Appendix H

Hydrology

HYDRO APPENDIX

The following section details the calculations and methods used in determining flow characteristics and pollutant transport for the Dixon Downs project and contained in Chapter 4.6 of the Draft Environmental Impact Report (DEIR).

Table 4.6-2 in the DEIR lists typical concentrations of pollutants in stormwater runoff. However, because some land use practices will have less runoff than others, it is important to assess the overall pollutant loads transported; the amount of pollutant, not just the concentration. This can be easily approximated by The Simple Method, detailed below. In general, the simple method uses a calculation of the total amount of water that runs off an area, times the pollutant concentration in the stormwater, to provide a total amount (e.g., pounds) of chemical that would leave the area in a certain amount of time (e.g., a typical year). In order to calculate the amount of runoff, certain site specific characteristics are used to determine how much rain that hits the ground will not infiltrate or be stored on site, but will run off the land. The Runoff Coefficient is often used to calculate the fraction of rainfall that will runoff and is determined by land use and landscape. Several methods for determining the Runoff Coefficient are used, often times based on the amount of impervious area since rainfall intercepting impervious areas cannot infiltrate and will only be minimally stored. The Runoff Coefficient can also be approximated by using table with typical values for typical land use types. For the Proposed Project analysis, Runoff Coefficient was determined based on the Storm Water Management Plan estimates of future land use percent imperviousness and a standard empirical equation relating the runoff to percent imperviousness.

Grassy swales are considered a potential Best Management Practice (BMP) for reducing the amount of pollutants from the developed property. Grassy swales will often slow water down and allow heavier particulates to fall out, allow for infiltration of water with nutrients and dissolved chemicals, and allow for biological process to help removed chemicals from the stormwater runoff. These processes require that water flowing through the swale have enough time to allow for infiltration and to let large particles settle out. Additionally, the water cannot flow through the swale too quickly, or it could cause erosion and gulley formation. All of these conditions are managed my designing the swale with the right geometry, slope, roughness (e.g., grass height and cover) to slow flows down and trap sediment, and overall size for the amount of water it must process.

In general, most of the pollutants in stormwater are carried in the initial runoff water (first flush); after the initial wash off, most of the pollutants are removed from the surfaces. Therefore, water quality treatment is generally designed to treat that first flush amount of pollutants. This is sometimes considered the first one-half inch of runoff spread over the entire area or for runoff cause by the 'design storm': generally, runoff small storm event or a certain rainfall intensity.

The Rational Method was used to calculated the storm event runoff. Rainfall intensity, watershed area, and the Runoff Coefficient (fraction of rainfall that runs off the landscape) are used to determine the amount runoff from the watershed per unit of time (e.g., cubic feet of water per second).

Rough swale design characteristics (length, width, slope, and others) were determined from the project Storm Water Quality Management Plan (SWQ0MP) figures. Using Manning's equation, for calculating flow through a channel, and the runoff rate entering the swale, the flow velocity in the swale and depth of flow can be determined to see if the proposed swales meet design criteria established by CASQA and others. A program was used to perform the calculations.

Effectiveness of the swale at removing the pollutants was also examined using a program (P8) that calculates flow rate and amount from the contributing area, channel flow characteristics, particle settling velocities, pollutant dissolved and total concentrations, and infiltration properties to calculate the relative amount of pollutants removed by the BMP.

Pollutant Load Calculations

<u>The Simple Method</u>

The Simple Method[1] estimates pollutant loads for chemical constituents as a product of annual runoff volume and pollutant concentration, as:

$$L = 0.226 * P*Pj*R* C * A \qquad [1]$$

Where: L = Annual load (lbs), R = Annual runoff (inches), C = Pollutant concentration (mg/l), A = Area (acres), P = Annual rainfall (inches), Pj = Fraction of annual rainfall events that produce runoff (usually 0.9), and 0.226 = Unit conversion factor

For bacteria, the equation is slightly different, to account for the differences in units. The modified equation for bacteria is:

$$L = 1.03 *10^{-3} * P*Pj*R * C * A \qquad [2]$$

Where: L = Annual load (Billion Colonies), R = Annual runoff (inches), C = Bacteria concentration (#/100 ml), A = Area (acres), P = Annual rainfall (inches), Pj = Fraction of annual rainfall events that produce runoff (usually 0.9), and $1.03 * 10^{-3}$ = Unit conversion factor

<u>Runoff Coefficient</u>

Runoff coefficients can be determined from fraction of imperviousness where[2]:

$$\text{Runoff Coefficient (R)} = 0.05 + 0.91*\text{fraction of imperviousness} \qquad [3]$$

For undeveloped area, fraction of imperviousness is estimated as three percent; therefore, Existing Conditions R = 0.05+0.91*(0.03) = 0.08

For developed areas, fraction of imperviousness is estimated as 90 percent, therefore, Proposed Project R = 0.05+ 0.91*(0.90) = 0.86

Swale Effectiveness

Swale Flow Conveyance and Design

The Rational Method is used to determine the flow rate of water running off the landscape into the swale:

WQF = CiA

Where WQF is the water quality flow rate, C is the runoff coefficient, i is the water quality design storm rainfall intensity, and A is the contributing area.

For analysis of swale design for water quality treatment, the water quality design storm can be found using Basin Sizer,[3] a program for determining regional precipitation amounts for the "Water Quality Volume" (WQV) and "Water Quality Flow" (WQF) calculations for sizing stormwater quality BMPs. Selecting stations at Vacaville and Davis (there were no stations available at Dixon), the water quality flow rate design storm was 0.16 inches per hour. From the above section, the runoff coefficient R = C and is 0.86 for Proposed Project conditions. Resulting water quality flow was calculated as 4.5 cfs for the 32 acre drainage area and 2.8 cfs for the 20 acre drainage area.

For analysis of swale capacity to convey flood flows, the 100-year storm peak intensity was estimated based on the Sacramento Method for Zone 3.[4] This corresponded to 45 cfs for a 20 acre site with 90 percent imperviousness and 66 cfs for a 32 acre site with 90 percent imperviousness.

Based on the SWQMP figures, swale characteristics were assumed to be grass-lined trapezoidal channels with:

- 120 ft length
- 3:1 side slopes
- 10 foot bottom width
- 1 percent slope
- Manning's roughness coefficient of 0.25 for water quality and 0.05 for flood flows

Manning's roughness values were chosen based on the CASQA recommendation for grassy swales (0.25) and selection of a slightly higher flood flow value than recommended for flood flow by the City of and County of Sacramento Hydrology Standards (0.03) to be more conservative. These values were input into the program CHANNELS, which solves Manning's equation and calculates the flow velocity and depth of flow for trapezoidal channels.

Table A-1 lists the swale flow properties for small (20 acre) and larger (32 acre) watersheds of the Proposed Project.

Table A-1 Swale flow properties for the range of Proposed Project drainage areas

Watershed				Channel		
Area	**Percent Impervious**	**Runoff Coefficient**		**Flow Velocity**	**Time to Travel Length of Swale**	**Depth of Flow**
area			*cfs*	*fps*	*mins*	*ft*
Water Quality Flow Rate						
32	0.9	0.86	4.5	0.5	4.0	0.09
20	0.9	0.86	2.8	0.4	4.8	0.09
100-year Storm Flow Rate						
32	0.9	0.86	66	3.5	NA	0.50
20	0.9	0.86	45	3.0	NA	0.48

Swale Pollutant Removals

P8 is a model for predicting the generation and transport of stormwater runoff pollutants in small urban catchments and for evaluating BMP effectiveness at removing basic pollutants. Continuous water- and mass- balance calculations on a user-defined system of watersheds, treatment devices (BMPs), particle classes, and water quality components are simulated with hourly rainfall to evaluate pollutant removal effectiveness. Particle classes and water quality components can be imported from general NURP (National Urban Runoff Program, 1983) data files. The NURP50 (50^{th} percentile distribution based on all NURP data) particle size class and water quality components were used in the simulation of an 'average' storm (6 hour) scaled to a local 2-year 6-hour storm (1.4 inches of rainfall) [5]. The impervious fraction was estimated to be 90 percent with swale infiltration rate of 0.2 inches per hour and a pervious curve number of 50; all other swale parameters as used in the above calculations. Modeled average removal rates were: 30 percent of total suspended solids (TSS), 5.1 percent of total Kjeldahl nitrogen (TKN), 5.6 percent of total phosphorous (TP), 5.1 percent of total copper (TCu), 28 percent of total lead (TPb), 5.1 percent of total zinc (TZn), and 28 percent of total petroleum hydrocarbons (TPH). Not all Constituents of Concern (COCs) were evaluated for removal efficiency since data is not available for many parameters. However, many chemicals have similar physical characteristics to the assessed COCs and these numbers can be used to approximate removal rates for other COCs. BOD was considered to have a similar removal rate as TPH; heavy metals were assigned copper removal rates and all removal was considered to be from the total versus dissolved fraction.

[1] Center for Watershed Protection. *The Simple Method to Calculate Urban Stormwater Loads.* http://www.stormwatercenter.net/monitoring%20and%20assessment/simple%20meth/simple.htm accessed 12/2/2004

[2] Schueler, T. Controlling *Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices*. MWCOG. Washington, D.C 1987
[3] Office of Water Programs California State University Sacramento. *Basin Sizer version 1.3*. 2001
[4] Sacramento County Water Resources Division and the City of Sacramento Department of Utilities Division of Engineering Services.Hydrology Standards: Volume 2 of the Sacramento City/County Drainage Manual, Dec 1996 http://www.msa.saccounty.net/waterresources/Drainage/vol2.asp
[5] HDSC/NWS Office of Hydrology. *NOAA Atlas 2*. 1973. http://www.wrcc.dri.edu/pcpnfreq.html