ESTIMATION OF NITROGEN, SALT AND HERBICIDE/PESTICIDE CONCENTRATIONS IN SURFACE WATER, AND MASS LOADING ANALYSIS FROM IRRIGATION WITH RECLAIMED WATER, WEST COUNTY AND SOUTH COUNTY ALTERNATIVES

SANTA ROSA SUBREGIONAL LONG-TERM WASTEWATER PROJECT

Prepared for

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

APRIL 1996

Prepared by

QUESTA ENGINEERING CORPORATION
1220 BRICKYARD COVE ROAD, POINT RICHMOND, CA 94807 ! 510/236-6114

For

HARLAND BARTHOLOMEW & ASSOCIATES, INC.

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1.0 INTRODUCTION

This report presents the results of the integration of the Cropping Scenarios Technical Memorandum developed by Questa Engineering Corp. (September, 1995) with the detailed, localized hydrology and water quality modeling performed for the project by U.C. Davis Professor K. Tanji, entitled *Water Quality Evaluations on Wastewater Irrigation in West and South County Alternatives*, *Santa Rosa Long-Term Wastewater Project* (July 1995). The Tanji model provides an estimate of nitrates, salts and pesticides in irrigation return flow drainage waters to nearby streams, and loading to groundwater for various irrigated crops, based on an assumed 100-acre parcel. The modeling is presented as a series of case studies in which various crops with differing management requirements are evaluated in detail. Therefore, it does not in itself provide a project or watershed-wide basis for water quality analysis.

The Tanji hydrology and irrigation drainage water quality model predicts the concentration of parameters at two time periods of biological interest. These are:

1. The spring, when there is abundant flow and biological activity in the creek, but when irrigation, which is just being initiated, has a relatively small contribution to the overall flow compared to rainfall-fed baseflow.

2. The summer, when flow in the creek is essentially reduced to a trickle and where the occasional lingering pool is thought to largely represent irrigation contributed baseflow.

Combining this analysis with the Cropping Scenarios report provides the basis for the evaluation of a mix of different, contrasting kinds of crops (i.e., crops with differing levels of agrochemical management needs). The integration of these two reports yields an overview of probable surface water quality effects from irrigation using reclaimed water on certain streams in the South County and West County project areas. This report focuses on the effects of translocation of chemicals in applied irrigation water to surface water as well as the effect of agrochemical use. Specifically addressed in the analysis are nitrate-nitrogen, salts (as total dissolved solids or TDS) and two herbicides/pesticides (2,4, D and carbaryl).

2.0 RELATED STUDIES

The reader is referred to several related Technical Memoranda which provide additional background on project hydrology, water quality effects and irrigation management approaches including:

1. Baseline Hydrology And Irrigation Drainage Evaluation For West And South County Reclamation Alternatives (Questa Engineering Corp., November 1995).

2. Irrigation Nitrogen Loading to Groundwater, West County and South County Reclamation Alternatives (Questa Engineering Corp., November 1995).

3. Water Quality Evaluations on Wastewater Irrigation in West County and South County Alternatives, Santa Rosa Long-Term Wastewater Project (Professor K. Tanji, U.C. Davis, July 1995).

4. Evaluation of Metals in Irrigation Affected Percolate, West County and South County Alternatives(Questa Engineering, April, 1996)

5. Trace Element Soil Loading Analysis for the South and West County Reclamation Alternatives (Questa Engineering Corp., September 1995)

6. Evaluation of Soil Erosion Impacts of the West and South County Alternatives (Questa Engineering Corp., September 1995)

7. Estimated Temperature of Irrigation Subflow Intercepted by Surface Streams, West County and South County Reclamation Project (Questa Engineering Corp., October, 1995).

8. Irrigation Management Plan for the West County and South County Alternatives, (Questa Engineering Corp., November, 1995).

9. Cropping Scenarios Technical Memorandum (Questa Engineering Corp., September, 1995)

3.0 APPROACH

Because of the required differences in modeling approach, the effects of metals additions from irrigation with reclaimed water on surface and groundwater are dealt with in a separate technical memorandum (see *Evaluation of Metals in Irrigation Affected Percolate, West County and South County Alternatives* (Questa Engineering, April, 1996). Nitrate impacts on shallow groundwater are also described in a separate technical memorandum.

Three streams were selected for analysis based on the likelihood of significant irrigation return flow impacts: Stemple and Americano Creeks in the West County and Tolay Creek in the South County. Watershed hydrology and the rationale for selecting these streams is further discussed in *Baseline Hydrology and Irrigation Drainage Evaluation for West and South County Reclamation Alternatives* (Questa, November 1995). Water quality effects from irrigation of Baylands areas are also discussed in a separate technical memorandum.

Metals behave much differently than nutrients, salts and, to a certain extent, pesticides in the soil and shallow zone groundwater. Various mechanisms exist in the soils which can partially retain or immobilize metals, preventing their translocation to groundwater. These attenuation mechanisms are discussed more fully in *Evaluation of Metals in Irrigation Affected Percolate, West County and South County Alternatives* (Questa Engineering, April, 1996). Such attenuation mechanisms are accounted for in the metals model by use of an estimated uptake coefficient. On the other hand, nitrogen transformations in an irrigated agricultural system are more complex and involve many input variables (manure, fertilizer, atmospheric N fixation, resident N in soil, and N in irrigation water) and output functions (crop uptake, soil storage, denitrification, and movement with groundwater).

When considering the attenuation of nitrogen, biological processes are most important; physical and chemical reactions are secondary factors. These various complex and interrelated functions and transformations are considered in the Tanji irrigation water quality model. Since the input and output functions may vary considerably depending upon the crop grown, farm management practices, and local soil and micro-climate conditions, the Tanji model individually evaluates various irrigated crops that could be raised in the West and South County areas. For example, corn and sudan silage crops have a high nitrogen demand and are typically fertilized with chemical fertilizers and/or animal wastes. In certain circumstances, they may require management of aggressive weeds through use of herbicides such as 2,4,D. The N in the reclaimed water can only partially meet the crop's N requirements. Irrigated pasture, once established, may receive no nitrogen fertilizer beyond that contained in the reclaimed water and occasional manure applications. Herbicides and insecticides are very seldom used. Other crops that could be grown in the West or South County, such as lettuce, melon or strawberries, may require extensive use of herbicides, pesticides and fertilizers. These functions are all assessed in the Tanji water quality model.

The basis for the Tanji model is a 100-acre agricultural field in which various types of crops are grown under good irrigation and farm management practices outlined in the Irrigation Management Plan. The crops have different agrochemical inputs and differing nitrogen requirements. Local soil types, climatic conditions, irrigation techniques and farm management practices are considered in a series of "case study" crops which allow for assessment of potential impacts. The model assesses average annual irrigation return flow discharge to the adjacent stream (in cfs and acre-feet) and predicts the concentration of N, TDS and herbicides/pesticides in mg/*l* for each of the 100-acre case study crops.

With some restrictions, each privately owned farm or ranch will choose individually which crops to grow. Consequently, it is not possible to predict the precise amount and type of crop grown within each watershed. Therefore, when considering the irrigation water quality effects of differing prospective irrigated crops on a watershed-wide basis, certain cropping scenario assumptions were made. The Cropping Scenarios Technical Memorandum presents possible project-wide future irrigation agricultural land uses under three contrasting levels or intensities of agricultural development. On the basis of soil and micro-climate suitability for crop production, possible acreages are presented by crop category (as shown in Appendix B) for: 1) Low Tech, 2) Medium Tech, and 3) High Tech agricultural land use scenarios. These are defined as follows:

1. The Low Tech scenario assumes suitable land will be used for irrigated pasture and forage crops. These crops have lower management requirements. This scenario represents the lowest acreage of crops that use agrochemicals.
2. The Medium Tech scenario assumes suitable lands will be utilized for forage, hay or silage production, and lesser acreage in specialty or vegetable crops and irrigated pasture. This scenario represents the largest area of crops with high N demand, and where use of manure and N fertilizer may be widespread.
3. The High Tech scenario assumes suitable lands in the project alternative areas are to be utilized for more intensively managed crops such as vineyards, orchards, specialty crops (melon, strawberries, etc.) and truck crops (vegetables), with little acreage in forage or irrigated pasture. This scenario represents the highest mix of crops that would use herbicides and pesticides.

These same scenarios are used in examining possible soil erosion impacts and the effects of a reclaimed water irrigation project on the area's agricultural economy. The levels of farming intensity examined (with respect to agrochemical additions) include, from highest to lowest:

1. Vineyards and orchards (none assumed for the three creeks studied);
2. Specialty crops such as strawberries, artichokes and melons;
3. Vegetable crops such as cool season vegetables (lettuce, broccoli, green beans) and potatoes;
4. Forage, hay or silage crops (irrigated hay, sudan grass, field corn); and,

5. Improved, irrigated permanent pasture.

Since not every possible crop can be modeled, the crops selected for evaluation must serve as representative or benchmark crops indicative of a common level of management and likely water quality effect. Strawberries were selected as representative of specialty crops for water quality modeling for the Stemple and Americano Creek watersheds, and melons for Tolay Creek. Lettuce and potatoes were used as the benchmark vegetable crop for all three areas, and sudan grass was used as the benchmark for the forage crop, with irrigated pasture as the lowest intensity crop in all areas.

As described in the Tanji Technical Memorandum, a number of assumptions are made for each crop evaluated regarding typical nitrogen requirements, fertilizer and manure application rates and irrigation amounts. These are based on discussions with U.C. Cooperative Extension Service, records available from the Sonoma County Agricultural Commissioner's office, and consultation with the project agronomist, Vern Marble, Ph.D.

Based on management needs, a large number of new herbicides and pesticides (insecticides, fungicides, etc.) potentially could be used in the West or South County project areas. Two of the most common currently used in Sonoma County (the herbicide 2,4,D and the insecticide carbaryl [trade name Sevin]) were selected as representative of possible water quality impacts. In part, their selection was based on knowledge of their behavior, toxicity and modeling capabilities.

The modeling assumed that all areas of forage crops would have 2,4,D applied and all areas of specialty and vegetable crops would have carbaryl applied at common application rates. This represents a worst-case scenario. In reality, only a portion of the forage crop lands would likely need herbicide management in any year, and a wide variety of pesticides would be used, in addition to and instead of carbaryl. The modeling also assumes direct runoff of some irrigation water to the adjacent creeks (one to two percent). This is a worst case assumption that will largely be controlled by implementing the Irrigation Management Plan.

4.0 PREDICTING WATERSHED STREAM WATER QUALITY EFFECTS

An estimate or prediction of the average annual concentration of nitrates, salts and herbicides/pesticides from study area watersheds was made by combining the cropping scenario acreages by crop type (e.g., High Tech = 600 acres of specialty crops and 500 acres of vegetables, etc.) with the Tanji agricultural water quality model for each 100 acres of crop. Since some crops have higher (or lower) stream discharges and different water quality effects than other crops, the discharge and concentration must be normalized or proportioned on a watershed-wide basis to properly estimate water quality impact. This can be accomplished by using the following weighted average formula:

$$Cw = \frac{(A_A)(Q_A)(C_A) + (A_B)(Q_B)(C_B) ... + (A_N)(Q_N)(C_N)}{Q_A + Q_B + ... + Q_N}$$

where:

Cw = Composite concentration (of nitrate, salts, pesticides) for watershed area.

A_A, A_B, etc. = number of 100 acres of Crop, A, Crop B, etc.

An = number of 100 acres of non-irrigated area.

Q_A, Q_B, etc. = Predicted discharge per 100 acres of Crop A, Crop B, etc. per Tanji model (cfs)

Q_N = Predicted discharge per 100 acres of non-irrigated land per Tanji model (cfs).

C_A, C_B, etc. = Predicted concentration (of nitrate, salts, pesticides) per 100 acres of Crop A, Crop B, etc. per Tanji model (mg/l).

C_N = Predicted concentration (of nitrate, salts, pesticides) per 100 acres of non-irrigated land per Tanji model (mg/l).

Since each cropping scenario has a different mix of crop types with different water quality effects, separate analyses are presented for the Low Tech, Medium Tech and High Tech scenarios. The results of integrating the Cropping Scenarios acreages for Low Tech, Medium Tech and High Tech are summarized in **Table 1** in Appendix A for each creek system evaluated. The individual computational tables are included in Appendix B.

The results of the model integration indicate that the Medium Tech cropping scenario will have the greatest overall effect on nitrogen increases in the creeks, with summer increases of nitrate-nitrogen from two (2) to 3.7 mg/l, or about 75 percent. Improved management of manure in the West County watershed, which is not directly assessed in the Tanji model but is an important element of the Irrigation Management Plan, may actually result in reductions in overall nitrogen concentrations in surface water.

The herbicide 2,4,D, which is assumed in the modeling to be in widespread use in the watershed on forage crop lands, is predicted to exist at concentrations in the range of parts per trillion for the Medium Tech scenario. These concentrations would be below detection levels for routine field and laboratory monitoring, but possibly detectable in more sophisticated research laboratories. If it is assumed that 2,4,D or other similar herbicides will actually be applied in any cropping year to only about 25 percent of the forage crop lands, then the predicted herbicide concentration would likely be below detection limits achievable in research facilities. Similarly, even when the non-persistent insecticide carbaryl (Sevin) is assumed to be widely applied to all specialty crops and vegetables crops, the model predicts concentrations at or below the detection limits of research grade laboratory instruments.

The most significant increase predicted by the water quality modeling is in salt discharge to the estuaries. Increases of more than three times in the salt content of return flow irrigation tail water to surface water are predicted for all streams. While this may seem somewhat surprising given the high quality-low TDS of the reclaimed water, it is due to the concentration of salts that occurs from evapotranspiration of the applied water. Salts, which are not accumulated to any significant extent in the growing crops and are relatively mobile in the soil environment, are easily transported through the watershed soils through rainfall and applied irrigation water. Virtually all salts added to the watershed eventually will be discharged to the estuaries. This predicted increase in the annual mass discharge of salts from project watershed lands should be put into proper perspective. The salt discharge from watershed runoff and subflow represents a very small amount of salt (estimated less than one percent) compared to the salts entering the estuaries with tidal inflow. The effects of this are discussed in the *Water Quality Impact Analysis Technical Report* (Meritt-Smith Consultants, April, 1996).

5.0 MASS DISCHARGE

Mass discharge refers to the total discharge quantity of an element such as nitrogen, salts or pesticides, in kilograms, pounds or tons, reported on an annual basis. Basically, it represents the multiplication of concentration with volume. The point of interest is the discharge of these constituents to the Estero Americano, Estero de San Antonio and the mouth of Tolay Creek at San Pablo Bay. Using the Tanji model, mass discharges of nitrate-nitrogen and salt can be estimated for the existing conditions scenario and compared with the Low Tech, Medium Tech and High Tech cropping scenarios. The results of the mass loading analysis are summarized in **Tables 2** and **3** in Appendix A; the calculation sheets are included in tables in Appendix B.

The capability of the watershed's soil-hydrologic system to retain these compounds can also be approximated. This can be accomplished by comparing the total load applied to each watershed in irrigation water (for nitrates and salts) with the stream mass loading discharge (**Table 4**). The difference between the two is an approximation of watershed retention or concentration (some salts and N are added from fertilizers, manure and imported feeds). For nitrogen, over 99 percent of the irrigation applied load is retained in the soil or crop. Salts, being relatively soluble and mobile, are retained in the watershed to a much less significant extent (84%).

The greatest increase in mass loading are: 1) for the Medium Tech scenario for nitrogen, about a 10-percent increase; and 2) the High Tech scenario for salts, an approximately 300-percent increase. Existing conditions assume essentially no detectable herbicides/pesticides in the surface water.

APPENDIX A
Tables

Table 1 Summary of Irrigation Water Quality Effects

	Discharge (ac-ft)	Salt TDS (mg/l)	Nitrogen (mg/l)	2,4,D (mg/l)	Carbaryl (mg/l)
STEMPLE CREEK					
Summer					
Low Tech	1019.33	1376.92	3.47	2.71E-06	2.03E-08
Med Tech	1091.18	1638.89	3.67	6.32E-06	5.63E-08
High Tech	940.93	1676.46	3.31	5.86E-06	1.88E-07
Existing Cond.	95.65	500	2	0	0
Winter					
Low Tech	7140.30	175.51	0.83	0	0
Med Tech	7488.45	163.76	0.90	0	0
High Tech	7372.40	167.56	0.96	0	0
Existing Cond.	6908.2	184	0.8	0	0
AMERICANO CREEK					
Summer					
Low Tech	769.83	1319.08	3.43	1.47E-06	1.79E-08
Med Tech	675.65	1549.34	3.51	4.57E-06	8.14E-08
High Tech	583.38	1644.36	3.01	4.32E-06	2.83E-07
Existing Cond.	51.03	500	2	0	0
Winter					
Low Tech	3875.40	171.20	0.84	0	0
Med Tech	4202.45	151.87	0.95	0	0
High Tech	4107.50	157.17	1.08	0	0
Existing Cond.	3685.5	184	0.8	0	0

Table 1, Continued

TOLAY CREEK					
Summer					
Low Tech	232.26	2077.90	3.44	3.78E-06	4.91E-08
Med Tech	219.46	2322.57	3.33	5.00E-06	1.30E-07
High Tech	204.62	2543.09	3.18	5.80E-06	2.23E-07
Existing Cond.	0	0	0	0	0
Winter					
Low Tech	1583.46	248.55	0.75	0	0
Med Tech	1600.66	250.57	0.76	0	0
High Tech	1607.54	251.37	0.77	0	0
Existing Cond.		450	.75	0	0

Ref.: 93012EST.T1

TABLE 2
NITROGEN MASS LOADING SUMMARY

STEMPLE CREEK

	LOW			MED			HIGH			EXISTING		
	Area (Acres)	Nitrogen (lbs/100 ac)	Total (lbs)	Area (Acres)	Nitrogen (lbs/100 ac)	Total (lbs)	Area (Acres)	Nitrogen (lbs/100 ac)	Total (lbs)	Area (Acres)	Nitrogen (lbs/100 ac)	Total (lbs)
Specialty Crops (Strawberries)	0	89	0	450	89	401	1,800	89	1,602	0	89	0
Vegetable (lettuce/potatoes)	300	111	333	600	111	666	1,400	111	1,554	100	111	111
Silage (Sudan Grass)	1,100	268	2,948	2,750	268	7,370	2,200	268	5,896	200	268	536
Pasture	4,800	193	9,264	2,400	193	4,632	800	193	1,544	200	193	386
Other/fallow (non irrigated)	20,370	155	31,574	20,370	155	31,574	20,370	155	31,574	26,070	155	40,409
Total			**44,119**			**44,642**			**42,170**			**41,442**

AMERICANO CREEK

	LOW			MED			HIGH			EXISTING		
	Area (Acres)	Nitrogen (lbs/100 ac)	Total (lbs)	Area (Acres)	Nitrogen (lbs/100 ac)	Total (lbs)	Area (Acres)	Nitrogen (lbs/100 ac)	Total (lbs)	Area (Acres)	Nitrogen (lbs/100 ac)	Total (lbs)
Specialty Crops (Strawberries)	0	89	0	400	89	356	1,700	89	1,513		89	0
Vegetable (lettuce/potatoes)	200	111	222	540	111	599	1,300	111	1,443		111	0
Silage (Sudan Grass)	900	268	2,412	2,450	268	6,566	2,000	268	5,360		268	0
Pasture	4,370	193	8,434	2,080	193	4,014	470	193	907		193	0
Other/fallow (non irrigated)	8,705	155	13,493	8,705	155	13,493	8,705	155	13,493	14,175	155	21,971
Total			**24,561**			**25,029**			**22,716**			**21,971**

TOLAY CREEK

	LOW			MED			HIGH			EXISTING		
	Area (Acres)	Nitrogen (lbs/100 ac)	Total (lbs)	Area (Acres)	Nitrogen (lbs/100 ac)	Total (lbs)	Area (Acres)	Nitrogen (lbs/100 ac)	Total (lbs)	Area (Acres)	Nitrogen (lbs/100 ac)	Total (lbs)
Specialty Crops (Strawberries)	0	97	0	200	97	193	400	97	386	0	97	0
Vegetable (lettuce/potatoes)	200	90	180	300	90	270	400	90	360	100	90	90
Silage (Sudan Grass)	400	366	1,464	500	366	1,830	540	366	1,976	0	366	0
Pasture	940	175	1,645	540	175	945	200	175	350	0	175	0
Other/fallow (non irrigated)	5,440	160	8,704	5,440	160	8,704	5,440	160	8,704	6,880	160	11,008
Total			**11,993**			**11,942**			**11,776**			**11,098**

Ref.: 93012SUM

TABLE 3
SALT (TDS) MASS LOADING SUMMARY

STEMPLE CREEK

	LOW			MED			HIGH			EXISTING		
	Area (Acres)	TDS (lbs/100 ac)	Total (lbs)	Area (Acres)	TDS (lbs/100 ac)	Total (lbs)	Area (Acres)	TDS (lbs/100 ac)	Total (lbs)	Area (Acres)	TDS (lbs/100 ac)	Total (lbs)
Specialty Crops (Strawberries)	0	50,980	0	450	50,980	229,410	1,800	50,980	917,640	0	50,980	0
Vegetable (lettuce/potatoes)	300	52,603	157,808	600	52,603	315,615	1,400	52,603	736,435	100	52,603	52,603
Silage (Sudan Grass)	1,100	58,430	642,730	2,750	58,430	1,606,825	2,200	58,430	1,285,460	200	58,430	116,860
Pasture	4,800	61,384	2,946,432	2,400	61,384	1,473,216	800	61,384	491,072	200	61,384	122,768
Other/fallow (non irrigated)	20,370	18,766	3,822,634	20,370	18,766	3,822,634	20,370	18,766	3,822,634	26,070	18,766	4,892,296
Total			**7,569,604**			**7,447,700**			**7,253,241**			**5,184,527**

AMERICANO CREEK

	LOW			MED			HIGH			EXISTING		
	Area (Acres)	TDS (lbs/100 ac)	Total (lbs)	Area (Acres)	TDS (lbs/100 ac)	Total (lbs)	Area (Acres)	TDS (lbs/100 ac)	Total (lbs)	Area (Acres)	TDS (lbs/100 ac)	Total (lbs)
Specialty Crops (Strawberries)	0	50,980	0	400	50,980	203,920	1,700	50,980	866,660	0	50,980	0
Vegetable (lettuce/potatoes)	200	52,603	105,205	540	52,603	284,054	1,300	52,603	683,833	0	52,603	0
Silage (Sudan Grass)	900	58,430	525,870	2,450	58,430	1,431,535	2,000	58,430	1,168,600	50	58,430	29,215
Pasture	4,370	61,384	2,682,481	2,080	61,384	1,276,787	470	61,384	288,505	100	61,384	61,384
Other/fallow (non irrigated)	8,705	18,766	1,633,580	8,705	18,766	1,633,580	8,705	18,766	1,633,580	14,025	18,766	2,631,932
Total			**4,947,136**			**4,829,876**			**4,641,178**			**2,722,531**

TOLAY CREEK

	LOW			MED			HIGH			EXISTING		
	Area (Acres)	TDS (lbs/100 ac)	Total (lbs)	Area (Acres)	TDS (lbs/100 ac)	Total (lbs)	Area (Acres)	TDS (lbs/100 ac)	Total (lbs)	Area (Acres)	TDS (lbs/100 ac)	Total (lbs)
Specialty Crops (Strawberries)	0	70,944.5	0	200	70,944.5	0	400	70,944.5	0	0	70,944.5	0
Vegetable (lettuce/potatoes)	200	88,149	176,298	300	88,149	264,447	400	88,149	352,596	100	88,149	88,149
Silage (Sudan Grass)	400	109,229	436,916	500	109,229	546,145	540	109,229	589,837	0	109,229	0
Pasture	940	78,820	740,908	540	78,820	425,628	200	78,820	157,640	0	78,820	0
Other/fallow (non irrigated)	5,440	99,957	5,437,661	5,440	99,957	5,437,661	5,440	99,957	5,437,661	6,880	99,957	6,877,042
Total			**6,791,783**			**6,673,881**			**6,537,733**			**6,965,191**

Ref.: 93012SUM

Table 4 Watershed Loading Analysis

	Stemple	Americano	Tolay
Irrigation Application (ft)	1.9	1.9	2.8
Irrigated Acreage	6,200	5,470	1,540
Total Application (acre-feet)	11,780	10,393	4,312
Total Watershed Loading [1]			
wastewater = 11.2 mg/l N	358,713 lbs	316,450 lbs	131,320 lbs
wastewater = 450 mg/l TDS	14,412,570 lbs	12,715,608 lbs	5,276,718 lbs
Net Total Watershed Discharge [2] (Table 3)			
N (Medium Tech)	3,200	3,058	844
TDS (Medium Tech)	2,263,173	2,107,345	(-291,310)
Retention in Watershed N - (%)	99.1	99.0	99.4
TDS (%)	84.3	84.5	--

1 Total mass loading applied to watershed in wastewater (volume multiplied by concentration).
2 Total mass load in stream discharge attributed to project Medium Tech (project discharge less existing condition discharge).

Ref.: 93012EST.T4

APPENDIX B
Model Calculations

Watershed Americano Creek
Modeling Scenario **High Tech**
Season **Summer**
Area (acres) **14175**

Crop Distribution	Area (acres)	Stream Outflow Concentration (mg/l) Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	Runoff Volume per 100 acres (ac-ft)
Speciality Crops (strawberries)	1700	1875	1.5	0	6E-07	7.4
Vegetable (lettuce/potatoes)	1300	1310	2.5	0	6E-07	11.5
Silage (sudan grass)	2000	2040	4.3	1.2E-05	0	10.5
Pasture	470	1251	3.4	0	0	14.2
Subtotal (irrigated lands)	**5470**					
Other/fallow (non irrigated)	8705	500	2	0	0	0.36
Total	**14175**					**583.38**
Weighted Average Concentrations for Stream Outflow (mg/l)		**1644.36**	**3.01**	**4.32E-06**	**2.83E-07**	

Ref: NUT_AMSH

Watershed	Americano Creek
Modeling Scenario	**Low Tech**
Season	**Summer**
Area (acres)	**14175**

Crop Distribution	**Area (acres)**	**Stream Outflow Concentration (mg/l)** Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	**Runoff Volume per 100 acres (ac-ft)**
Speciality Crops (strawberries)	0	1875	1.5	0	6E-07	7.4
Vegetable (lettuce/potatoes)	200	1310	2.5	0	6E-07	11.5
Silage (sudan grass)	900	2040	4.3	1.2E-05	0	10.5
Pasture	4370	1251	3.4	0	0	14.2
Subtotal (irrigated lands)	**5470**					
Other/fallow (non irrigated)	8705	500	2	0	0	0.36
Total	**14175**					**769.38**
Weighted Average Concentrations for Stream Outflow (mg/l)		**1319.08**	**3.43**	**1.47E-06**	**1.79E-08**	

Ref: NUT_AMSL

Watershed	Americano Creek
Modeling Scenario	**Med Tech**
Season	**Summer**
Area (acres)	**14175**

Crop Distribution	**Area (acres)**	**Stream Outflow Concentration (mg/l)** Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	**Runoff Volume per 100 acres (ac-ft)**
Speciality Crops (strawberries)	400	1875	1.5	0	6E-07	7.4
Vegetable (lettuce/potatoes)	540	1310	2.5	0	6E-07	11.5
Silage (sudan grass)	2450	2040	4.3	1.2E-05	0	10.5
Pasture	2080	1251	3.4	0	0	14.2
Subtotal (irrigated lands)	**5470**					
Other/fallow (non irrigated)	8705	500	2	0	0	0.36
Total	**14175**					**675.65**
Weighted Average Concentrations for Stream Outflow (mg/l)		**1549.34**	**3.51**	**4.57E-06**	**8.14E-08**	

Ref: NUT_AMSM

Watershed Americano Creek
Modeling Scenario High Tech
Season Winter
Area (acres) 14175

Crop Distribution	Area (acres)	Stream Outflow Concentration (mg/l) Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	Runoff Volume per 100 acres (ac-ft)
Speciality Crops (strawberries)	1700	184	2.5	0	0	26
Vegetable (lettuce/potatoes)	1300	184	0.8	0	0	26
Silage (sudan grass)	2000	67	1.2	0	0	47.1
Pasture	470	184	0.8	0	0	26
Subtotal (irrigated lands)	**5470**					
Other/fallow (non irrigated)	8705	184	0.8	0	0	26
Total	**14175**					**4107.50**
Weighted Average Concentrations for Stream Outflow (mg/l)		**157.17**	**1.07**	**0.00E+00**	**0.00E+00**	

Ref: NUT_AMWH

Watershed Americano Creek

Modeling Scenario **Low Tech**

Season **Winter**

Area (acres) **14175**

Crop Distribution	Area (acres)	Stream Outflow Concentration (mg/l) Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	Runoff Volume per 100 acres (ac-ft)
Speciality Crops (strawberries)	0	184	2.5	0	0	26
Vegetable (lettuce/potatoes)	200	184	0.8	0	0	26
Silage (sudan grass)	900	67	1.2	0	0	47.1
Pasture	4370	184	0.8	0	0	26
Subtotal (irrigated lands)	**5470**					
Other/fallow (non irrigated)	8705	184	0.8	0	0	26
Total	**14175**					**3875.40**
Weighted Average Concentrations for Stream Outflow (mg/l)		**171.20**	**0.84**	**0.00E+00**	**0.00E+00**	

Ref: NUT_AMWL

Watershed Americano Creek
Modeling Scenario Med Tech
Season Winter
Area (acres) 14175

Crop Distribution	Area (acres)	Stream Outflow Concentration (mg/l) Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	Runoff Volume per 100 acres (ac-ft)
Speciality Crops (strawberries)	400	184	2.5	0	0	26
Vegetable (lettuce/potatoes)	540	184	0.8	0	0	26
Silage (sudan grass)	2450	67	1.2	0	0	47.1
Pasture	2080	184	0.8	0	0	26
Subtotal (irrigated lands)	**5470**					
Other/fallow (non irrigated)	8705	184	0.8	0	0	26
Total	**14175**					**4202.45**
Weighted Average Concentrations for Stream Outflow (mg/l)		**151.87**	**0.95**	**0.00E+00**	**0.00E+00**	

Ref: NUT_AMWM

Watershed Stemple Creek
Modeling Scenario **High Tech**
Season **Summer**
Area (acres) **26570**

Crop Distribution	Area (acres)	Stream Outflow Concentration (mg/l) Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	Runoff Volume per 100 acres (ac-ft)
Speciality Crops (strawberries)	1800	1875	1.5	0	6E-07	7.4
Vegetable (lettuce/potatoes)	1400	1310	2.5	0	6E-07	11.5
Silage (sudan grass)	2200	2040	4.3	1.2E-05	0	20.9
Pasture	800	1251	3.4	0	0	14.2
Subtotal (irrigated lands)	**6200**					
Other/fallow (non irrigated)	20370	500	2	0	0	0.36
Total	**26570**					**940.93**
Weighted Average Concentrations for Stream Outflow (mg/l)		**1676.46**	**3.31**	**5.86E-06**	**1.88E-07**	

Ref: NUT_STSH

Watershed Stemple Creek
Modeling Scenario **Low Tech**
Season **Summer**
Area (acres) **26570**

Crop Distribution	Area (acres)	Stream Outflow Concentration (mg/l) Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	Runoff Volume per 100 acres (ac-ft)
Speciality Crops (strawberries)	0	1875	1.5	0	6E-07	7.4
Vegetable (lettuce/potatoes)	300	1310	2.5	0	6E-07	11.5
Silage (sudan grass)	1100	2040	4.3	1.2E-05	0	20.9
Pasture	4800	1251	3.4	0	0	14.2
Subtotal (irrigated lands)	**6200**					
Other/fallow (non irrigated)	20370	500	2	0	0	0.36
Total	**26570**					**1019.33**
Weighted Average Concentrations for Stream Outflow (mg/l)		**1376.92**	**3.47**	**2.71E-06**	**2.03E-08**	

Ref: NUT_STSL

Watershed Stemple Creek
Modeling Scenario **Med Tech**
Season **Summer**
Area (acres) **26570**

Crop Distribution	Area (acres)	Stream Outflow Concentration (mg/l) Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	Runoff Volume per 100 acres (ac-ft)
Speciality Crops (strawberries)	450	1875	1.5	0	6E-07	7.4
Vegetable (lettuce/potatoes)	600	1310	2.5	0	6E-07	11.5
Silage (sudan grass)	2750	2040	4.3	1.2E-05	0	20.9
Pasture	2400	1251	3.4	0	0	14.2
Subtotal (irrigated lands)	**6200**					
Other/fallow (non irrigated)	20370	500	2	0	0	0.36
Total	**26570**					**1091.18**
Weighted Average Concentrations for Stream Outflow (mg/l)		**1638.89**	**3.67**	**6.32E-06**	**5.63E-08**	

Ref.: NUT_STSM

Watershed Stemple Creek
Modeling Scenario **High Tech**
Season **Winter**
Area (acres) **26570**

Crop Distribution	Area (acres)	Stream Outflow Concentration (mg/l) Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	Runoff Volume per 100 acres (ac-ft)
Speciality Crops (strawberries)	1800	184	2.5	0	0	26
Vegetable (lettuce/potatoes)	1400	184	0.8	0	0	26
Silage (sudan grass)	2200	67	1.2	0	0	47.1
Pasture	800	184	0.8	0	0	26
Subtotal (irrigated lands)	**6200**					
Other/fallow (non irrigated)	20370	184	0.8	0	0	26
Total	**26570**					**7372.40**
Weighted Average Concentrations for Stream Outflow (mg/l)		**167.56**	**0.96**	**0.00E+00**	**0.00E+00**	

Ref: NUT_STWH

Watershed	Stemple Creek
Modeling Scenario	**Low Tech**
Season	**Winter**
Area (acres)	**26570**

Crop Distribution	Area (acres)	Stream Outflow Concentration (mg/l) Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	Runoff Volume per 100 acres (ac-ft)
Speciality Crops (strawberries)	0	184	2.5	0	0	26
Vegetable (lettuce/potatoes)	300	184	0.8	0	0	26
Silage (sudan grass)	1100	67	1.2	0	0	47.1
Pasture	4800	184	0.8	0	0	26
Subtotal (irrigated lands)	**6200**					
Other/fallow (non irrigated)	20370	184	0.8	0	0	26
Total	**26570**					**7140.30**
Weighted Average Concentrations for Stream Outflow (mg/l)		**175.51**	**0.83**	**0.00E+00**	**0.00E+00**	

Ref: NUT_STWL

Watershed Stemple Creek
Modeling Scenario Med Tech
Season Winter
Area (acres) 26570

Crop Distribution	Area (acres)	Stream Outflow Concentration (mg/l) Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	Runoff Volume per 100 acres (ac-ft)
Speciality Crops (strawberries)	450	184	2.5	0	0	26
Vegetable (lettuce/potatoes)	600	184	0.8	0	0	26
Silage (sudan grass)	2750	67	1.2	0	0	47.1
Pasture	2400	184	0.8	0	0	26
Subtotal (irrigated lands)	**6200**					
Other/fallow (non irrigated)	20370	184	0.8	0	0	26
Total	**26570**					**7488.45**
Weighted Average Concentrations for Stream Outflow (mg/l)		**163.76**	**0.90**	**0.00E+00**	**0.00E+00**	

Ref: NUT_STWM

Watershed Tolay Creek

Modeling Scenario **High Tech**

Season **Summer**

Area (acres) **6980**

Crop Distribution	**Area (acres)**	**Stream Outflow Concentration (mg/l)** Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	**Runoff Volume per 100 acres (ac-ft)**
Speciality Crops (strawberries)	400	2301	1.95	0	6E-07	9.5
Vegetable (lettuce/potatoes)	400	2871	1.9	0	6E-07	9.5
Silage (sudan grass)	540	2796	4.1	1.2E-05	0	18.3
Pasture	200	1595	3.3	0	0	14.9
Subtotal (irrigated lands)	**1540**					
Other/fallow (non irrigated)	5440	0	0	0	0	0
Total	**6980**					**204.62**
Weighted Average Concentrations for Stream Outflow (mg/l)		**2543.09**	**3.18**	**5.80E-06**	**2.23E-07**	

Ref: NUT_TOSH

Watershed Tolay Creek
Modeling Scenario **Low Tech**
Season **Summer**
Area (acres) **6980**

Crop Distribution	Area (acres)	Stream Outflow Concentration (mg/l) Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	Runoff Volume per 100 acres (ac-ft)
Speciality Crops (strawberries)	0	2301	1.95	0	6E-07	9.5
Vegetable (lettuce/potatoes)	200	2871	1.9	0	6E-07	9.5
Silage (sudan grass)	400	2796	4.1	1.2E-05	0	18.3
Pasture	940	1595	3.3	0	0	14.9
Subtotal (irrigated lands)	**1540**					
Other/fallow (non irrigated)	5440	0	0	0	0	0
Total	**6980**					**232.26**
Weighted Average Concentrations for Stream Outflow (mg/l)		**2077.90**	**3.44**	**3.78E-06**	**4.91E-08**	

Ref: NUT_TOSL

Watershed Tolay Creek
Modeling Scenario **Med Tech**
Season **Summer**
Area (acres) **6980**

Crop Distribution	Area (acres)	Stream Outflow Concentration (mg/l) Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	Runoff Volume per 100 acres (ac-ft)
Speciality Crops (strawberries)	200	2301	1.95	0	6E-07	9.5
Vegetable (lettuce/potatoes)	300	2871	1.9	0	6E-07	9.5
Silage (sudan grass)	500	2796	4.1	1.2E-05	0	18.3
Pasture	540	1595	3.3	0	0	14.9
Subtotal (irrigated lands)	**1540**					
Other/fallow (non irrigated)	5440	0	0	0	0	0
Total	**6980**					**219.46**
Weighted Average Concentrations for Stream Outflow (mg/l)		**2322.57**	**3.33**	**5.00E-06**	**1.30E-07**	

Ref: NUT_TOSM

Watershed Tolay Creek
Modeling Scenario **High Tech**
Season **Winter**
Area (acres) **6980**

Crop Distribution	Area (acres)	Stream Outflow Concentration (mg/l) Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	Runoff Volume per 100 acres (ac-ft)
Speciality Crops (strawberries)	400	240	0.7	0	0	21.7
Vegetable (lettuce/potatoes)	400	240	0.7	0	0	21.7
Silage (sudan grass)	540	327	1.2	0	0	38.9
Pasture	200	240	0.7	0	0	21.7
Subtotal (irrigated lands)	**1540**					
Other/fallow (non irrigated)	5440	240	0.7	0	0	21.7
Total	**6980**					**1607.54**
Weighted Average Concentrations for Stream Outflow (mg/l)		**251.37**	**0.77**	**0.00E+00**	**0.00E+00**	

Ref: NUT_TOWH

Watershed — Tolay Creek

Modeling Scenario — **Low Tech**
Season — **Winter**
Area (acres) — **6980**

Crop Distribution	Area (acres)	Stream Outflow Concentration (mg/l) Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	Runoff Volume per 100 acres (ac-ft)
Speciality Crops (strawberries)	0	240	0.7	0	0	21.7
Vegetable (lettuce/potatoes)	200	240	0.7	0	0	21.7
Silage (sudan grass)	400	327	1.2	0	0	38.9
Pasture	940	240	0.7	0	0	21.7
Subtotal (irrigated lands)	**1540**					
Other/fallow (non irrigated)	5440	240	0.7	0	0	21.7
Total	**6980**					**1583.46**
Weighted Average Concentrations for Stream Outflow (mg/l)		**248.55**	**0.75**	**0.00E+00**	**0.00E+00**	

Ref: NUT_TOWL

Watershed Tolay Creek
Modeling Scenario **Med Tech**
Season **Winter**
Area (acres) **6980**

Crop Distribution	Area (acres)	Stream Outflow Concentration (mg/l) Salts (TDS)	Nitrogen as N	Herbicide 2,4,D	Insecticide Carbaryl	Runoff Volume per 100 acres (ac-ft)
Speciality Crops (strawberries)	200	240	0.7	0	0	21.7
Vegetable (lettuce/potatoes)	300	240	0.7	0	0	21.7
Silage (sudan grass)	500	327	1.2	0	0	38.9
Pasture	540	240	0.7	0	0	21.7
Subtotal (irrigated lands)	**1540**					
Other/fallow (non irrigated)	5440	240	0.7	0	0	21.7
Total	**6980**					**1600.66**
Weighted Average Concentrations for Stream Outflow (mg/l)		**250.57**	**0.76**	**0.00E+00**	**0.00E+00**	

Ref: NUT_TOWM