FOR A DRY RAINFALL YEAR AT HIGHWAY 1 (EXISTING CONDITIONS)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.26	0.0	3.5	0.0	0.0	0.0	0.00
OCT	0.88	0.0	2.3	2.6	0.0	2.6	0.04
NOV	1.94	0.0	1.1	998.7	0.0	998.7	16.10
DEC	2.69	0.0	0.6	2022.7	285.4	2308.1	36.00
JAN	3.57	0.0	1.0	3433.1	594.5	4027.6	62.82
FEB	3.11	0.0	1.2	2673.9	1010.1	3683.9	63.62
MAR	3.22	0.0	2.0	2851.5	496.8	3348.3	52.22
APR	0.75	0.0	2.8	25.4	263.6	289.0	4.66
MAY	0.66	0.0	3.5	7.0	193.1	200.1	3.12
JUN	0.11	0.0	4.5	0.0	54.5	54.5	0.88
JUL	0	0.0	4.0	0.0	20.4	20.4	0.32
AUG	0.07	0.0	4.0	0.0	7.5	7.5	0.12
TOTAL	**17.26**	**0**	**30.5**	**12015.0**	**2925.68**	**14940.7**	

Table B3S. STEMPLE CREEK - OVERALL WATER BUDGET FOR STEMPLE CREEK FOR A WET RAINFALL YEAR AT HIGHWAY 1 (EXISTING CONDITIONS)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.66	0.0	3.5	7.0	2.3	2.5	0.04
OCT	3.15	0.0	2.3	100.8	0.0	100.8	1.57
NOV	4.92	0.0	1.1	5853.2	0.0	5853.2	94.34
DEC	6.44	0.0	0.6	8789.5	453.7	9243.2	144.17
JAN	9.53	0.0	1.0	15099.2	967.0	16066.2	250.59
FEB	7.17	0.0	1.2	10248.6	1586.4	11835.0	204.37
MAR	6.07	0.0	2.0	8060.2	1609.8	9670.0	150.83
APR	2.71	0.0	2.8	2052.7	766.9	2819.6	45.44
MAY	0.45	0.0	3.5	0.0	432.9	432.9	6.75
JUN	0.23	0.0	4.5	0.0	179.0	179.0	2.89
JUL	0	0.0	4.0	0.0	42.3	42.3	0.66
AUG	0.09	0.0	4.0	0.0	15.5	15.5	0.24
TOTAL	**41.42**	**0**	**30.5**	**50211.2**	**6055.82**	**56260.3**	

Table B4S. STEMPLE CREEK - OVERALL WATER BUDGET FOR STEMPLE CREEK FOR AN AVERAGE RAINFALL YEAR AT HIGHWAY 1 (80% IRRIGATION EFFICIENCY)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.39	3.7	3.5	0.0	19.5	19.5	0.31
OCT	2.06	0.3	2.3	17.5	19.6	37.2	0.58
NOV	3.95	0.0	1.1	3686.4	20.3	3706.7	59.74
DEC	4.55	0.0	0.6	4708.2	483.5	5191.7	80.98
JAN	6.6	0.0	1.0	8494.4	1009.7	9504.1	148.24
FEB	5	0.0	1.2	5505.5	1614.0	7119.5	122.94
MAR	4.42	0.0	2.0	4482.5	1625.9	6108.4	95.27
APR	1.68	1.3	2.8	571.1	774.8	1345.9	21.69
MAY	0.44	3.7	3.5	0.0	432.0	432.0	6.74
JUN	0.23	5.1	4.5	0.0	174.9	174.9	2.82
JUL	0	4.8	4.0	0.0	42.2	42.2	0.66
AUG	0.07	4.7	4.0	0.0	24.8	24.8	0.39
TOTAL	**29.39**	**23.616**	**30.5**	**27465.5**	**6241.17**	**33706.7**	

Table B5S. STEMPLE CREEK - OVERALL WATER BUDGET FOR STEMPLE CREEK FOR A DRY RAINFALL YEAR AT HIGHWAY 1 (80% IRRIGATION EFFICIENCY)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.26	3.9	3.5	0.0	18.9	18.9	0.30
OCT	0.88	1.7	2.3	0.0	20.0	20.0	0.31
NOV	1.94	0.0	1.1	833.5	20.3	853.8	13.76
DEC	2.69	0.0	0.6	1759.6	359.0	2118.6	33.04
JAN	3.57	0.0	1.0	3069.1	708.2	3777.3	58.92
FEB	3.11	0.0	1.2	2360.7	1156.0	3516.7	60.73
MAR	3.22	0.0	2.0	2525.8	1130.5	3656.2	57.03
APR	0.75	2.4	2.8	18.6	535.2	553.8	8.93
MAY	0.66	3.4	3.5	5.1	308.9	314.0	4.90
JUN	0.11	5.3	4.5	0.0	114.6	114.6	1.85
JUL	0	4.8	4.0	0.0	31.8	31.8	0.50
AUG	0.07	4.7	4.0	0.0	20.8	20.8	0.32
TOTAL	**17.26**	**26.184**	**30.5**	**10572.3**	**4424.19**	**14996.5**	

Table B6S. STEMPLE CREEK - OVERALL WATER BUDGET FOR STEMPLE CREEK FOR A WET RAINFALL YEAR AT HIGHWAY 1 (80% IRRIGATION EFFICIENCY)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.66	3.4	3.5	5.1	16.8	16.8	0.27
OCT	3.15	0.0	2.3	57.5	17.9	75.4	1.18
NOV	4.92	0.0	1.1	5362.1	19.5	5381.6	86.74
DEC	6.44	0.0	0.6	8187.0	573.9	8761.0	136.65
JAN	9.53	0.0	1.0	14338.6	1188.1	15526.7	242.17
FEB	7.17	0.0	1.2	9601.9	1887.8	11489.7	198.41
MAR	6.07	0.0	2.0	7482.3	1953.6	9435.9	147.17
APR	2.71	0.0	2.8	1787.1	926.9	2714.0	43.74
MAY	0.45	3.7	3.5	0.0	511.8	511.8	7.98
JUN	0.23	5.1	4.5	0.0	222.5	222.5	3.59
JUL	0	4.8	4.0	0.0	53.0	53.0	0.83
AUG	0.09	4.7	4.0	0.0	19.3	19.3	0.30
TOTAL	**41.42**	**21.732**	**30.5**	**46821.6**	**7391.09**	**54207.6**	

Table B7S. STEMPLE CREEK - OVERALL WATER BUDGET FOR STEMPLE CREEK FOR AN AVERAGE RAINFALL YEAR AT HIGHWAY 1 (80% IRRIGATION EFFICIENCY) (COOL SUMMER)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.39	3.7	3.5	0.0	39.2	39.2	0.63
OCT	2.06	0.3	2.3	17.5	40.3	57.8	0.90
NOV	3.95	0.0	1.1	3686.4	40.9	3727.2	60.07
DEC	4.55	0.0	0.6	4708.2	491.7	5199.9	81.10
JAN	6.6	0.0	1.0	8494.4	1012.7	9507.1	148.29
FEB	5	0.0	1.2	5505.5	1615.0	7120.5	122.96
MAR	4.42	0.0	2.0	4482.5	1625.9	6108.4	95.27
APR	1.68	1.3	2.2	571.1	774.8	1345.9	21.69
MAY	0.44	3.7	2.8	0.0	432.0	432.0	6.74
JUN	0.23	5.1	3.6	0.0	174.9	174.9	2.82
JUL	0	4.8	3.2	0.0	51.0	51.0	0.79
AUG	0.07	4.7	3.2	0.0	39.7	39.7	0.62
TOTAL	29.39	23.62	26.7	27465.5	6338.12	33803.6	

Table B8S. STEMPLE CREEK - OVERALL WATER BUDGET FOR STEMPLE CREEK FOR A DRY RAINFALL YEAR AT HIGHWAY 1 (80% IRRIGATION EFFICIENCY) (WINTER IRRIGATION)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.26	3.9	3.5	0.0	20.9	20.9	0.34
OCT	0.88	1.7	2.3	0.0	20.1	20.1	0.31
NOV	1.94	1.5	1.1	833.5	20.3	853.8	13.76
DEC	2.69	1.5	0.6	1759.6	429.3	2188.9	34.14
JAN	3.57	1.5	1.0	3069.1	878.4	3947.5	61.57
FEB	3.11	1.5	1.2	2360.7	1437.2	3797.9	65.58
MAR	3.22	1.5	2.0	2525.8	1481.7	4007.4	62.51
APR	0.75	2.5	2.8	18.6	702.9	721.4	11.63
MAY	0.66	3.4	3.5	5.1	398.4	403.5	6.29
JUN	0.11	5.3	4.5	0.0	170.9	170.9	2.75
JUL	0	4.8	4.0	0.0	47.4	47.4	0.74
AUG	0.07	4.7	4.0	0.0	26.6	26.6	0.42
TOTAL	17.26	33.74	30.5	10572.3	5634.17	16206.5	

Table B1T. TOLAY CREEK - OVERALL WATER BUDGET AND FLOW MODEL FOR AN AVERAGE RAINFALL YEAR AT HIGHWAY 12 (EXISTING CONDITIONS)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.25	0.0	3.5	0.0	0.0	0.0	0.00
OCT	1.4	0.0	2.3	1.4	0.0	1.4	0.02
NOV	3.16	0.0	1.1	828.8	0.0	828.8	13.36
DEC	4.33	0.0	0.6	1354.4	58.8	1413.3	22.04
JAN	5.95	0.0	1.0	2128.4	127.1	2255.5	35.18
FEB	3.97	0.0	1.2	1188.6	212.4	1401.0	24.19
MAR	2.64	0.0	2.0	611.0	106.6	717.6	11.19
APR	1.71	0.0	2.8	265.1	56.7	321.9	5.19
MAY	0.31	0.0	3.5	0.0	41.0	41.0	0.64
JUN	0.17	0.0	4.5	0.0	11.7	11.7	0.19
JUL	0.05	0.0	4.0	0.0	4.3	4.3	0.07
AUG	0.08	0.0	4.0	0.0	1.6	1.6	0.02
TOTAL	**24.02**	**0.00**	**30.5**	**6377.8**	**620.15**	**6997.9**	

Table B2T. TOLAY CREEK - OVERALL WATER BUDGET AND FLOW MODEL FOR A DRY RAINFALL YEAR AT HIGHWAY 121 (EXISTING CONDITIONS)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.17	0.0	3.5	0.0	0.0	0.0	0.00
OCT	0.92	0.0	2.3	0.3	0.0	0.3	0.01
NOV	2.09	0.0	1.1	397.8	0.0	397.8	6.41
DEC	2.86	0.0	0.6	701.6	47.0	748.5	11.68
JAN	3.93	0.0	1.0	1170.4	100.6	1271.0	19.82
FEB	2.62	0.0	1.2	602.9	168.7	771.6	13.32
MAR	1.74	0.3	2.0	275.0	84.8	359.8	5.61
APR	1.13	0.0	2.8	98.2	44.9	143.1	2.31
MAY	0.2	0.0	3.5	0.0	32.7	32.7	0.51
JUN	0.11	0.0	4.5	0.0	9.3	9.3	0.15
JUL	0.03	0.0	4.0	0.0	3.4	3.4	0.05
AUG	0.05	0.0	4.0	0.0	1.3	1.3	0.02
TOTAL	**15.85**	**0.31**	**30.5**	**3246.3**	**492.66**	**3739.0**	

Table B3T. TOLAY CREEK - OVERALL WATER BUDGET AND FLOW MODEL FOR A WET RAINFALL YEAR AT HIGHWAY 121 (EXISTING CONDITIONS)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.33	0.0	3.5	0.0	0.0	0.0	0.00
OCT	1.86	0.0	2.3	2.9	0.0	2.9	0.04
NOV	4.2	0.0	1.1	1294.2	0.0	1294.2	20.86
DEC	5.76	0.0	0.6	2035.9	65.9	2101.8	32.78
JAN	7.91	0.0	1.0	3100.9	142.5	3243.4	50.59
FEB	5.28	0.0	1.2	1803.8	238.0	2041.7	35.26
MAR	3.51	0.0	2.0	981.7	230.5	1212.1	18.91
APR	2.27	0.0	2.8	465.2	109.9	575.1	9.27
MAY	0.41	0.0	3.5	0.0	64.4	64.4	1.00
JUN	0.23	0.0	4.5	0.0	22.3	22.3	0.36
JUL	0.07	0.0	4.0	0.0	4.8	4.8	0.08
AUG	0.11	0.0	4.0	0.0	1.8	1.8	0.03
TOTAL	31.94	0.00	30.5	9684.6	880.06	10564.6	

Table B4T. TOLAY CREEK - OVERALL WATER BUDGET AND FLOW MODEL FOR AN AVERAGE RAINFALL YEAR AT HIGHWAY 12 (WITH 80% IRRGATION EFFECIENCY)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.25	3.9	3.5	0.0	3.3	3.3	0.05
OCT	1.4	1.1	2.3	1.4	4.4	5.8	0.09
NOV	3.16	0.0	1.1	786.1	4.8	790.9	12.75
DEC	4.33	0.0	0.6	1300.2	68.0	1368.3	21.34
JAN	5.95	0.0	1.0	2062.8	141.7	2204.5	34.38
FEB	3.97	0.0	1.2	1137.6	233.8	1371.4	23.68
MAR	2.64	0.0	2.0	574.7	117.1	691.8	10.79
APR	1.71	1.3	2.8	242.8	62.9	305.6	4.93
MAY	0.31	3.8	3.5	0.0	44.9	44.9	0.70
JUN	0.17	5.2	4.5	0.0	12.8	12.8	0.21
JUL	0.05	4.7	4.0	0.0	4.7	4.7	0.07
AUG	0.08	4.7	4.0	0.0	1.7	1.7	0.03
TOTAL	**24.02**	**24.76**	**30.5**	**6105.6**	**700.03**	**6805.6**	

Table B5T. TOLAY CREEK - OVERALL WATER BUDGET AND FLOW MODEL FOR A DRY RAINFALL YEAR AT HIGHWAY 121 (WITH 80% IRRGATION EFFECIENCY)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.17	4.0	3.5	0.0	4.4	4.4	0.07
OCT	0.92	1.7	2.3	0.3	4.9	5.2	0.08
NOV	2.09	0.0	1.1	369.3	5.1	374.4	6.03
DEC	2.86	0.0	0.6	662.4	57.6	720.0	11.23
JAN	3.93	0.0	1.0	1119.8	113.9	1233.7	19.24
FEB	2.62	0.0	1.2	566.9	185.5	752.4	12.99
MAR	1.74	0.3	2.0	252.2	92.9	345.1	5.38
APR	1.13	2.0	2.8	86.3	49.5	135.8	2.19
MAY	0.2	4.0	3.5	0.0	35.5	35.5	0.55
JUN	0.11	5.3	4.5	0.0	10.1	10.1	0.16
JUL	0.03	4.8	4.0	0.0	3.7	3.7	0.06
AUG	0.05	4.7	4.0	0.0	3.9	3.9	0.06
TOTAL	**15.85**	**26.70**	**30.5**	**3057.2**	**567.16**	**3624.4**	

Table B6T. TOLAY CREEK - OVERALL WATER BUDGET AND FLOW MODEL FOR A WET RAINFALL YEAR AT HIGHWAY 121 (WITH 80% IRRGATION EFFECIENCY)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.33	3.8	3.5	0.0	3.3	3.3	0.05
OCT	1.86	0.5	2.3	2.9	4.4	7.3	0.11
NOV	4.2	0.0	1.1	1241.1	4.8	1245.9	20.08
DEC	5.76	0.0	0.6	1971.5	75.9	2047.4	31.93
JAN	7.91	0.0	1.0	3025.9	159.2	3185.1	49.68
FEB	5.28	0.0	1.2	1742.4	263.0	2005.4	34.63
MAR	3.51	0.0	2.0	935.2	255.1	1190.2	18.56
APR	2.27	0.6	2.8	434.0	122.2	556.2	8.96
MAY	0.41	3.7	3.5	0.0	71.1	71.1	1.11
JUN	0.23	5.1	4.5	0.0	24.7	24.7	0.40
JUL	0.07	4.7	4.0	0.0	5.3	5.3	0.08
AUG	0.11	4.7	4.0	0.0	1.9	1.9	0.03
TOTAL	**31.94**	**23.18**	**30.5**	**9353.0**	**990.79**	**10343.8**	

Table B7T. TOLAY CREEK - OVERALL WATER BUDGET AND FLOW MODEL FOR AN AVERAGE RAINFALL YEAR AT HIGHWAY 121 (WITH 80% IRRGATION EFFECIENCY) (20% REDUCTION PET FOR COOL SUMMER

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.25	3.9	3.5	0.0	8.9	8.9	0.14
OCT	1.4	1.1	2.3	1.4	9.6	11.0	0.17
NOV	3.16	0.0	1.1	786.1	10.1	796.2	12.83
DEC	4.33	0.0	0.6	1300.2	70.1	1370.3	21.37
JAN	5.95	0.0	1.0	2062.8	142.4	2205.2	34.40
FEB	3.97	0.0	1.2	1137.6	234.0	1371.6	23.69
MAR	2.64	0.0	2.0	574.7	117.1	691.8	10.79
APR	1.71	1.3	2.2	242.8	62.9	305.6	4.93
MAY	0.31	3.8	2.8	0.0	44.9	44.9	0.70
JUN	0.17	5.2	3.6	0.0	12.8	12.8	0.21
JUL	0.05	4.7	3.2	0.0	4.7	4.7	0.07
AUG	0.08	4.7	3.2	0.0	6.7	6.7	0.10
TOTAL	**24.02**	**24.68**	**26.7**	**6105.6**	**724.16**	**6829.8**	

Table B8T. TOLAY CREEK - OVERALL WATER BUDGET AND FLOW MODEL FOR A DRY RAINFALL YEAR AT HIGHWAY 121

(WITH 80% IRRGATION EFFECIENCY)
(WINTER IRRIGATION)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.17	4.0	3.5	0.0	4.9	4.9	0.08
OCT	0.92	1.7	2.3	0.3	5.0	5.3	0.08
NOV	2.09	1.5	1.1	369.3	5.1	374.4	6.03
DEC	2.86	1.5	0.6	662.4	74.5	736.9	11.49
JAN	3.93	1.5	1.0	1119.8	155.9	1275.7	19.90
FEB	2.62	1.5	1.2	566.9	255.1	822.0	14.19
MAR	1.74	1.5	2.0	252.2	127.7	379.9	5.92
APR	1.13	2.0	2.8	86.3	69.3	155.6	2.51
MAY	0.2	4.0	3.5	0.0	49.0	49.0	0.76
JUN	0.11	5.3	4.5	0.0	17.4	17.4	0.28
JUL	0.03	4.8	4.0	0.0	7.5	7.5	0.12
AUG	0.05	4.7	4.0	0.0	5.3	5.3	0.08
TOTAL	15.85	33.89	30.5	3057.2	776.69	3833.9	

Table B1A. AMERICANO CREEK - OVERALL WATER BUDGET AND FLOW MODEL FOR AN AVERAGE RAINFALL YEAR AT VALLEY FORI (EXISTING CONDITIONS)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.71	0.0	3.5	8.5	0.5	0.8	0.01
OCT	2.12	0.0	2.3	23.7	0.0	23.7	0.37
NOV	4.79	0.0	1.1	2993.7	0.0	2993.7	48.25
DEC	5.38	0.0	0.6	3587.7	224.8	3812.5	59.47
JAN	7.29	0.0	1.0	5597.7	474.8	6072.5	94.71
FEB	4.84	0.0	1.2	3043.4	763.7	3807.1	65.74
MAR	4.28	0.0	2.0	2495.3	741.4	3236.7	50.48
APR	1.68	0.0	2.8	373.7	355.4	729.1	11.75
MAY	0.34	0.0	3.5	0.0	200.0	200.0	3.12
JUN	0.11	0.0	4.5	0.0	74.9	74.9	1.21
JUL	0.03	0.0	4.0	0.0	16.8	16.8	0.26
AUG	0.08	0.0	4.0	0.0	6.0	6.0	0.09
TOTAL	**31.65**	**0.00**	**30.5**	**18123.8**	**2858.22**	**20973.8**	

Table B2A. AMERICANO CREEK - OVERALL WATER BUDGET FOR STEMPLE CREEK FOR A DRY RAINFALL YEAR AT VALLEY FORD (EXISTING CONDITIONS)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.41	0.0	3.5	0.0	0.0	0.0	0.00
OCT	1.24	0.0	2.3	0.8	0.0	0.8	0.01
NOV	2	0.0	1.1	559.8	0.0	559.8	9.02
DEC	2.54	0.0	0.6	944.0	155.7	1099.7	17.15
JAN	4.91	0.0	1.0	3078.0	367.4	3445.3	53.74
FEB	3.63	0.0	1.2	1859.7	613.6	2473.3	42.71
MAR	3.29	0.0	2.0	1558.6	596.5	2155.1	33.61
APR	0.95	0.0	2.8	52.9	287.7	340.5	5.49
MAY	0.54	0.0	3.5	0.0	165.7	165.7	2.58
JUN	0.1	0.0	4.5	0.0	57.5	57.5	0.93
JUL	0.08	0.0	4.0	0.0	12.3	12.3	0.19
AUG	0.12	0.0	4.0	0.0	4.4	4.4	0.07
TOTAL	**19.81**	**0.00**	**30.5**	**8053.6**	**2260.72**	**10314.4**	

Table B3A. AMERICANO CREEK - OVERALL WATER BUDGET FOR STEMPLE CREEK FOR A WET RAINFALL YEAR AT VALLEY FORD (EXISTING CONDITIONS)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.67	0.0	3.5	4.4	1.2	1.2	0.02
OCT	2.72	0.0	2.3	20.9	0.0	20.9	0.33
NOV	7.24	0.0	1.1	5497.1	0.0	5497.1	88.60
DEC	7.66	0.0	0.6	5949.9	284.8	6234.8	97.25
JAN	10.47	0.0	1.0	9051.0	585.9	9636.9	150.31
FEB	6.3	0.0	1.2	4499.5	906.0	5405.5	93.34
MAR	5.96	0.0	2.0	4145.0	907.0	5052.0	78.80
APR	2.53	0.0	2.8	936.3	430.0	1366.3	22.02
MAY	0.13	0.0	3.5	0.0	235.2	235.2	3.67
JUN	0.2	0.0	4.5	0.0	96.1	96.1	1.55
JUL	0	0.0	4.0	0.0	22.0	22.0	0.34
AUG	0.12	0.0	4.0	0.0	7.9	7.9	0.12
TOTAL	44	0.00	30.5	30104.2	3476.22	33576.1	

Table B4A. AMERICANO CREEK - OVERALL WATER BUDGET FOR STEMPLE CREEK FOR AN AVERAGE RAINFALL YEAR AT VALLEY FO (WITH 80% IRRIGATION EFFECIENCY)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.71	3.3	3.5	4.9	17.2	17.2	0.28
OCT	2.12	0.2	2.3	10.1	17.4	27.6	0.43
NOV	4.79	0.0	1.1	2593.5	17.9	2611.4	42.09
DEC	5.38	0.0	0.6	3147.7	298.8	3446.5	53.76
JAN	7.29	0.0	1.0	5053.0	615.2	5668.2	88.41
FEB	4.84	0.0	1.2	2639.6	957.4	3597.0	62.11
MAR	4.28	0.0	2.0	2133.0	961.2	3094.2	48.26
APR	1.68	1.3	2.8	265.9	460.2	726.1	11.70
MAY	0.34	3.8	3.5	0.0	251.8	251.8	3.93
JUN	0.11	5.3	4.5	0.0	103.5	103.5	1.67
JUL	0.03	4.8	4.0	0.0	25.7	25.7	0.40
AUG	0.08	4.7	4.0	0.0	17.9	17.9	0.28
TOTAL	31.65	23.44	30.5	15847.8	3744.24	19587.1	

Table B5A. AMERICANO CREEK - OVERALL WATER BUDGET FOR STEMPLE CREEK FOR A WET RAINFALL YEAR AT VALLEY FORD (WITH 80% IRRIGATION EFFECIENCY)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.67	3.4	3.5	2.6	14.0	14.0	0.23
OCT	2.72	0.0	2.3	20.9	15.8	36.8	0.57
NOV	7.24	0.0	1.1	5001.4	6.6	5008.0	80.71
DEC	7.66	0.0	0.6	5436.7	341.8	5778.5	90.13
JAN	10.47	0.0	1.0	8444.2	711.2	9155.3	142.80
FEB	6.3	0.0	1.2	4047.6	1099.9	5147.5	88.89
MAR	5.96	0.0	2.0	3710.5	1138.5	4849.1	75.63
APR	2.53	0.3	2.8	751.2	543.2	1294.3	20.86
MAY	0.13	4.0	3.5	0.0	293.3	293.3	4.58
JUN	0.2	5.2	4.5	0.0	130.4	130.4	2.10
JUL	0	4.8	4.0	0.0	31.3	31.3	0.49
AUG	0.12	4.7	4.0	0.0	11.2	11.2	0.18
TOTAL	**44**	**22.38**	**30.5**	**27415.1**	**4337.15**	**31749.6**	

Table B6A. AMERICANO CREEK - OVERALL WATER BUDGET FOR STEMPLE CREEK FOR A DRY RAINFALL YEAR AT VALLEY FORD (WITH 80% IRRIGATION EFFECIENCY)

MONTH	PRECIP (INCHES)	IRRIG. (INCHES)	P ET (INCHES)	RUNOFF (AC-FT)	RETURN SHALLOW GW (AC-FT)	OUTFLOW OF WATERSHED (AC-FT)	AVERAGE STREAM FLOW (CFS)
SEPT	0.41	3.7	3.5	0.0	16.8	16.8	0.27
OCT	1.24	1.3	2.3	0.8	17.5	18.3	0.28
NOV	2	0.0	1.1	427.6	17.7	445.4	7.18
DEC	2.54	0.0	0.6	757.8	196.1	953.9	14.88
JAN	4.91	0.0	1.0	2704.5	437.4	3141.9	49.00
FEB	3.63	0.0	1.2	1577.6	718.7	2296.2	39.65
MAR	3.29	0.0	2.0	1304.5	726.0	2030.4	31.67
APR	0.95	2.2	2.8	31.7	351.8	383.6	6.18
MAY	0.54	3.6	3.5	0.0	199.5	199.5	3.11
JUN	0.1	5.3	4.5	0.0	77.0	77.0	1.24
JUL	0.08	4.7	4.0	0.0	22.6	22.6	0.35
AUG	0.12	4.7	4.0	0.0	16.4	16.4	0.26
TOTAL	**19.81**	**25.39**	**30.5**	**6804.5**	**2797.53**	**9602.0**	