Final

TECHNICAL MEMORANDUM

WATER BALANCE MODEL
SUMMARY AND RESULTS

TO: Ed Brauner, City of Santa Rosa
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FROM: John Hake, Parsons ES

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RE: Santa Rosa Subregional Long-Term Wastewater Project

INTRODUCTION

This technical memorandum serves as a summary of water balance model work completed by Parsons ES and presents the most recent Water Balance Model results, which will be used as design criteria for the alternative projects.

The Water Balance Model described here is used to determine system requirements (storage volume and irrigation area) for alternatives 2 and 3, South and West County agricultural irrigation projects, respectively. System requirements (component sizing) for alternatives 4 and 5, the Geysers and Russian River Discharge projects, respectively, were developed concurrently, and based partially on the results from this model, including wastewater flows.

WATER BALANCE MODEL DEVELOPMENT

CH2M Hill constructed the original Water Balance Model to determine the operational strategy and anticipated discharge allowances of the Santa Rosa reclaimed water system at system buildout. Essentially, system requirements are either to store, irrigate, or discharge as necessary to reliably dispose of the reclaimed water generated by the Laguna Wastewater Treatment Plant. The model was developed in several stages over approximately a five-year period. The development of the model is described in four technical memorandums prepared by CH2M Hill and is summarized below in chronological order.

TM-L-2, *Statistical Analysis of Russian River Streamflows*, 1988. The primary purpose of this technical memorandum was to estimate mean monthly low streamflows for various recurrence intervals so that wastewater discharge to the river could be estimated based on percentage of river flow. Tables in the appendix contain mean monthly streamflows for the Russian River as determined by the Sonoma County Water Agency (SCWA). The SCWA, using the Russian River Flow Model, determined mean monthly streamflows over an approximate sixty year period of record. The model adjusts streamflows for diversion conditions expected in the year 2010. This technical memo was actually prepared by Dames and Moore for CH2M Hill.

TM-R-1, *Irrigation Expansion Feasibility*, 1989. The purpose of this study was to evaluate the feasibility of expanding the existing agricultural irrigation area into the west county. A prototype Water Balance Model was developed to estimate flows for irrigation reuse, habitat release (wetlands), direct river discharge, and storage. Results were generated on an annual basis for average normal, wet, and dry year conditions.

TM-R-6, *Reclamation Systems Operations Model*, 1989. The model was improved by evaluating annual water balances for consecutive wet or dry years rather than for a single wet or dry year conditions. Cumulative annual storage was also introduced into the model. Streamflows for the years 1923-1938 (wet) and 1974-1984 (dry) were taken from the SCWA model results provided in TM-L-2.

TM-RA-1, *Russian River Model Water Balance*, 1993. The following improvements were made to the Water Balance Model described in TM-R-6 including: utilizing monthly streamflow data from 1923 to 1985, statistically evaluating the reliability of the system (i.e., determining the number of times river discharge exceeds the allowable rate), and adding new project components (wetlands, agricultural lands outside west county). The Water Balance Model described in this document was received by Parsons ES for use in developing the Long-Term Wastewater Project EIR/EIS.

DESCRIPTION OF ORIGINALWATER BALANCE MODEL OPERATION

This section describes the operation of the original water balance model. Revisions to the model are described in a subsequent section.

The Water Balance Model for reclamation system operations is based on Russian River flow estimates generated by the Sonoma County Water Agency (SCWA) Russian River Flow Model. The SCWA model generated river flow estimates for the Hacienda Bridge (USGS) gauging station between 1923 and 1992. The SCWA model data is based on diversion conditions projected for the year 2010.

The Water Balance Model includes components for reclaimed water inflow (i.e., treatment plant effluent or inflow to the irrigation system), irrigation requirements, storage requirements, and wastewater discharge to the Russian River. The model balances the reclaimed water inflow with the various demands for irrigation and storage and subsequently determines actual discharge to the Russian River. The water reclamation system is being designed to have a reliability of 1:20, i.e., the allowable river discharge rate may be exceeded only one month in twenty discharge months. Discharge is allowed between October 1 and May 15, approximately eight months of the year, and this translates to about one excess discharge every 2-1/2 calendar years. This reliability requirement was tentatively agreed upon with the Regional Water Quality Control Board (RWQCB). Irrigated acreage and storage parameters are adjusted until the desired reliability is achieved. A contingency plan is also being developed with alternatives to increased river discharge during periods when allowable river discharge rates would be exceeded. The following is a description of the various model components.

Reclaimed Water Inflow

Reclaimed water inflow is defined as treatment plant effluent that supplies the reclaimed water system. The Laguna treatment plant average daily flow (ADF) is adjusted for hydrologic conditions for each water year and converted into an annual flow volume. The annual flow volume is divided into monthly flow volumes based upon the estimated monthly reclaimed water flow distribution. The estimated monthly reclaimed water flow distribution was developed from influent flow data for 1981 to 1985 at the Laguna Treatment Plant and is discussed in TM-R-1, *Irrigation Expansion Feasibility*.

Irrigation Requirements

Irrigation requirements are subdivided into various categories depending upon land use. The land application areas and annual application rate requirements for each category are used to determine annual volume requirements. The annual volume requirements are further subdivided into monthly irrigation reuse flow volumes based upon the estimated monthly hydraulic loading distribution. This monthly distribution was also developed in TM-R-1. Irrigation application rates were held constant for each year as no attempt was made to adjust the irrigation requirements for annual temperature or precipitation variations. Irrigated area is one variable that can be adjusted in solving the water balance and achieving the required reliability.

Russian River Discharge

Allowable river discharge is the monthly volume of Russian River flow multiplied by the allowable discharge rate (1, 5, 10, or 20 percent of the river discharge rate). Actual river discharge is calculated by comparing water available for storage to the target storage volume. Target storage is defined as the accumulated volume desired in the storage system for any given month. Monthly target storage values are input to the model as a fraction of maximum storage. Collectively, the target storage values comprise the target storage curve, which is assumed as part of the model. Actual river discharge is calculated based on irrigation demand, reclaimed water inflow, and target storage. Actual river discharge is compared to allowable river discharge and any actual discharge in excess of the allowable is calculated and recorded by the model as "contingency volume."

Storage Requirements

The determination of storage requirements is an iterative process beginning with the actual river discharge calculation. After irrigation requirements are satisfied, actual river discharge is calculated based on target storage requirements, as described above. Preliminary storage volume (based on target storage), is compared to the maximum storage available to ensure that the maximum is not exceeded. Maximum available storage and the target storage curve are additional variables which can be adjusted in solving the water balance and achieving the required reliability.

Supplementary Water

"Supplementary water" is water that is required to meet irrigation demand when reclaimed water from storage and reclaimed water from the Laguna Plant are insufficient to meet that demand. The Water Balance Model calculates and records supplementary water requirements. Supplementary water is not required for the existing reclamation system and it was assumed that supplementary water should not be required for this project. Supplementary water requirements for all alternatives and at all discharge rates are zero.

Goal of the Model

The goal of the model is to minimize the required irrigation area and storage volume while maintaining a contingency volume frequency of 1 month in 20. The key variables to manipulate are the land application areas for the various irrigation categories (e.g., South County, West County, Sebastopol) and the maximum storage criteria. Increasing irrigation area or maximum storage capacity increases the reliability of the system by decreasing the frequency of contingency volumes. The objective is to bring the reliability number as close to 1 as possible.

WATER BALANCE MODEL REVISIONS

A number of revisions were made to the Water Balance Model received by Parsons ES. The major changes are summarized below.

Reclaimed Water Inflow Calculations

Reclaimed water inflows are calculated in the model using the Average Daily Flow (ADF) of wastewater to the treatment plant. The ADF is converted to an annual flow and distributed monthly according to the monthly flow distribution established in TM-R-1. In the original model, ADF determination is unclear. It appears that ADFs were hand-entered into the model, according to Russian River flows. The basic premise is that greater precipitation would increase both the Russian River flow and the ADF (due to infiltration and inflow). Instead of hand-entering ADF data, Parsons ES modified the model by establishing a relationship between Russian River flow and Laguna Plant flow. Actual river and plant flow data were entered into a regression model for the years 1986-1992 and a regression equation was derived. The regression equation was entered into the Water Balance Model so that the ADF could be calculated automatically. This modification provides a more realistic variation of ADF in response to climatic conditions.

ADF calculation is also dependent upon the Average Dry Weather Flow (ADWF). Theoretically speaking, the ADF is equivalent to the ADWF when Russian River flow is lowest, approaching zero. The y-intercept of the regression equation (based on actual plant and river flows) was very close to the actual ADWF. Therefore, the projected ADWF is used as the y-intercept of the regression equation incorporated into the model. The projected ADWF was calculated by West-Yost Associates using data from the General Plans of the Subregional system's member entities (Water Conservation Technical Memorandum No. WYA-1, 1995). Buildout data from the General Plans were used in the calculations. Sustainable conservation measures were also considered in calculating the ADWF.

Russian River Flows

As mentioned previously, Russian River flows used in the Water Balance Model were determined by another model, the Russian River Flow Model, constructed and operated by the SCWA. The original Russian River flows used in the Water Balance Model have subsequently been updated by the SCWA. (Apparently, the Russian River Flow Model failed to account for a significant flow source. The revised Russian River flow data were substantially different from the original flow data. This difference was particularly noticeable during the winter peak flow periods when revised flows were substantially greater.) Revised data were received from SCWA and incorporated into the Water Balance Model. Water Balance Model results were not noticeably affected by the revised flow since increased flows during heavy winter rains did not substantially affect discharge potential to the Russian River. Wastewater available for river discharge was already being released at the maximum rate based on the target storage curve.

Agricultural Irrigation Area and Rates

Additional irrigation areas (within the West County, South County, and Sebastopol areas) were added to the Water Balance Model. Composite irrigation rates for each of these areas were determined by Questa Engineering, agricultural specialists for the project, based on projected crop selection. The composite irrigation rates were also added to the model.

From the perspective of the Water Balance Model, Sebastopol is the least efficient irrigation area for the disposal of wastewater. Annual irrigation rates assumed for Sebastopol, West County, South County, and urban irrigation are 17, 20, 28, and 28 inches, respectively. South County and urban irrigation are the most disposal-efficient irrigation areas. An average annual rate of 24 inches for the existing irrigation areas was determined from the 1994 Reclamation Annual Report prepared by the City of Santa Rosa.

RESULTS

The modeling process is iterative. Initially estimates are made of storage volumes, irrigation areas, irrigation rates, and wastewater flows and entered into the model. The model is then run and the output reviewed. Adjustments are made to the initial assumptions and the model is rerun. This process is repeated until satisfactory results that meet the established criteria are obtained.

The most recent Water Balance Model results are presented in Tables 1 and 2 for the South and West County Reclamation alternatives, respectively. Both alternatives include urban irrigation components for the Fountaingrove and East Santa Rosa/Bennett Valley irrigation areas. Both alternatives were evaluated with and without the Sebastopol agricultural irrigation area, which is a common component that could be affiliated with either alternative. In addition, any fraction of the total available Sebastopol irrigation area (2,200 acres) may be used with either alternative.

Existing storage and irrigation area data are taken from the 1994 Reclamation Annual Report prepared by the City of Santa Rosa. The reported existing irrigation area is about 5,300 acres. An additional 200 acres is currently being added through the interim reclamation master plan for the Rohnert Park pipeline extension. The reported existing storage is 1,500 million gallons (MG). However, only 1,200 MG was used in the Water Balance Model to account for dead storage and to allow for some flexibility in the management of the existing storage system. Existing system capacity is assumed fixed for all alternatives and discharge rates.

The model was run for both Alternatives 2 and 3, at four permitted Russian River discharge rates: 1, 5, 10, and 20 percent. As the permitted Russian River discharge rate increases, system requirements for irrigation and storage decrease. The 1 percent permitted discharge rate with maximum Sebastopol irrigation area requires the greatest total number of acres for irrigation because Sebastopol irrigation has the lowest annual irrigation demand or consumption rate. The maximum total required irrigated acreage (includes existing acreage) for the South County and Sebastopol is 10,700 acres, the maximum total for West County and Sebastopol is 12,400 acres. The maximum active reclaimed water storage volume required for both alternatives, with or without Sebastopol agricultural irrigation, is 4,000 MG. Additional storage volume will be required for stormwater runoff and dead storage, and is included as part of the reservoir calculations.

Irrigation areas were adjusted subsequent to water balance model runs. The effects of collected stormwater runoff and evaporation were considered for the storage reservoirs. The model results for irrigation acreage were adjusted for disposal of collected stormwater. Irrigation acreage results were also adjusted to account for irrigation efficiency. Previously, model results were based on crop requirements only. Considering irrigation efficiency (losses due to evaporation, percolation, etc.), allows for less land to be used for the disposal of reclaimed water. Model results were revised accordingly.

The 20 percent discharge option requires almost no expansion beyond existing facilities. A relatively small addition of urban irrigation area (100 acres) would achieve the required reliability at this discharge rate and no additional storage would be required.

Average and maximum contingency volumes are also shown for each alternative at the permitted discharge rates in Tables 1 and 2. Contingency volume is defined as the amount of reclaimed water in excess of the permitted discharge rate. Contingency volumes would be disposed of through winter irrigation, emergency conservation, and as a last resort, additional river discharge. Contingency volumes occur only 1 in 20 discharge months. Discharge months are October to mid-May. Based on the present reliability requirements, contingency volumes would occur approximately once every 2-3 years. Average contingency volumes range from

109-137 MG per month in which a contingency volume occurs. The maximum contingency volumes are 326, 491, 438, and 327 MG, for the 1, 5, 10, and 20 percent permitted discharge rates, respectively. Contingency volumes will be evaluated and described in greater detail in a separate technical memorandum.

MODEL ACCURACY AND PRECISION

The Water Balance Model, like all numerical models, is built upon a number of assumptions. The accuracy of the model is largely dependent upon the accuracy of these assumptions and the input data. Wherever possible, conservative assumptions are built into the model. Examples of some conservative assumptions include the following:

- The largest Average Dry Weather Flow (ADWF) estimated for General Plan buildout is used, which itself assumes a sustainable level of water conservation. This figure is rounded up to the nearest whole number (21 MGD) which is an appropriate level of precision.

- Irrigation rates are estimated to reflect a conservative crop selection for each major irrigation area. Under-irrigation is assumed to occur in the West County where irrigation drainage may prove to be a constraint.

- Irrigation areas and storage volumes have been consistently rounded up to the nearest hundred acres and hundred million gallons, respectively. This reflects an appropriate level of precision.

Although the water balance analysis is thorough, the water reclamation system being modeled is complex. Simplifications were made in the construction of the model for purposes of analysis. Simplifying complex systems reduces precision but the level of accuracy is satisfactory. Also, the model is largely based upon Russian River flows which are dependent upon the weather. A 70-year record of flow was used to account for variations in weather which might reasonably be anticipated to occur during the operation of the system. The 1995 winter storms should be an adequate reminder of how difficult it is to predict weather patterns and to account for weather conditions.

In summary, although the water balance model is a simplification of a complex system, the analysis is thorough and conservative assumptions were made, to ensure that adequate storage volume and irrigation areas are provided by the reclamation system.

cc: Andy Hauge, HBA
Robin Cort, Parsons ES
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Dave Smith, Merritt Smith
Jeff Peters, Questa

Table 1

South County Annual Reclamation System Requirements
(Based on ADWF = 21 MGD)
Alternative 2 - South County Reclamation

	Permitted Russian River Discharge Rate[2]			
System Requirements[1]	**1%**	**5%**	**10%**	**20%**
Existing Storage (MG)	1,200	1,200	1,200	1,200
New Storage (MG)	4,000	2,900	1,900	0
Total Storage (MG)	5,200	4,100	3,100	1,200
Existing Irrigation Area (acres)	5,500	5,500	5,500	5,500
Urban Irrigation Area (acres)	400	400	400	100
South County Agricultural Irrigation Area (acres)	3,800	2,600	1,600	0
Total Irrigation Area (acres)	9,700	8,500	7,500	5,600
Contingency Volume Summary				
Average Contingency Volume (MG/month)[3]	124	137	111	118
Maximum Contingency Volume (MG/month)[3]	326	491	438	327

Alternative 2 - South County with Sebastopol Reclamation

	Permitted Russian River Discharge Rate[2]			
System Requirements[1]	**1%**	**5%**	**10%**	**20%**
Existing Storage (MG)	1,200	1,200	1,200	1,200
New Storage (MG)	4,000	2,900	1,900	0
Total Storage (MG)	5,200	4,100	3,100	1,200
Existing Irrigation Area (acres)	5,500	5,500	5,500	5,500
Urban Irrigation Area (acres)	400	400	400	100
South County Agricultural Irrigation Area (acres)	2,600	1,300	300	0
Sebastopol Agricultural Irrigation Area (acres)	2,200	2,200	2,200	0
Total Irrigation Area (acres)	10,700	9,400	8,400	5,600
Contingency Volume Summary				
Average Contingency Volume (MG/month)[3]	125	137	109	118
Maximum Contingency Volume (MG/month)[3]	326	491	438	327

Table 1 (cont.)

[1] System requirements are defined as the storage volume and irrigation area necessary to meet the reliability requirement. The reliability requirement is that reclaimed water discharge to the Russian River may exceed the permitted discharge rate only one month in twenty.

[2] Reclaimed water discharge rate as a percentage of Russian River Flow, as permitted by the RWQCB.

[3] Contingency volume is defined as the amount of reclaimed water discharged to the Russian River in excess of the permitted discharge rate. Contingency volumes occur only one month in twenty discharge months (i.e., discharge months are October to May) or about once every 2-1/2 years. Average and maximum contingency volumes are based on a statistical analysis covering a 70 year period of record of Russian River flow.

Table 2

West County Annual Reclamation System Requirements
Alternative 3 - West County Reclamation
(Based on ADWF = 21 MGD)

System Requirements[1]	Permitted Russian River Discharge Rate[2] 1%	5%	10%	20%
Existing Storage (MG)	1,200	1,200	1,200	1,200
New Storage (MG)	4,000	2,900	1,900	0
Total Storage (MG)	5,200	4,100	3,100	1,200
Existing Irrigation Area (acres)	5,500	5,500	5,500	5,500
Urban Irrigation Area (acres)	400	400	400	100
West County Agricultural Irrigation Area (acres)	6,200	4,400	2,900	0
Total Irrigation Area (acres)	12,100	10,300	8,800	5,600
Contingency Volume Summary				
Average Contingency Volume (MG/month)[3]	126	137	109	118
Maximum Contingency Volume (MG/month)[3]	326	491	438	327

Alternative 3 - West County with Sebastopol Reclamation

System Requirements[1]	Permitted Russian River Discharge Rate[2] 1%	5%	10%	20%
Existing Storage (MG)	1,200	1,200	1,200	1,200
New Storage (MG)	4,000	2,900	1,900	0
Total Storage (MG)	5,200	4,100	3,100	1,200
Existing Irrigation Area (acres)	5,500	5,500	5,500	5,500
Urban Irrigation Area (acres)	400	400	400	100
West County Agricultural Irrigation Area (acres)	4,300	2,600	1,000	0
Sebastopol Agricultural Irrigation Area (acres)	2,200	2,200	2,200	0
Total Irrigation Area (acres)	12,400	10,700	9,100	5,600
Contingency Volume Summary				
Average Contingency Volume (MG/month)[3]	126	137	109	118
Maximum Contingency Volume (MG/month)[3]	326	491	438	327

Table 2 (cont.)

[1] System requirements are defined as the storage volume and irrigation area necessary to meet the reliability requirement. The reliability requirement is that reclaimed water discharge to the Russian River may exceed the permitted discharge rate only one month in twenty.

[2] Reclaimed water discharge rate as a percentage of Russian River Flow, as permitted by the RWQCB.

[3] Contingency volume is defined as the amount of reclaimed water discharged to the Russian River in excess of the permitted discharge rate. Contingency volumes occur only one month in twenty discharge months (i.e., discharge months are October to May) or about once every 2-1/2 years. Average and maximum contingency volumes are based on a statistical analysis covering a 70 year period of record of Russian River flow.