Fecal Coliform Bacteria Total Maximum Daily Load, Río Culebrinas, Puerto Rico

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1 INTRODUCTION

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (Title 40 of the *Code of Federal Regulations* [CFR] Part 130) require states to develop total maximum daily loads (TMDLs) for waterbodies that are not meeting their designated uses even though pollutant sources have implemented technology-based controls. A TMDL establishes the allowable load of a pollutant or other quantifiable parameters on the basis of the relationship between pollutant sources and in-stream water quality. A TMDL provides the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of the state's water resources (USEPA 1991).

EPA Region 2 and the Puerto Rico Environmental Quality Board (PREQB) have coordinated a watershed assessment and an analysis of ambient water quality monitoring data to support the calculation of a fecal coliform bacteria TMDL for the Río Culebrinas watershed in Puerto Rico. This waterbody is listed as impaired on Puerto Rico's 2008 section 303(d) list. This document presents the results of the TMDL study and provides the technical basis for calculating the TMDL.

2 PROBLEM IDENTIFICATION

2.1 Background

The Río Culebrinas is in northwest Puerto Rico and flows northwest toward the Atlantic Ocean, draining approximately 109 square miles of land. The Río Culebrinas watershed is part of the 10-digit U.S. Geological Survey (USGS) Cataloging Unit 2101000301. Figure 2-1 shows the location of the Río Culebrinas watershed.

Major tributaries include Río Guatemala, Río Sonador, Quebrada Grande, Río Cañas, Quebrada Las Marías, Quebrada Yagruma, Quebrada Lasalle, Quebrada El Salto, Quebrada Grande de la Majagua, and Quebrada Salada. The Río Culebrinas watershed falls within portions of the municipalities of Aguadilla, Aguada, Moca, San Sebastián, and Lares. Land use in the watershed consists of a mix of urban and rural populated sections, pastures, and forested areas. The highest point in the watershed is 522 meters above sea level. The lowest point of the watershed is its outlet at sea level. The mean elevation of the watershed is 124 meters above sea level.

The Culebrinas watershed has a tropical climate. Both temperatures and rainfall are affected by the northeastern trade winds. Humidity is relatively high in the summer, and most rainfall occurs between May and December. Showers, which can be locally heavy, can be expected any time of the year. Most showers have a short duration. The hurricane season runs from June to November, but hurricanes occur most often between August and October.

Because of municipal point sources, collection system failure, urban runoff/storm sewers, confined animal feeding operations, agricultural practices, and onsite wastewater systems, the Río Culebrinas system no longer meets the applicable water quality standards for Puerto Rico (PRWQSR Section 3.2.4[B][2]). As a result, assessment units in the Río Culebrinas watershed are included on Puerto Rico's 2008 Clean Water Act section 303(d) list of impaired waterbodies for fecal coliform bacteria (Table 2-1).

Figure 2-1. The Río Culebrinas watershed and surrounding municipalities.

Table 2-1. Assessment units in the Río Culebrinas watershed, including those identified on Puerto Rico's 2008 section 303(d) list of impairments

BASIN	2008 Assessment unit	State impairment	Associated station(s)
RÍO CULEBRINAS	Río Culebrinas (PRWR95A)	Fecal Coliform (1700)	50146675 50146800 50147050 50147600 50147800 50148050 50149100
	Río Caño (Rio Cañas) (PRWR95B)	Fecal Coliform (1700)	50148500 50148700
	Quebrada Grande (Sector Cuchillas) (PRWQ95C)	Fecal Coliform (1700)	50147997
	Quebrada Las Marias (PRWQ95D)	Fecal Coliform (1700)	50147900
	Quebrada Yagruma (PRWQ95E)	Unlisted	--
	Quebrada La Salle (PRWQ95F)	Fecal Coliform (1700)	50147675
	Quebrada El Salto (PRWQ95G)	Fecal Coliform (1700)	50147630
	Quebrada Grande de la Majagua (PRWQ95H)	Fecal Coliform (1700)	--
	Quebrada Salada (PRWQ95I)	Fecal Coliform (1700)	50147475
	Río Sonador (PRWR95J)	Fecal Coliform (1700)	50147400 50147450
	Río Guatemala (PRWR95K)	Fecal Coliform (1700)	50147200
	PR Unnamed 1 (417)	Unlisted	--
	PR Unnamed 2 (401, PRWR0304a)	Unlisted	--
	PR Unnamed 3 (418, PRWE0303)	Unlisted	--
	PR Unnamed 4 (419)	Unlisted	--

2.2 Water Quality Criteria

Impaired waters in the Río Culebrinas system are classified as *SD* and are subject to assessment methodologies and beneficial uses described in the *Rivers* category of Puerto Rico's section 303(d) list of impaired waters. Four beneficial use categories are identified here: Primary Contact Recreation (R1), Secondary Contact Recreation (R2), Aquatic Life (AL), and Drinking Water (DW).

Of the 15 assessment units identified in Table 2-1, 10 are listed for fecal coliform bacteria impairments. None of the 10 impaired assessment units fully support the designated uses of aquatic life or drinking water. While 3 of the 10 remaining assessment units support the designated use of secondary contact recreation, none fully support the designated use of primary contact recreation. The water quality standards that apply to these waters are as follows:

▪ Section 3.2.4.(A) of the Puerto Rico Water Quality Standards Regulations (PRWQSR) includes the following designated use for Class SD waters:

> *ASurface waters intended for use as raw water supply, propagation and preservation of desirable species, including threatened or endangered species, as well as primary and secondary contact recreation.*"

▪ Section 3.2.4(B)(2) of the PRWQSR, as amended in March 2003, includes the following criteria for coliform:

> *A<u>Coliforms</u>: The coliform geometric mean of a series of representative samples (at least five samples) of the water taken sequentially shall not exceed 10,000 colonies/100 mL of total coliforms or 200 colonies/100 mL of fecal coliforms. Not more than 20 percent of the samples shall exceed 400 colonies/100 mL of fecal coliforms.@*

The waterbodies are impaired for fecal coliform bacteria, so the numeric criteria described above will define the water quality target identified for determining the TMDL. Because the TMDL development approach uses a watershed model to compare fecal coliform bacteria concentrations against the water quality target, those streams that exhibit exceedances of the water quality targets are considered impaired by fecal coliform bacteria and will require TMDLs, even if they were not specifically listed in the 303(d) list. The watershed model shows fecal coliform exceeding water quality standards throughout the watershed for all 15 waters in Table 2-1. Therefore, all 15 waters are impaired by fecal coliform, and require TMDLs.

2.3 Pollutant Sources

Potential sources that contribute fecal coliform bacteria can be grouped into two categories: point sources and nonpoint sources. Point sources include permitted discharges that were calculated on the basis of National Pollutant Discharge Elimination System (NPDES) limits for each facility and permitted stormwater under NPDES General Permit PRR040000 for Discharges from Small Municipal Separate Storm Sewer Systems (MS4). Nonpoint sources are diffuse and include watershed contributions (e.g., non-permitted stormwater runoff and septic contributions; estimated on the basis of population data) and local sources.

2.3.1 Point Sources

A point source, according to 40 CFR 122.3, is any discernible, confined, and discrete conveyance, including any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, and vessel or other floating craft from which pollutants are or could be discharged. The NPDES program, established under Clean Water Act Parts 318, 402, and 405, requires permits for the discharge of pollutants from point sources.

NPDES permit information was obtained from EPA's Permit Compliance System (PCS) database and verified with PREQB information for four permitted facilities in the Río

Culebrinas watershed. The data from PCS include location, permit limits and discharge monitoring data for the four active facilities, which were compiled and used to configure the Loading Simulation Program C++ (LSPC) model. For the locations of these facilities, see Figure 2-2, and for details on how point sources were accounted for in the TMDL, see Sections 4 and 5. Table 2-2 shows the permitted flows, permitted concentrations, and calculated fecal coliform bacteria loads for each permitted facility.

Table 2-2. Permitted loads from NPDES facilities

NPDES ID	Facility Name	AU	Present Flow (MGD)	Present Flow (cfs)	Permitted Flow (MGD)	Permitted Flow (cfs)	Present FC (#/100 mL)	Permitted FC (#/100 mL)	Present FC (#/day)	Permitted FC (#/day)
PR0020851	PRASA SAN SEBASTIAN	PRWR95A	0.3536	0.5470	0.4	0.6188	2409	2000	3.23E+10	3.03E+10 *
PR0023981	PRASA WTP SAN SEBASTIAN	PRWR95A	0.0227	0.0351	0.3024	0.4678	2.60	400	2.23E+06	4.58E+09
PR0024317	HOYAMALA WARD SECONDARY SCHOOL	PRWR95K	0.0080	0.0124	0.007	0.0108	639	2000	1.93E+08	5.30E+08
PR0025551	PRASA SAN SEBASTIAN WWTP	PRWR95A	0.5904	0.9133	1.0	1.5470	1008	2000	2.25E+10	7.57E+10

*Note : Scientific notation was used to display the #/day of fecal coliform bacteria, this is a way of writing numbers that accommodates values too large or small to be conveniently written in standard decimal notation. The letter E represents times ten raised to the power noted. To know the given value: after the point add the quantity of zeros to complete the number of spaces determined by the number at the right of the letter “E”. Example: 1.11E+13 = 11,100,000,000,000. This applies, anywhere that a value of this type appears.

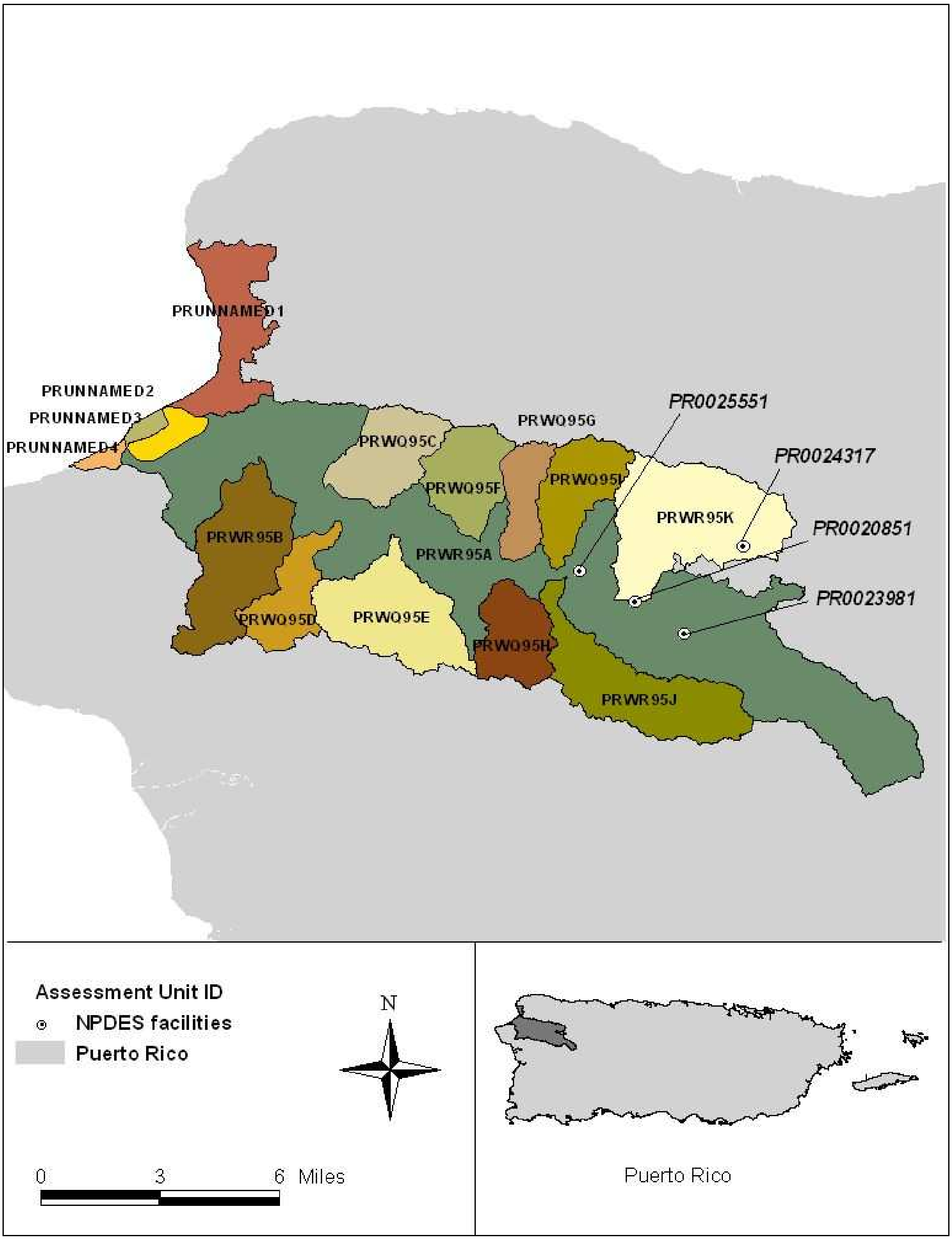

Figure 2-2. Permitted facilities in the Río Culebrinas watershed.

Runoff from *urbanized areas* (UAs)[1] as defined by the U.S. Bureau of the Census is defined as a point source discharge, while runoff from urban areas outside the Census UAs is considered a nonpoint source discharge. A geographical information system (GIS) coverage of UAs from the 2000 Census was used to separate the urban areas into municipal separate storm sewer systems (MS4s) and non-MS4 urban areas. Table 2-3 presents the estimated fecal coliform bacteria loads from MS4 areas in the Culebrinas watershed. The estimated fecal coliform bacteria loads from MS4 areas were calculated based on the unit area load of fecal coliform bacteria for the urban landuses from the LSPC model, and applied to the urban areas within the UAs defined by the census.

Table 2-3. Estimated fecal coliform bacteria loads for MS4 areas

Urbanized Area	County	UA Code	Assessment Unit	Baseline (#/day FC Bacteria)
Aguadilla--Isabela--San Sebastian, PR	Aguada	631	PRUNNAMED1	2.21E+09
Aguadilla--Isabela--San Sebastian, PR	Aguadilla	631	PRUNNAMED1	2.35E+10
Aguadilla--Isabela--San Sebastian, PR	Aguada	631	PRUNNAMED2	1.62E+09
Aguadilla--Isabela--San Sebastian, PR	Aguada	631	PRUNNAMED3	5.08E+08
Aguadilla--Isabela--San Sebastian, PR	Aguada	631	PRUNNAMED4	3.12E+09
Aguadilla--Isabela--San Sebastian, PR	Moca	631	PRWQ95C	9.91E+09
Aguadilla--Isabela--San Sebastian, PR	Aguada	631	PRWQ95D	1.76E+09
Aguadilla--Isabela--San Sebastian, PR	Moca	631	PRWQ95D	1.60E+09
Aguadilla--Isabela--San Sebastian, PR	Moca	631	PRWQ95E	2.31E+09
Aguadilla--Isabela--San Sebastian, PR	Moca	631	PRWQ95F	7.18E+09
Aguadilla--Isabela--San Sebastian, PR	Moca	631	PRWQ95G	3.56E+09
Aguadilla--Isabela--San Sebastian, PR	San Sebastian	631	PRWQ95G	2.24E+09
Aguadilla--Isabela--San Sebastian, PR	Moca	631	PRWQ95H	1.73E+09
Aguadilla--Isabela--San Sebastian, PR	San Sebastian	631	PRWQ95H	1.66E+09
Aguadilla--Isabela--San Sebastian, PR	San Sebastian	631	PRWQ95I	4.53E+09
Aguadilla--Isabela--San Sebastian, PR	Aguada	631	PRWR95A	1.10E+10
Aguadilla--Isabela--San Sebastian, PR	Aguadilla	631	PRWR95A	4.30E+09
Aguadilla--Isabela--San Sebastian, PR	Moca	631	PRWR95A	2.41E+10
Aguadilla--Isabela--San Sebastian, PR	San Sebastian	631	PRWR95A	2.51E+10
Aguadilla--Isabela--San Sebastian, PR	Aguada	631	PRWR95B	1.37E+10
Aguadilla--Isabela--San Sebastian, PR	Moca	631	PRWR95B	5.24E+07
Aguadilla--Isabela--San Sebastian, PR	San Sebastian	631	PRWR95J	6.47E+09
Aguadilla--Isabela--San Sebastian, PR	San Sebastian	631	PRWR95K	1.70E+10
			TOTALS:	1.69E+11

[1] http://cfpub.epa.gov/npdes/stormwater/urbanmapresult.cfm?state=PR

2.3.2 Nonpoint Sources

Nonpoint sources are considered diffuse sources of pollution. They can contribute to a waterbody because of rainfall-runoff processes or diffusely during dry conditions. The following subsections describe potential sources of fecal coliform bacteria to the Río Culebrinas system and identify likely contributors. These sources are ultimately used as the basis for load estimation and TMDL determination.

2.3.2.1 Agriculture

Agricultural land, which typically consists of cropland, pastureland, and refined animal management, represents significant percentage of the total watershed acreage. Land use data from the year 2000 was obtained by associating the classified land cover distribution determined using an ERDAS Imagine[2] imagery by the International Institute of Tropical Forestry (IITF) into land use areas which classifies 1,685 acres as agricultural land and 30,739 acres as pasture (see Table 4-2). This acreage represents 46.4 percent of the watershed and likely has a significant impact on fecal coliform bacteria levels downstream. Table 2-4 provides the livestock population from the single known livestock operation facility in the watershed. The bacteria load from these animals was combined with estimated background loads during the modeling process for a refined estimate of bacteria loading to agricultural lands.

Table 2-4. Livestock operations in the Río Culebrinas watershed

Subbasin	Assessment Unit	Animal	# of Facilities	# of Animals	Land Use Type
406	PRWR95A	HOG	1	347	Agriculture

EPA's Bacteria Indicator Tool indicates that hogs produce 1.08E10 counts/animal/day of fecal coliform bacteria (10,800,000,000 counts/animal/day of fecal coliform bacteria). The agricultural area of the subwatershed is located is 472.6 acres. Accounting for the 347 hogs, the result is an accumulation rate of fecal coliform of 7.93E09 counts/ac/day (7,930,000,000 counts/acres/day of fecal coliform bacteria) . After adding the background sources (6.26E07 count/ac/day) (62,600,000 count/ac/day), the final accumulation rate for agricultural areas was estimated as 7.99E09 count/ac/day (7,990,000,000 count/ac/day). Because no information for the number of horses and/or cows was available for this watershed, the same loading rate calculated for agricultural areas was used for pastures.

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[2] AERDAS Imagine@ is a specific format of geospatial imagery. The imagery used was provided by the International Institute of Tropical Forestry (IITF). IITF=s work is documented in the following reference:
Helmer, E.H., O. Ramos, T. del Mar Lopez, M. Quiñones,and W. Diaz. 2002. *Mapping forest type and land cover of Puerto Rico, a component of the Caribbean biodiversity hotspot.* Caribbean Journal of Science 38:165-183.

2.3.2.2 Non-Permitted Urban Runoff

Urban areas are generally characterized by higher percentages of impervious land because of cover of the land surface by pavement, concrete, and buildings. Higher percentages of impervious area, if not properly managed, result in higher surface runoff potential because of the reduced ability of water to infiltrate into the ground during rainfall events. As water runs over the land and paved surfaces, debris and pollutants such as fecal coliform bacteria are entrained and subsequently flow into storm drains and ditches, which lead to local coastal waterbodies. Harmful bacteria and viruses from pet wastes carried by urban runoff to a waterbody can contribute to shellfish contamination, harm other aquatic life, and threaten human health. Studies have shown that fecal coliform bacteria levels are typically high in urban runoff (USEPA 2001) and, thus, can be a significant source of pollution to the Río Culebrinas system.

EPA's Bacteria Indicator Tool includes fecal coliform accumulation rates for single family low density residential, single family high density residential, and multifamily residential landuses. We estimated the modeled low/medium density residential landuse accumulation rate as the average of both single family low density and single family high density residential. We also estimated the medium/high density residential landuse accumulation rate as the average of both single family high density and multifamily residential, as shown on Table 2-5. Table 2-6 presents the estimated fecal coliform bacteria loads from nonpermitted stormwater by Assessment Unit and landuse type for the Culebrinas watershed.

Table 2-5. Urban landuse accumulation rates of fecal coliform bacteria

Landuse	FECALTOOL Loading Rate (count/ac/day)	Modeled Landuse	Average Loading Rate (count/ac/day)
Single family low density	1.03E+07		
		= Low / Medium Density	1.35E+07
Single family high density	1.66E+07		
		= Medium / High Density	2.00E+07
Multifamily residential	2.33E+07		

Table 2-6. Nonpermitted stormwater fecal coliform bacteria loads by Assessment Unit and landuse type

Landuse Type	Units	Assessment Unit ID						
		PR UNNAMED 1	PR UNNAMED 2	PR UNNAMED 3	PR UNNAMED4	PRWQ95C	PRWQ95D	PRWQ95E
Urban High Density	(#/day FC Bacteria)	5.04E+07	1.11E+07	1.23E+07	1.26E+06	0.00E+00	0.00E+00	6.49E+06
Urban Low Density	(#/day FC Bacteria)	0.00E+00	0.00E+00	4.42E+03	0.00E+00	0.00E+00	2.30E+08	3.41E+09
Landuse Type	Units	PRWQ95F	PRWQ95G	PRWQ95H	PRWQ95I	PRWR95A	PRWR95B	PRWR95J
Urban High Density	(#/day FC Bacteria)	1.75E+05	0.00E+00	0.00E+00	0.00E+00	2.67E+07	9.66E+03	0.00E+00
Urban Low Density	(#/day FC Bacteria)	1.23E+08	3.61E+07	6.18E+08	9.81E+08	8.25E+09	6.18E+06	1.99E+09
Landuse Type	Units	PRWR95K						
Urban High Density	(#/day FC Bacteria)	9.01E+05						
Urban Low Density	(#/day FC Bacteria)	3.66E+08						

2.3.2.3 Wastewater Disposal

In addition to urban runoff contributions, other possible sources for contribution of fecal coliform bacteria from human waste to the Río Culebrinas system include the following:

- Illegal discharges of untreated wastewater
- Transport of water from failed septic systems toward a water body
- Leaking sewage mains

These processes are all more common in areas with higher populations, for example, in residential or commercial zones. Within the Río Culebrinas system, residential septic systems treat human waste using a collection system that discharges liquid waste into the soil through a series of distribution lines that comprise the drain field. Fecal coliform bacteria naturally die off as the effluent percolates through the soil to the groundwater. These systems effectively remove fecal coliform bacteria when properly installed and maintained. A septic system failure occurs when there is a discharge of waste to the soil surface where it is available for washoff into surface waters. Failing septic systems can deliver high bacteria loads to surface waters, depending on the proximity of the discharge to a waterbody and the timing of rainfall events. Septic system failures typically occur in older systems that are not adequately maintained with periodic sewage pump-outs.

Septic system failure may be a more significant source of fecal coliform bacteria in the watershed, based on census data for the region. Based on 2000 Census data, the estimated population in the watershed is 115,560. Based on the percentage of households that are sewered, on septics, or other from the Census 1990 by municipality (see Appendix A, this breakdown was not available for Census 2000), it is estimated that approximately 61 percent (70,178) of the population in this watershed is serviced by on-site septic systems, and approximately 6 percent (7,398) are serviced by latrine systems. The remaining population (37,987) is estimated to be sewered.

To calculate a fecal coliform bacteria load from failing septic systems, a 100 percent failure rate was used for latrines, and a 10 percent failure rate was used for septic systems (a rate used in the *Salt River Bay Biochemical Oxygen Demand TMDL* (USEPA 2004)). EPA's *Onsite Wastewater Treatment Systems Manual* (USEPA 2002) provides an estimate of average daily wastewater flows in residential systems of between 50 and 70 gallons per capita per day (GPCD) for residential dwellings built before 1994 and between 40 and 60 GPCD for residential dwellings built after 1994 (U.S. Energy Policy Act standards went into effect in 1994). Considering the nature of the housing stock of the unsewered areas in Puerto Rico, an estimate of 50 GPCD was selected to develop a population-based estimate. Horsley and Witten (1996) estimated that septic system discharge contains a concentration of 1e4 (10,000) colony forming units (CFU)/100 mL, while Metcalf and Eddy (1991) estimated typical concentrations in untreated sewage at 1e6 (1,000,000) CFU/100 mL. On the basis of these estimates, an average value of 1e5 (100,000) CFU/100 mL was selected for use in the TMDL. Table 2-7 presents estimated septic system loading rates by modeled subwatershed. A map of the modeled subwatersheds is shown in Figure 4-1.

Table 2-7. Fecal coliform bacteria loading rates from failing septic systems by subwatershed

SWS_ID	Assessment Unit	Total Population	Population on Sewers	Population on Septics	Population Latrines	Population on Failing Systems = 100% of Latrines, 10% of Septics	Flow Overcharge (gal/person/day)	Flow Total (cfs)	Fecal Coliform Conc. (#/100mL)	FC Load (#/day)
401	PRUNNAMED2	2733	743	1780	209	387	50	0.029966	1.00E+05	7.33E+10
402	PRWR95A	6914	2194	4240	480	904	50	0.069946	1.00E+05	1.71E+11
403	PRWR95A	9980	2908	6393	679	1319	50	0.102019	1.00E+05	2.50E+11
404	PRWR95A	4110	1048	2764	298	574	50	0.044401	1.00E+05	1.09E+11
405	PRWR95A	3375	1087	2079	209	417	50	0.032251	1.00E+05	7.89E+10
406	PRWR95A	15849	5105	9715	1030	2001	50	0.154820	1.00E+05	3.79E+11
407	PRWR95K	9262	3001	5691	571	1140	50	0.088178	1.00E+05	2.16E+11
408	PRWR95J	3718	1204	2284	229	457	50	0.035392	1.00E+05	8.66E+10
409	PRWQ95I	2730	884	1677	168	336	50	0.025991	1.00E+05	6.36E+10
410	PRWQ95H	2359	680	1521	159	311	50	0.024033	1.00E+05	5.88E+10
411	PRWQ95G	2247	634	1460	153	299	50	0.023152	1.00E+05	5.66E+10
412	PRWQ95E	4500	1169	3009	323	624	50	0.048258	1.00E+05	1.18E+11
413	PRWQ95F	3897	994	2621	282	544	50	0.042108	1.00E+05	1.03E+11
414	PRWQ95D	2579	673	1716	190	362	50	0.027995	1.00E+05	6.85E+10
415	PRWQ95C	7061	1801	4748	511	986	50	0.076288	1.00E+05	1.87E+11
416	PRWR95B	10285	2797	6701	788	1458	50	0.112780	1.00E+05	2.76E+11
417	PRUNNAMED1	20878	10227	9770	882	1859	50	0.143784	1.00E+05	3.52E+11
418	PRUNNAMED3	1039	282	677	80	147	50	0.011391	1.00E+05	2.79E+10
419	PRUNNAMED4	2044	556	1332	157	290	50	0.022418	1.00E+05	5.48E+10
							Totals:	**1.115170**		2.73E+12

2.3.2.4 Background Conditions

Background fecal coliform bacteria loads are from non-human, natural sources. Their contributions can be directly to a waterbody or to the watershed surface where they are ultimately carried to a waterbody. Watershed contributions can be estimated from water quality data collected at headwater stations where the contributing land consists almost entirely of natural landscape with little or no human influence. However, no headwater stations of this type exist for the Río Culebrinas study area. Native bird and mammal populations residing in and around the streams can contribute fecal coliform bacteria directly to the river system. Similarly, flocks of native or migrating birds can land for a short time, and contribute to the bacteria load before departing.

The fecal coliform accumulation rate for background conditions was calculated using an estimate of 10 small animals per square mile. A rate of 8.02E9 count/animal/day was used (8,020,000,000 count/animal/day). This value is the average loading rate for small animals from EPA's Bacteria Indicator Tool. An estimated 50 percent of the accumulated load was assumed to be available for runoff to carry into the streams. Using these inputs, the estimated accumulation rate of fecal coliform bacteria for forested areas was 6.26E7 count/acre/day (62,600,000 count/animal/day).

2.4 Current Conditions

The TMDLs for the Río Culebrinas basin were developed on the basis of conditions that existed from 1995 to 2004. This time frame is concurrent with the majority of the available ambient water quality and flow data. Although data were collected over a significant time frame and at regular intervals, they do not demonstrate insight to suggest improvement or deterioration over this time period. However, seasonal trends are observed. Section 3 summarizes the available data.

3 DATA ANALYSIS

3.1 Monitoring Data

The Río Culebrinas system has elevated fecal coliform bacteria concentrations. Data from a representative station for the Río Culebrinas watershed were reviewed to obtain an initial estimate of critical conditions in the watershed. Water quality stations that also measure flow are most useful for this initial analysis, because flow also provides insight into meteorological conditions and thus the sources affecting the waterbody.

In the Río Culebrinas watershed, two USGS gages are maintained and are listed in Table 3-1. The locations of the stations and water quality stations maintained by PREQB are shown in Figure 3-1 and have been verified by PREQB staff.

Table 3-1. USGS gages in the Río Culebrinas watershed

Site no.	Station name	Elevation (ft)	Drainage area (mi^2)
50147800	Rio Culebrinas at Hwy 404 Near Moca, PR	45	71.2
50148890	Rio Culebrinas at Margarita Dam Site Near Aguada, PR	14.8	94.6

USGS water quality station 50147600, Río Culebrinas near San Sebastián, provides bacteria data (n = 128) collected between 1980 and 2008. This station provides the highest quantity of water quality data points in the watershed, so this station was used to further investigate flow (and thus seasonal) conditions in the Río Culebrinas watershed. There are no stations in the watershed that provide a significant amount of both coincident flow and bacteria data at the same location; therefore, streamflow at water quality station 50147600 was estimated on the basis of flow-weighted measurements at USGS flow gage 50147800, near Moca. Table 3-2 presents the data in tabular format and categorizes the data by flow percentile. The same data are graphically presented in Figure 3-2.

The data shown in Table 3-2 and Figure 3-2 suggest that the majority of bacteria loading occur during higher flow conditions in the watershed. Although Table 3-2 and Figure 3-2 clearly suggest that low flows (0–30th percentile) but also higher flows (80–100th percentile) exhibit higher fecal coliform bacteria concentrations, all flow percentiles exhibit average bacteria concentrations higher than the geomean criteria concentration of 200 colonies/100 mL. Therefore, both point and nonpoint source loading of bacteria are likely significant sources of bacteria in this watershed. The Source Assessment section discusses potential point source and nonpoint source contributions in the watershed.

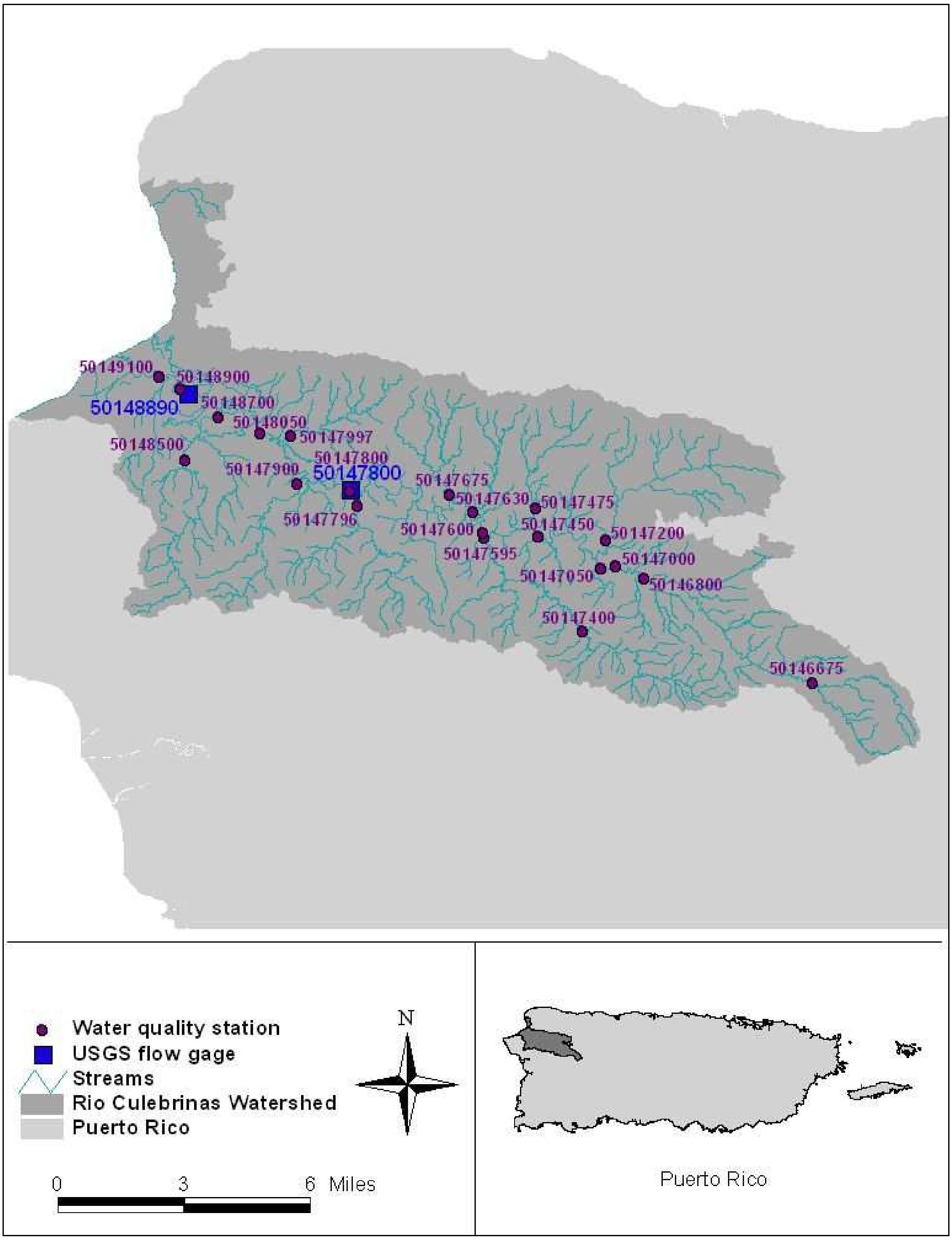

Figure 3-1. Flow and water quality stations in the Río Culebrinas watershed.

Table 3-2. Fecal coliform bacteria data grouped by flow percentile at USGS 50147600 (Rio Culebrinas near San Sebastian)

Flow Range	# Obs	Flow (cfs)			Concentration (#/100mL)			
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Median*	*Min*	*Max*
0-10	13	29.427	22.070	34.331	521	380	70	1,700
10-20	13	44.392	38.419	49.045	5,645	960	200	60,000
20-30	13	57.659	50.680	62.941	12,755	1,400	200	70,000
30-40	12	71.251	63.758	77.654	10,205	3,250	270	64,000
40-50	13	98.530	80.924	108.716	9,087	6,000	810	45,000
50-60	13	134.811	112.803	156.126	16,675	4,100	470	66,000
60-70	12	185.690	161.848	227.242	7,771	4,850	520	24,000
70-80	13	267.043	232.963	308.983	12,796	5,300	1,600	54,000
80-90	13	391.982	317.157	574.643	25,914	8,100	230	140,000
90-100	13	1829.502	578.730	4855.449	27,787	10,000	3,700	150,000

Note: Data from 3/20/1980 to 8/19/2008 (128 Observations)

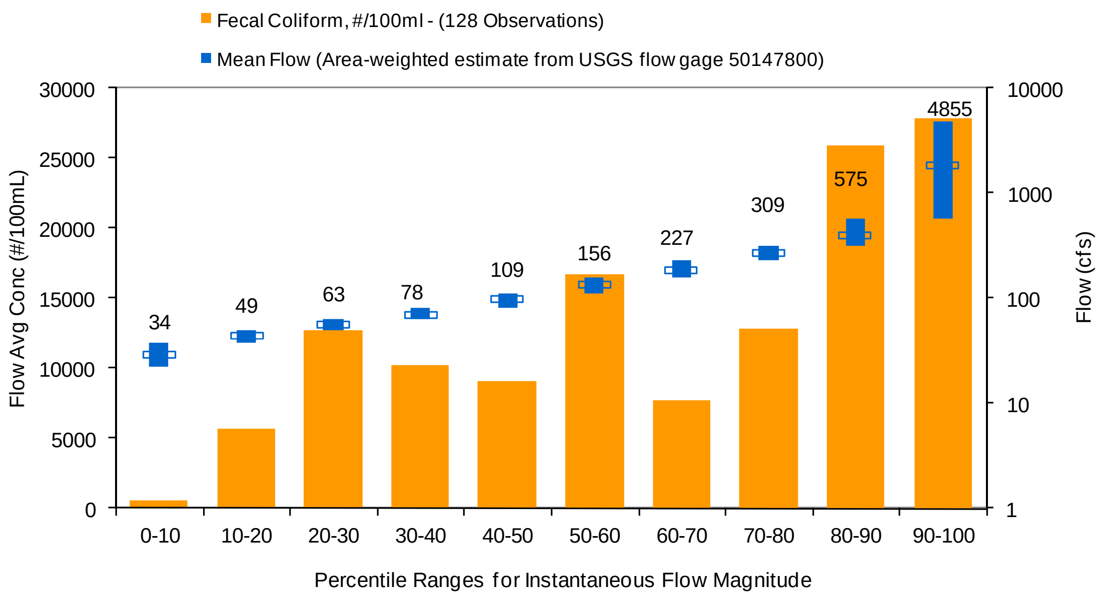

Figure 3-2. Bacteria data grouped by flow percentile at USGS 50147600.

Table 3-3. Fecal coliform bacteria data grouped by month at USGS 50147600 (Rio Culebrinas near San Sebastian)

Time Period	# Obs	Flow (cfs)			Concentration (#/100 mL)		
Month	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
January	4	68.050	51.497	102.994	17304.83	570.00	60000.00
February	15	233.508	27.792	2852.781	46924.00	70.00	60000.00
March	12	47.887	22.070	127.517	9283.61	170.00	70000.00
April	8	51.497	26.157	171.657	2415.73	260.00	4600.00
May	12	485.136	49.045	3122.528	8055.66	300.00	47000.00
June	11	309.801	50.680	1626.657	17229.53	520.00	60000.00
July	4	174.110	103.812	328.601	9089.44	2500.00	12400.00
August	19	501.463	66.211	4855.449	15093.64	230.00	140000.00
September	9	176.108	66.211	293.452	11657.19	600.00	24000.00
October	9	344.859	105.447	1046.292	14972.93	3900.00	28000.00
November	13	628.593	98.090	2542.163	41127.08	1600.00	150000.00
December	12	258.440	58.037	2002.669	27441.66	430.00	64000.00

Note: Data from 3/20/1980 to 8/19/2008 (128 Observations)

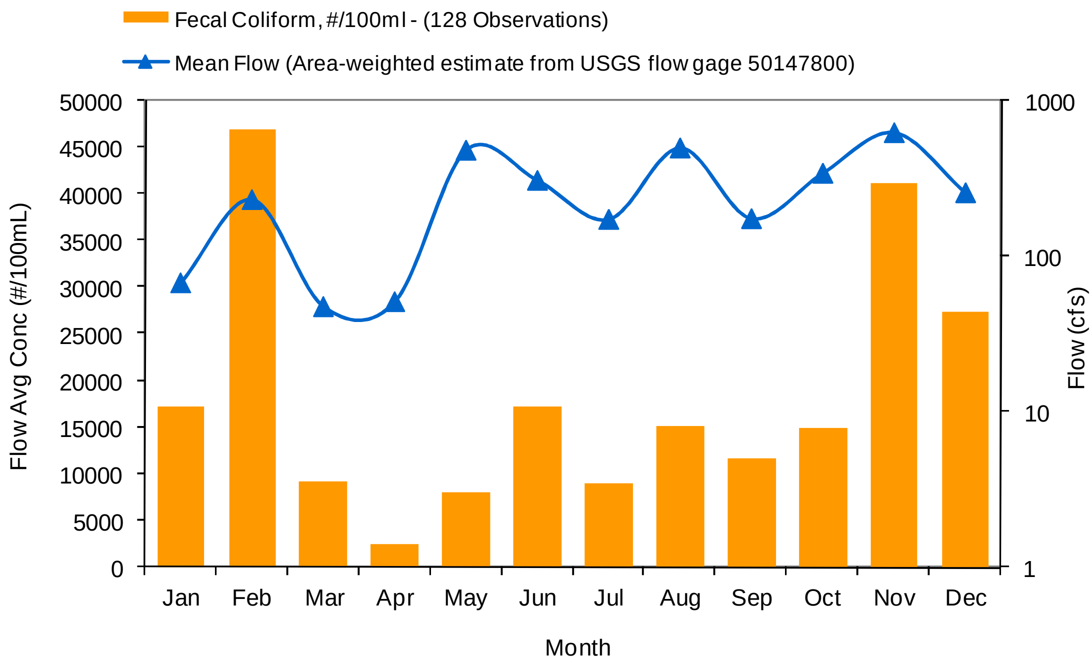

Figure 3-3. Bacteria data grouped by month at USGS 50147600.

3.2 Critical Conditions

The goal of the TMDL is to determine the assimilative capacity of a waterbody on the basis of established water quality standards and to identify potential allocation scenarios that enable the waterbody to achieve the standards. The critical condition is the set of environmental conditions for which controls designed to protect water quality will ensure attainment of objectives for all other conditions. This is typically the period of time in which the impaired waterbody exhibits the most vulnerability.

Puerto Rico experiences relatively high humidity in the summer, and most rainfall occurs between May and December. Showers, which can be locally heavy, can be expected any time of the year. Most showers have a short duration. The hurricane season runs from June to November, but hurricanes occur most often between August and October.

Flow data from the watershed were used to identify whether elevated bacteria levels occur during rainfall events (and are likely watershed-driven) or during dry conditions.
Available data for the watershed were evaluated with respect to seasonality to identify possible trends and critical conditions. As shown in Section 3.1, the data suggest that low-flow conditions and high-flow periods are the critical periods in the watershed.

The TMDL analytical framework (further described in subsequent sections) predicts bacteria concentrations in-stream and in tidally influenced portions of the system on the basis of all sources present. Note that the TMDL analytical approach considers all conditions for TMDL development, not only the critical condition. It also considers dry condition sources (e.g., septic system failure) in addition to rainfall-driven sources.

4 ANALYTICAL APPROACH

Establishing the relationship between the in-stream water quality targets and source loadings is a critical component of TMDL development. It allows for evaluation of management options that will achieve the desired source load reductions necessary to meet water quality standards. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody responses with flow and loading conditions. This section presents the approach taken to develop the linkage between sources and in-stream response for TMDL development in the Río Culebrinas watershed.

A watershed model is a useful tool for providing a quantitative linkage between sources and in-stream response. It is essentially a series of algorithms applied to watershed characteristics and meteorological data to simulate naturally occurring, land-based processes over an extended period, including hydrology and pollutant transport. Many watershed models are also capable of simulating in-stream processes using the land-based and subsurface calculations as input. After a model has been adequately set up and calibrated for a watershed, it can be used to quantify the existing loading of pollutants from subwatersheds or from land use categories and also can be used to assess the effects of a variety of management scenarios.

To support TMDL development objectives and evaluate the linkage between bacteria sources and in-stream water quality, Tetra Tech created an analytical framework combining a tidal prism model of the tidal portions of the Río Culebrinas mainstem and a detailed watershed loading model. The LSPC model was used to simulate source loading and attenuation of bacteria in the watershed, and the results of the model were applied to a separate tidal prism, or box model, style representation of the tidal portions of the watershed.

The following technical factors were fundamental to selecting an appropriate watershed model to support development of the Río Culebrinas watershed TMDLs:

- The model should be able to address a variety of pollutants including the pollutants of concern (e.g., bacteria).
- The model should be able to simulate processes and interactions in the surface and subsurface environments.
- The model should be able to address a watershed with mixed land uses.
- The model should provide adequate time-step estimation of flow and not oversimplify storm events to provide accurate representation of rainfall events and resulting peak runoff.
- The model should be capable of simulating various pollutant transport mechanisms (e.g., groundwater contributions, sheet flow).

The LSPC (USEPA 2003a) was selected for simulation of watershed hydrology and water quality. The present version of LSPC includes algorithms for simulating pollutant accumulation and washoff of land surfaces and is a component of EPA's TMDL Modeling Toolbox (Toolbox) (USEPA 2003b), which has been developed through a joint effort between EPA and Tetra Tech. LSPC integrates comprehensive data storage and management capabilities and a dynamic watershed model (a re-coded version of EPA's Hydrological Simulation Program – FORTRAN [HSPF] [Bicknell et al. 1996]) that dictates no software requirements.

Because LSPC is based on a re-coded version of HSPF, a brief overview of HSPF is provided here. HSPF is a comprehensive watershed and receiving water quality modeling framework that was originally developed in the mid-1970s. During the past several years, it has been used to develop hundreds of EPA-approved TMDLs, and it is generally considered the most advanced hydrologic and watershed loading model available. The hydrologic portion of HSPF is based on the Stanford Watershed Model (Crawford and Linsley 1966), which was one of the pioneering watershed models developed in the 1960s. The HSPF framework is developed modularly with many different components that can be assembled in different ways, depending on the objectives of a project. The model includes three major modules:

- PERLND for simulating watershed processes on pervious land areas
- IMPLND for simulating processes on impervious land areas
- RCHRES for simulating processes in streams and vertically mixed lakes

All three of these modules include many subroutines that calculate the various hydrologic and water quality processes in the watershed. Many options are available for both simplified and complex process formulations. Spatially, the watershed is divided into a series of subwatersheds representing the drainage areas that contribute to each of the stream reaches. These subwatersheds are then further subdivided into segments representing different land uses.

For the developed areas, the land use segments are further divided into the pervious (PERLND) and impervious (IMPLND) fractions. The stream network (RCHRES) links the surface runoff and groundwater flow contributions from each of the land segments and subbasins and routes them through the waterbodies using storage routing techniques. The stream model includes precipitation and evaporation from the water surfaces as well as flow contributions from the watershed, tributaries, and upstream stream reaches. It also accommodates flow withdrawals. The stream network is constructed to represent all the major tributary streams and different portions of stream reaches where significant changes in water quality occur.

4.1 Watershed Model Configuration

The LSPC model was configured for the areas contributing to impaired streams in the Río Culebrinas watershed and then used to simulate a series of hydrologically connected subwatersheds. Configuring the model involved subdividing the watersheds into modeling units, followed by continuous simulation of flow and water quality for these units using meteorological, land use, soils, stream, and bacteria data. Development and application of the watershed model to address the project objectives involved the following major steps, which are discussed further below:

1. Watershed delineation
2. Configuration of key watershed model components
3. Watershed model calibration and validation

4.1.1 Watershed Delineation

Watershed delineation refers to subdividing the entire watershed into smaller, discrete subwatersheds for modeling and analysis. LSPC calculates watershed processes on the basis of user defined, hydrologically connected subwatersheds. This subdivision was primarily based on stream networks and topographic variability and secondarily on the locations of flow and water quality monitoring stations to facilitate model calibration. Nineteen subwatersheds were defined for the Río Culebrinas watershed, as shown in Table 4-1 and Figure 4-1.

Table 4-1. Modeled subbasins defined for the Río Culebrinas watershed

Subbasin	AU code	Assessment unit name	Area (acres)
401	PRUNNAMED2	UNNAMED 2	841
402	PRWR95A	RIO CULEBRINAS	3,289
403	PRWR95A	RIO CULEBRINAS	5,559
404	PRWR95A	RIO CULEBRINAS	3,866
405	PRWR95A	RIO CULEBRINAS	2,988
406	PRWR95A	RIO CULEBRINAS	11,373
407	PRWR95K	RIO GUATEMALA	6,801
408	PRWR95J	RIO SONADOR	5,308
409	PRWQ95I	QUEBRADA SALADA	2,840
410	PRWQ95H	QUEBRADA GRANDE DE LA MAJAGUA	2,547
411	PRWQ95G	QUEBRADA EL SALTO	1,753
412	PRWQ95E	QUEBRADA YAGRUMA	4,857
413	PRWQ95F	QUEBRADA LASALLE	2,811
414	PRWQ95D	QUEBRADA LAS MARIAS	2,352
415	PRWQ95C	QUEBRADA GRANDE	3,101
416	PRWR95B	RIO CANAS	5,181
417	PRUNNAMED1	UNNAMED 1	3,762
418	PRUNNAMED3	UNNAMED 3	312
419	PRUNNAMED4	UNNAMED 4	335

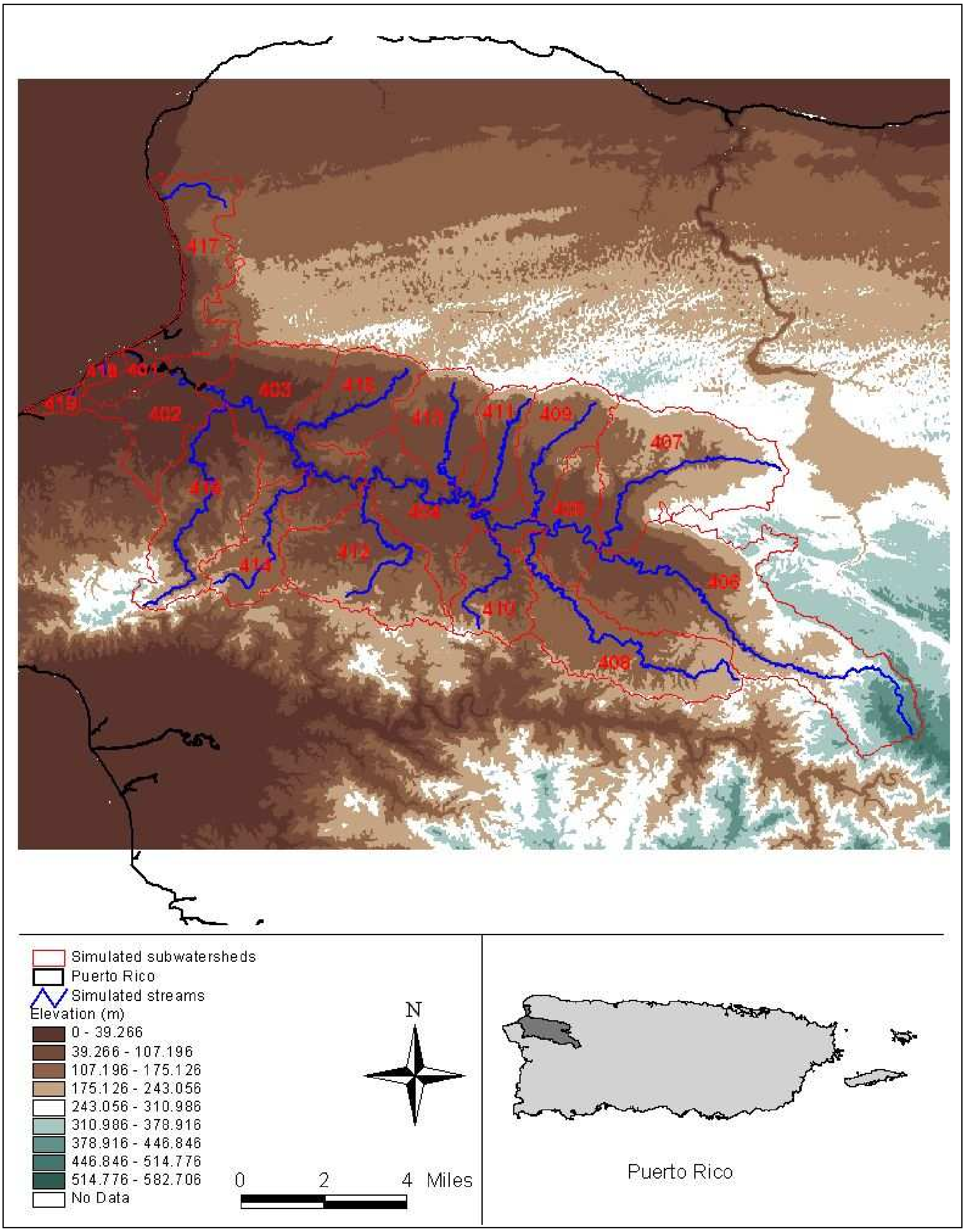

Figure 4-1. Modeled subwatersheds and stream network.

4.1.2 Configuration of Key Watershed Model Components

Configuring the watershed model involved considering the following five major components:

- Waterbody representation
- Land use representation
- Meteorological data
- Hydrologic representation
- Pollutant representation

These components provided the basis for the LSPC model's ability to estimate flow and pollutant loadings. Detailed discussions about developing each component for the LSPC model are provided in the following subsections.

4.1.2.1 Waterbody Representation

Waterbody representation refers to modules, or algorithms, in the LSPC model used to simulate flow and pollutant transport through streams, rivers, and lakes. Each delineated subwatershed was represented with a single stream or lake feature. Streams are assumed to be completely mixed, one-dimensional segments with a constant trapezoidal cross-section. EPA's National Hydrography Dataset (NHD) stream reach network was used to determine the representative stream length for each subwatershed. The stream lengths were used along with the 30-meter National Elevation Dataset to calculate reach slope.

Assuming representative trapezoidal geometry for all streams, mean stream depth and channel width were estimated using regression curves that relate upstream drainage area to stream dimensions (Rosgen and Silvey 1996). Rating curves consisted of a representative depth-outflow-volume-surface area relationship. An estimated Manning's roughness coefficient of 0.02 was applied to each representative stream reach on the basis of typical literature values for natural streams (Chapra 1997).

4.1.2.2 Land Use Representation

The LSPC watershed model requires a basis for distributing hydrologic and pollutant loading parameters. Hydrologic variability within a watershed is influenced by land surface and subsurface characteristics. Variability in pollutant loading is highly correlated to land use practices. Land use representation provides the basis for distributing soils and pollutant loading characteristics throughout the watershed. Land cover data were obtained from the IITF and used as the basis for estimating pollutant loading from nonpoint sources. These data provide land cover data as of 2000, which fall within the model calibration and validation periods (1995–2004) discussed later in this section. Land use area within each subbasin is provided in Appendix D: Subbasin Land Use Area.

LSPC algorithms require that land use categories be divided into separate pervious and impervious land units for modeling. This division was made for the appropriate land uses (primarily urban) to represent impervious and pervious areas separately. The division was based on typical impervious percentages associated with different land use types from the

Soil Conservation Service's TR-55 Manual (USDA 1986) as summarized in Table 4-2. Land use distribution in the Río Culebrinas watershed is shown in Figure 4-2.

Table 4-2. Land cover data and for the Río Culebrinas watershed and aggregation into simulated land use categories

ID	Land Cover Description	Modeled Landuse	Area (ac)	%
0	Background/water	Water	312	0.45%
1	High-Medium Density Urban	Urban_HighD	1,286	1.84%
2	Low-Medium Density Urban	Urban_LowD	10,713	15.33%
3	Herbaceous Agriculture - Cultivated Lands	Agriculture	0	0.00%
4	Active Sun Coffee and Mixed Woody Agriculture	Agriculture	1,685	2.41%
5	Pasture, Hay or Inactive Agriculture (e.g. abandoned sugar cane)	Pasture	0	0.00%
6	Pasture, Hay or other Grassy Areas (e.g. soccer fields)	Pasture	30,739	43.99%
7	Drought Deciduous Open Woodland	Forest	0	0.00%
8	Drought Deciduous Dense Woodland	Forest	2	0.00%
9	Deciduous, Evergreen Coastal and Mixed Forest or Shrubland with Succulents	Forest	0	0.00%
10	Semi-Deciduous and Drought Deciduous Forest on Alluvium and Non-Carbonate Substrates	Forest	20	0.03%
11	Semi-Deciduous and Drought Deciduous Forest on Karst (includes semi-evergreen forest)	Forest	465	0.67%
12	Drought Deciduous, Semi-deciduous and Seasonal Evergreen Forest on Serpentine	Forest	0	0.00%
13	Seasonal Evergreen and Semi-Deciduous Forest on Karst	Forest	3,815	5.46%
14	Seasonal Evergreen and Evergreen Forest	Forest	20,445	29.26%
15	Seasonal Evergreen Forest with Coconut Palm	Forest	2	0.00%
16	Evergreen and Seasonal Evergreen Forest on Karst	Forest	1	0.00%
17	Evergreen Forest on Serpentine	Forest	0	0.00%
18	Elfin, Sierra Palm, Transitional and Tall Cloud Forest	Forest	0	0.00%
19	Emergent Wetlands Including Seasonally Flooded Pasture	Wetland	128	0.18%
20	Salt or Mud Flats	Wetland	0	0.00%
21	Mangrove	Wetland	29	0.04%
22	Seasonally Flooded Savannahs and Woodlands	Wetland	0	0.00%
23	Pterocarpus Swamp	Wetland	0	0.00%
24	Tidally Flooded Evergreen Dwarf-Shrubland and Forb Vegetation	Wetland	0	0.00%
25	Quarries	Barren	0	0.00%
26	Coastal Sand and Rock	Barren	28	0.04%
27	Bare Soil (including bulldozed land)	Barren	205	0.29%
	TOTAL		**69,875**	**100.00%**

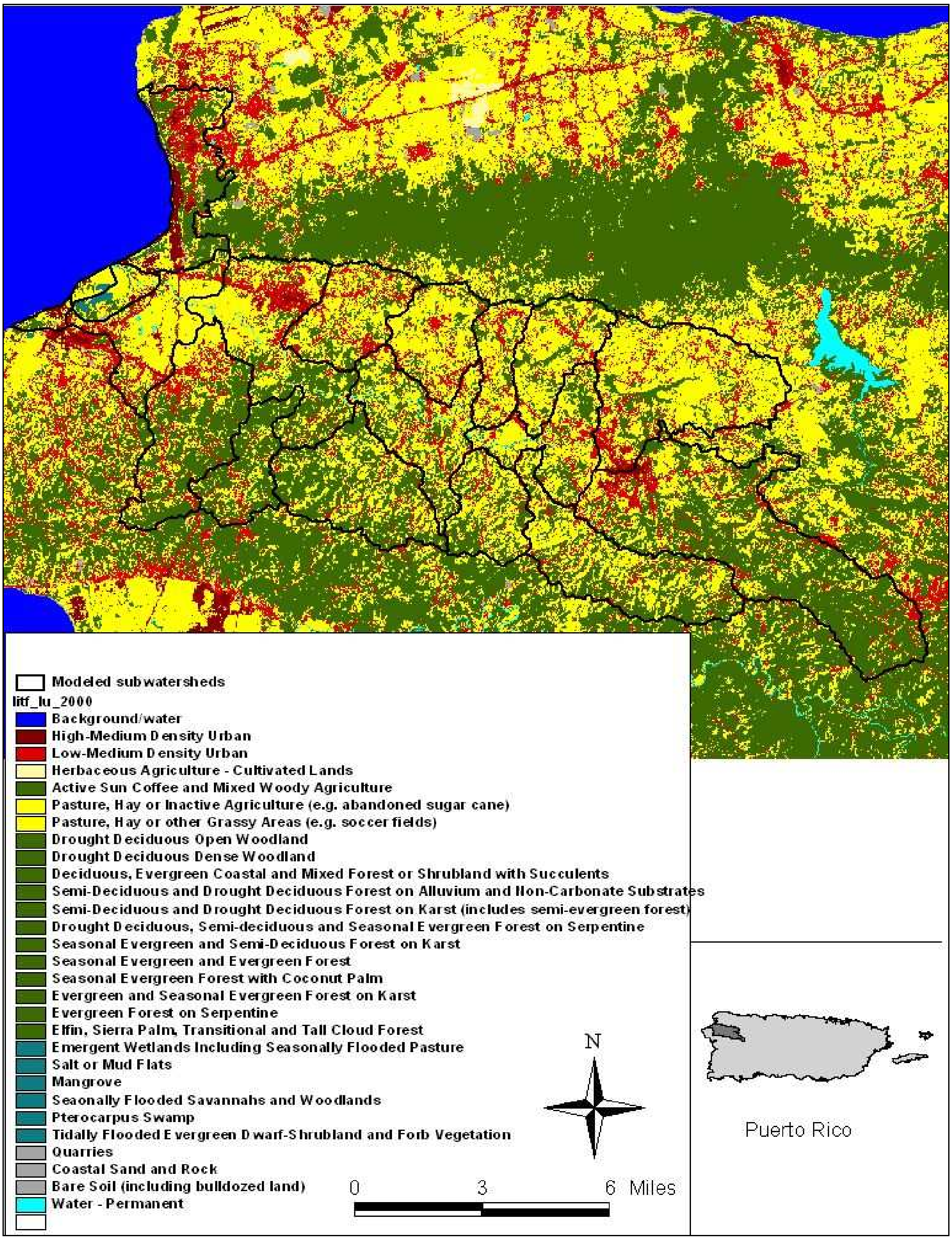

Figure 4-2. Land cover distribution in the Río Culebrinas watershed.

4.1.2.3 Hydrologic Representation

Hydrologic representation refers to the LSPC modules or algorithms used to simulate hydrologic processes (e.g., surface runoff, evapotranspiration, and infiltration). The LSPC PWATER (water budget simulation for pervious land segments) and IWATER (water budget simulation for impervious land segments) modules, which are identical to those in HSPF, were used to represent hydrology for all pervious and impervious land units (Bicknell et al. 1996). Designation of key hydrologic parameters in the PWATER and IWATER modules of LSPC were required. These parameters are associated with infiltration, groundwater flow, and overland flow. U.S. Department of Agriculture, Natural Resources Conservation Service STATSGO Soils Database served as a starting point for designating infiltration and groundwater flow parameters. STATSGO data are shown in Figure 4-3. For parameter values not easily derived from these sources, documentation on recent HSPF applications was reviewed. Starting values were refined through the hydrologic calibration process (described in Section 4.1.3.1).

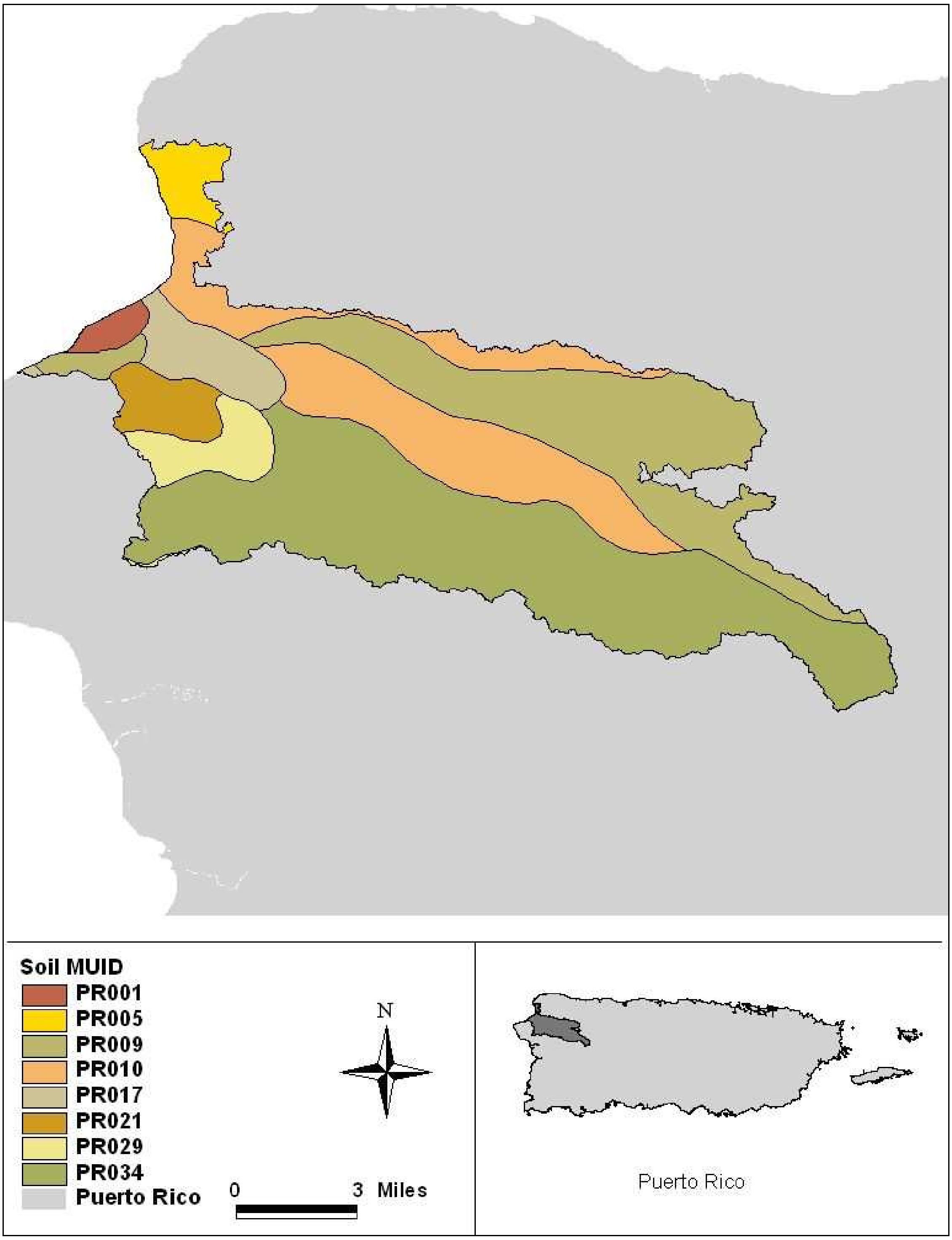

Figure 4-3. STATSGO soil data used in the LSPC watershed model.

4.1.2.4 Meteorological Representation

Meteorological data are a critical component of the watershed model, and appropriate representation of precipitation and evapotranspiration are required to develop a valid modeling system. These data provide necessary input to LSPC algorithms for hydrologic and water quality representation. Meteorological data have been accessed for two weather stations in an effort to develop the most representative data set for the Río Culebrinas watershed. Weather station attributes are listed in Table 4-3, and the locations of these sources are shown in Figure 4-4. Hourly precipitation and minimum and maximum daily temperature records were obtained from Earth Info's weather CD set. The original source of the data is the National Climatic Data Center.

Table 4-3. Attributes of weather stations represented in the watershed model

Parameter	Station ID	Station Name	Lat (dd)	Long (dd)	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Precipitation (in)	PR2801	Coloso	18.383056	-67.160833	2.06	2.43	2.82	4.66	9.50	9.18	7.39	9.65	9.10	8.69	4.88	2.72
Precipitation (in)	PR8881	San Sebastian 2WNW	18.346944	-67.011667	2.90	2.52	4.17	7.74	11.95	9.48	7.31	11.22	10.99	11.61	6.60	2.78
Temperature (min)	668881	San Sebastian 2WNW	18.346944	-67.011667	60.53	60.57	61.90	63.59	66.26	67.38	67.32	67.57	66.88	66.58	65.05	62.49
Temperature (max)	668881	San Sebastian 2WNW	18.346944	-67.011667	87.57	87.83	88.79	89.81	90.73	91.67	92.12	92.58	92.22	91.74	89.70	87.81

LSPC requires appropriate precipitation and potential evapotranspiration data. In general, hourly precipitation data are recommended for hydrologic modeling to help assess pollutant loading (although in some cases, such as small, flashy, highly urbanized watersheds 15-minute data might be necessary). Therefore, only weather stations with hourly recorded data have been considered thus far in the process of selecting precipitation data. Rainfall-runoff processes for each subwatershed were driven by precipitation data from the most representative station. Meteorological data from two stations in and around the Río Culebrinas watershed were assessed for the watershed model.

During the processing phase of the assessment, gaps in data were identified in addition to unreliable values that could misrepresent observed conditions. Missing and unreliable values were encountered frequently in the precipitation and temperature data sets. Missing values were patched using a program that fills missing values with data from surrounding stations, and unreasonable values were deleted to allow for patching. The patched meteorological data were subsequently formatted for use in the modeling effort.

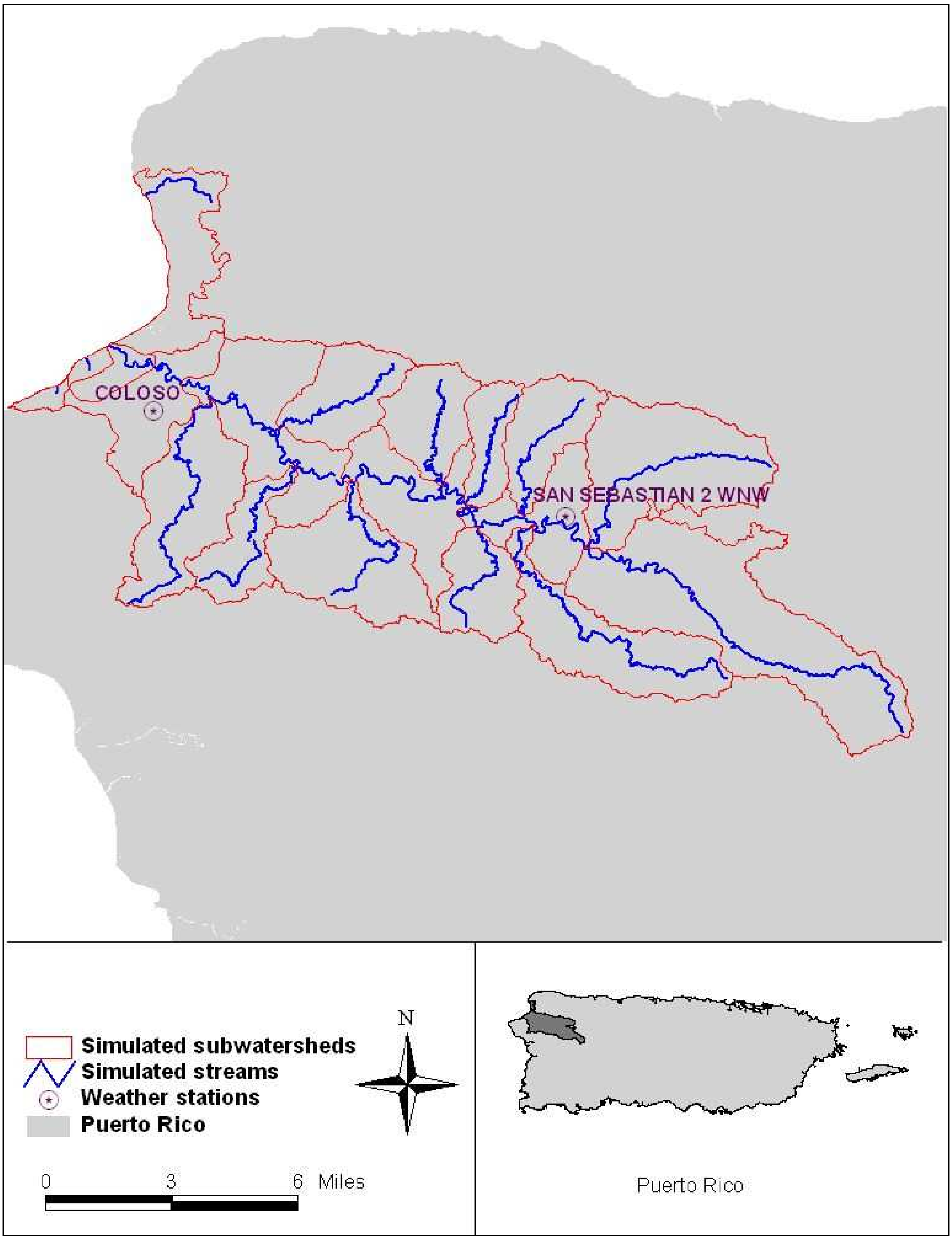

Figure 4-4. Weather stations used in the Río Culebrinas watershed modeling process.

Potential evapotranspiration was calculated using the Hamon method. This method generates daily potential evapotranspiration (inches) using air temperature, a monthly variable coefficient, the number of hours of sunshine (computed from latitude), and absolute humidity (computed from air temperature). The computations are based on the Hamon (1961) formula:

$$PET = CTS \times DYL \times DYL \times VDSAT$$

where

PET = daily potential evapotranspiration (in inches)
CTS = monthly variable coefficient
DYL = possible hours of sunshine, in units of 12 hours, computed as a function of latitude and time of year
$VDSAT$ = saturated water vapor density (absolute humidity) at the daily mean air temperature (g/cm^3)

$$VDSAT = (216.7 \times VPSAT) / (TAVC + 273.3)$$

where

$VPSAT$ = saturated vapor pressure at the air temperature
$TAVC$ = mean daily air temperature, computed from the daily max-min data (C)

$$VPSAT = 6.108 \times \mathrm{EXP}((17.26939 \times TAVC) / (TAVC + 237.3))$$

Hamon (1961) suggests a constant value of 0.0055 for CTS.

A sine function is used to disaggregate the daily *PET* over the daylight hours. Daylight hours are computed as a function of date and latitude (and the shape of the earth).

The final set of LSPC weather files created included hourly precipitation and calculated potential evapotranspiration for the time period starting on 1/1/1980 through 12/31/2004. The model is run using an hourly time-step.

4.1.2.5 Pollutant Representation

On the basis of analysis of the water quality data in the Río Culebrinas watershed and potential sources listed with the impairment, possible sources of bacteria include major and minor municipal point sources, landfills, collection system failure, urban runoff/storm sewers, minor industrial point sources, confined animal feeding operations, agricultural practices, and onsite wastewater systems..

The primary pollutant represented in the watershed model to estimate loading in the Río Culebrinas watershed is fecal coliform bacteria. Loading processes for pollutants were represented for each land unit using the LSPC PQUAL (simulation of quality constituents for pervious land segments) and IQUAL (simulation of quality constituents for impervious land segments) modules, which are identical to those in HSPF. These modules simulate the accumulation of bacteria on the land surface and removal during overland flow, which is simulated as being removed at a rate related to the volume of water flowing over the land surface.

Point Source Representation

Point source contributions of flow and bacteria were incorporated into the model to represent the sources described in Section 2.3. During calibration, representative flow and pollutant concentrations obtained from discharge monitoring data were used. During the baseline condition, permitted flows and concentrations were used to represent the worst case condition allowable under permit limits.

Nonpoint Source Representation

The watershed model distributes hydrologic and pollutant loading parameters on the basis of land use type to appropriately represent hydrologic variability throughout the watershed. This variability can be influenced by land use-specific surface and subsurface characteristics. It is also necessary to represent variability in pollutant loading, which is highly correlated to land practices. As discussed in Section 4.1.2.2, land cover data from IITF were used to configure the Culebrinas LSPC model. LSPC model algorithms that simulate hydrologic and pollutant loading processes for pervious and impervious lands were then applied to the corresponding land units.

Surface and subsurface hydrologic behavior drives pollutant transport in the watershed. On the basis of the distribution of rainfall between the surface and subsurface components, a quantity of bacteria is washed off into a stream reach. Here, it is subject to decay as it travels through the simulated stream network.

Bacteria were modeled as a pollutant that builds up and washes off. LSPC can simulate pollutants as either sediment-associated or using a buildup-washoff relationship. To simulate bacteria, hydrology must first be simulated and calibrated. Once this is complete, accumulation rates for the land surface are then assigned to identify the quantity available for washoff. As rainfall removes the bacteria from the land surface, it is discharged to receiving waters proportional to the overland flow.

Fecal coliform loading rates were obtained using information from EPA's Bacterial Indicator Tool, which is a spreadsheet that estimates the bacteria contribution from multiple sources.

Thomann and Mueller (1987) present a range of die-off rates for different organisms and conditions. The average die-off rate for coliform bacteria in freshwater is 0.8 1/day. A slightly lower and more conservative value of 0.7 1/day was used in the model.

4.1.3 Watershed Model Calibration and Validation

After initially configuring the watershed model, Tetra Tech performed model calibration and validation for hydrology and water quality. Calibration refers to the adjustment or fine-tuning of modeling parameters to reproduce observations. Validation is performed for different monitoring stations without further adjustments to ensure that the model represents other locations as well as it does at the original calibration locations and periods. The years 1995–1999 were used to calibrate hydrology and water quality. The 2000–2004 period was used for validation. Selection criteria for these time periods are discussed below.

4.1.3.1 Hydrology Calibration and Validation

Hydrologic calibration was performed after the initial model setup. For LSPC, calibration is an iterative procedure of parameter evaluation and refinement as a result of comparing simulated and observed values of interest. It is required for parameters that cannot be deterministically and uniquely evaluated from topographic, climatic, physical, and chemical characteristics of the watershed and compounds of interest. Calibration is based on several years of simulation to evaluate parameters under a variety of climatic conditions. The calibration procedure results in parameter values that produce the best overall agreement between simulated and observed flows throughout the calibration period. One USGS flow gaging station provided sufficient data for calibrating and validating the LSPC model. The *Rio Culebrinas At Hwy 404 Nr Moca, PR* station, or USGS 50147800, and its drainage area and elevation are listed in Table 3-1. It is the station used to illustrate the comparison in this section.

Calibration and validation years were selected on the basis of an examination of annual precipitation variability and the availability of observation data. The periods were determined to represent hydrologic conditions common to the region with respect to seasonal flow regimes. Calibration for these conditions is necessary to ensure that the model accurately predicts the seasonal range of conditions over the entire simulation period.

During calibration, parameters influencing the simulation of runoff, infiltration, and evapotranspiration were adjusted depending on land use and soil type. Modeling parameters were varied to mirror observed temporal trends and soil and land cover characteristics. Tetra Tech attempted to keep the modeling parameters within the guidelines included in the BASINS Technical Note 6 (USEPA 2000). Key considerations in the hydrology calibration included the overall water balance, high-flow and low-flow distribution, storm flow volumes and timing, and seasonal variation. At least three criteria for goodness of fit were used for calibration: volumetric comparison, graphical comparison, and the relative error method. Calibration and validation plots and water budget analyses for these periods are shown in Figures 4-5 and 4-6, and Tables 4-5 and 4-6, respectively.

Water budget graphical comparisons for the calibration and validation periods are shown in Figures 4-5 and 4-6. In addition, summary statistical comparisons for calibration and validation periods are shown on Table 4-4 and Table 4-5. Given the critical conditions of the TMDL, the most relevant criteria for evaluating the goodness of fit for this calibration were the percent error in total volume, 50 percent lowest flows, and 10 percent highest flows. For the calibration period, the resulting errors were -7.44 percent, -12.12 percent, and -11.73 percent. The errors for total volume and 10 percent highest flows are well within the recommended criteria. The error in the 50 percent lowest flows is -12.12 percent, slightly outside the recommended criteria (10 percent). This means that the model's predicted low flows are slightly lower than the observed flows during the calibration period (6.56 in vs. 7.46 in). The result of the slight underestimate in 50 percent lowest flows is an extra margin of safety, since it means that in the model there's a slightly lower loading capacity during these conditions than in the stream. For the validation period, the resulting errors were -4.54 percent, 0.43 percent, and -5.94 percent. The errors are well within the recommended criteria.

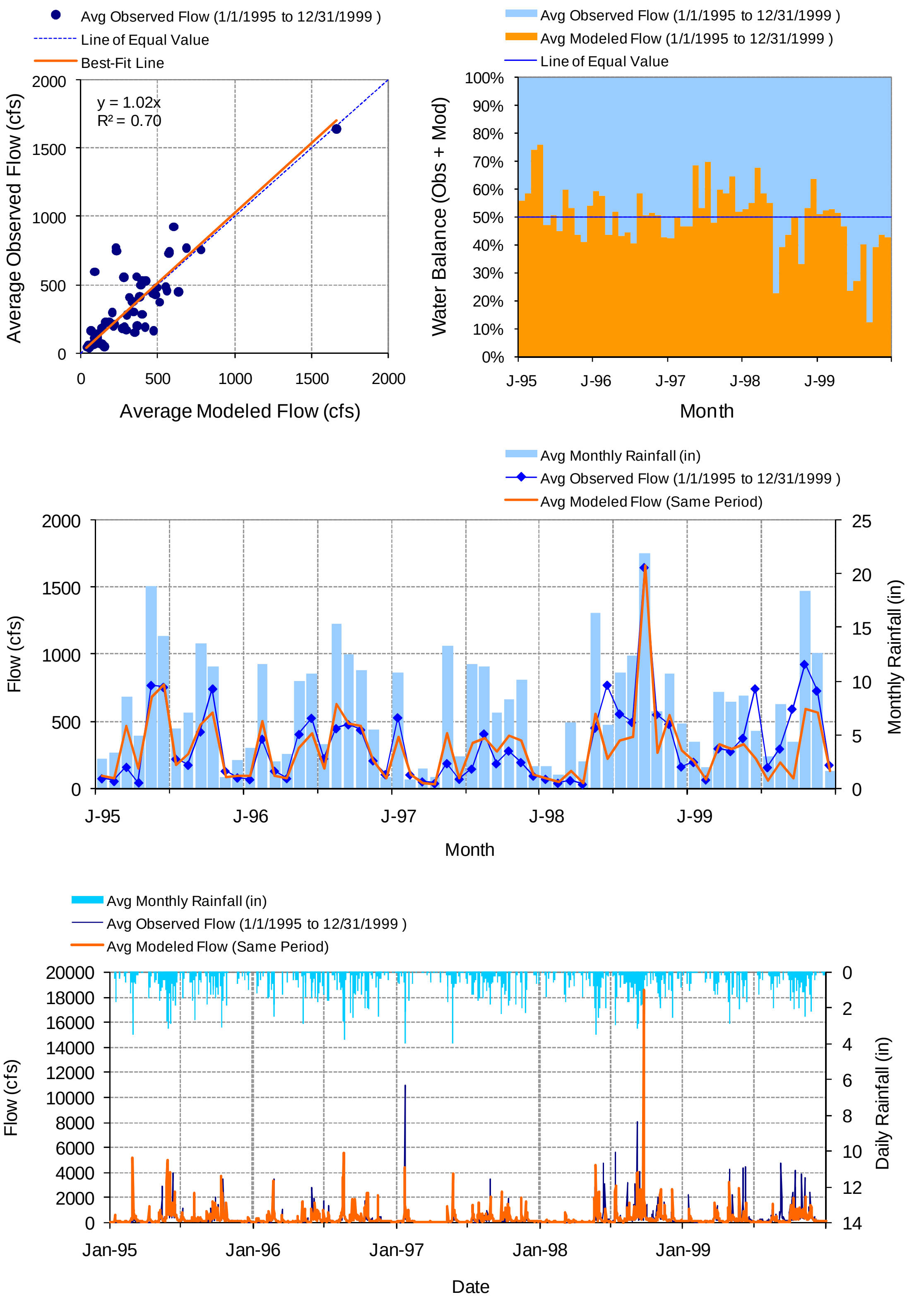

Figure 4-5. LSPC hydrology calibration for 1995–1999 at USGS 50147800: Río Culebrinas at highway 404 near Moca, Puerto Rico.

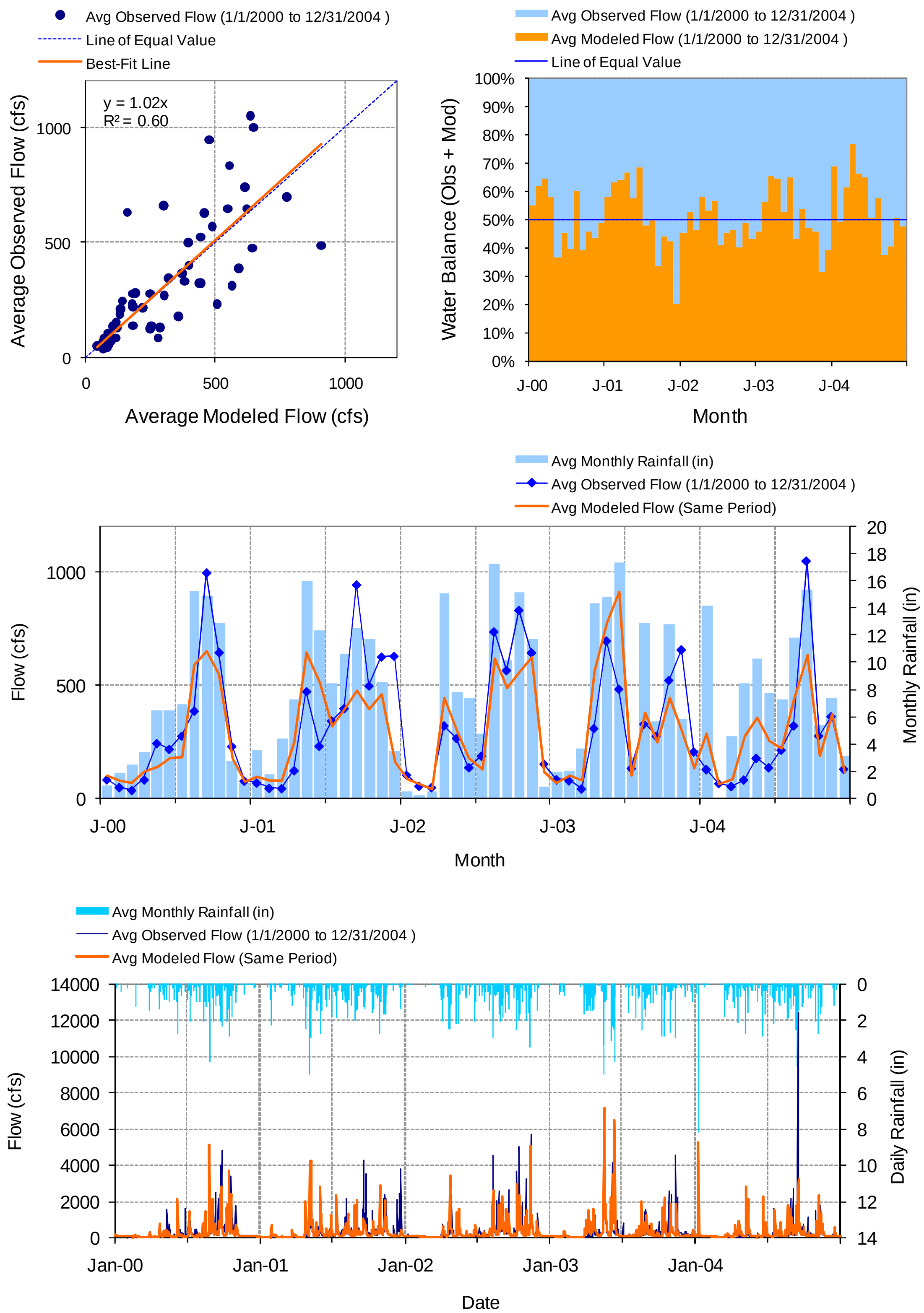

Figure 4-6. LSPC hydrology validation for 2000–2004 at USGS 50147800: Río Culebrinas at highway 404 near Moca, Puerto Rico.

Table 4-4. Water budget statistical comparison for 1995–1999 at USGS 50147800: Río Culebrinas at highway 404 near Moca, Puerto Rico

LSPC Simulated Flow		**Observed Flow Gage**		
REACH OUTFLOW FROM SUBBASIN 404 5-Year Analysis Period: 1/1/1995 - 12/31/1999 Flow volumes are (inches/year) for upstream drainage area		**USGS 50147800 RIO CULEBRINAS AT HWY 404 NR MOCA, PR** Hydrologic Unit Code: 21010003 Latitude: 18.35967037 Longitude: -67.09212429 Drainage Area (sq-mi): 71.2		
Total Simulated In-stream Flow:	**58.00**	Total Observed In-stream Flow:		**62.67**
Total of simulated highest 10% flows:	**30.09**	Total of Observed highest 10% flows:		**34.09**
Total of Simulated lowest 50% flows:	**6.56**	Total of Observed Lowest 50% flows:		**7.46**
Simulated Summer Flow Volume (months 7-9):	**19.00**	Observed Summer Flow Volume (7-9):		**20.64**
Simulated Fall Flow Volume (months 10-12):	**15.38**	Observed Fall Flow Volume (10-12):		**17.08**
Simulated Winter Flow Volume (months 1-3):	**8.83**	Observed Winter Flow Volume (1-3):		**7.30**
Simulated Spring Flow Volume (months 4-6):	**14.80**	Observed Spring Flow Volume (4-6):		**17.63**
Total Simulated Storm Volume:	**30.08**	Total Observed Storm Volume:		**33.26**
Simulated Summer Storm Volume (7-9):	**10.80**	Observed Summer Storm Volume (7-9):		**11.82**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	-7.44	10		
Error in 50% lowest flows:	-12.12	10		
Error in 10% highest flows:	-11.73	15		
Seasonal volume error - Summer:	-7.97	30		
Seasonal volume error - Fall:	-9.99	30		
Seasonal volume error - Winter:	20.88	30		
Seasonal volume error - Spring:	-16.08	30		
Error in storm volumes:	-9.55	20		
Error in summer storm volumes:	-8.70	50		

Table 4-5. Water budget statistical comparison for 2000–2004 at USGS 50147800: Río Culebrinas at highway 404 near Moca, Puerto Rico

LSPC Simulated Flow		**Observed Flow Gage**		
REACH OUTFLOW FROM SUBBASIN 404 5-Year Analysis Period: 1/1/2000 - 12/31/2004 Flow volumes are (inches/year) for upstream drainage area		**USGS 50147800 RIO CULEBRINAS AT HWY 404 NR MOCA, PR** Hydrologic Unit Code: 21010003 Latitude: 18.35967037 Longitude: -67.09212429 Drainage Area (sq-mi): 71.2		
Total Simulated In-stream Flow:	**56.83**	Total Observed In-stream Flow:		**59.52**
Total of simulated highest 10% flows:	**28.86**	Total of Observed highest 10% flows:		**30.68**
Total of Simulated lowest 50% flows:	**7.51**	Total of Observed Lowest 50% flows:		**7.48**
Simulated Summer Flow Volume (months 7-9):	**18.75**	Observed Summer Flow Volume (7-9):		**22.83**
Simulated Fall Flow Volume (months 10-12):	**14.90**	Observed Fall Flow Volume (10-12):		**20.80**
Simulated Winter Flow Volume (months 1-3):	**4.43**	Observed Winter Flow Volume (1-3):		**3.17**
Simulated Spring Flow Volume (months 4-6):	**18.74**	Observed Spring Flow Volume (4-6):		**12.73**
Total Simulated Storm Volume:	**28.82**	Total Observed Storm Volume:		**31.39**
Simulated Summer Storm Volume (7-9):	**10.00**	Observed Summer Storm Volume (7-9):		**13.47**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	-4.54	10		
Error in 50% lowest flows:	0.43	10		
Error in 10% highest flows:	-5.94	15		
Seasonal volume error - Summer:	-17.85	30		
Seasonal volume error - Fall:	-28.36	30		
Seasonal volume error - Winter:	39.73	30		
Seasonal volume error - Spring:	47.25	30		
Error in storm volumes:	-8.20	20		
Error in summer storm volumes:	-25.76	50		

4.1.4 Water Quality Calibration

After hydrology was sufficiently calibrated, water quality calibration was performed. The water quality calibration consisted of running the watershed model, comparing water quality output to available water quality observation data, and adjusting pollutant loading and in-stream water quality parameters within a reasonable range. Recent data were used for the calibration process to capture current conditions. Specifically, the years 1995–1999 were used for calibration, and 2000–2004 were used to validate the model to maintain consistency with the hydrology calibration.

The water quality stations shown in Figure 3-1 were used for LSPC water quality calibration and validation. These stations were selected on the basis of the quantity, age, and temporal resolution of data. Initial water quality calibration was conducted by varying the constituent concentrations in overland flow and interflow. Predicted pollutant concentrations were graphically compared to observed values. Once the model was calibrated for flow and water quality, it was validated by comparing model results representing another time period with inherently different hydrologic conditions. Table 4-6 presents the set of calibrated fecal coliform inputs to the model by landuse.

The model validation was performed to test the calibrated parameters at different locations or for different periods, without further adjusting model parameters. If the model exhibited a poor validation, the calibration process was revisited. After completing the calibration and validation at selected locations, a calibrated data set containing parameter values for each modeled land use and soil type was obtained. The validation between ambient data and LSPC results was rudimentary in nature, based on the infrequency of data collection. All fecal coliform monitoring data used were collected quarterly. Therefore, the modeling data was verified using simple comparisons to the fecal coliform monitoring data by visual comparisons of computed versus measured data. The model captures the spatial and temporal dynamics and fecal coliform concentrations, including the cause and effect relationships between sources (loads) and water column concentrations. The model also over-predicted fecal coliform concentrations during certain low flows when compared to the ambient monitoring values. The calibrated LSPC surface accumulation rate and limit for each modeled landuse is presented in Table 4-6. Water quality calibration results at the USGS station 50147600 (to coincide with the flow calibration shown in the previous section) are shown in Figure 4-7. Validation results are shown in Figure 4-8.

Table 4-6. Calibrated LSPC accumulation rate and limit of fecal coliform bacteria by modeled landuse

Modeled Landuse	Surface Accumulation (#/day/ac)	Accumulation Limit (#/day/ac)
Water	0.000E+00	0.000E+00
Forest	6.263E+07	1.127E+08
Agriculture	7.992E+09	1.439E+10
Pasture	7.992E+09	1.439E+10
Wetland	6.263E+07	1.127E+08
Barren	1.996E+05	3.592E+05
Urban_HighD_Pervious	1.996E+07	3.592E+07
Urban_LowD_Pervious	1.347E+07	2.425E+07
Urban_HighD_Impervious	1.996E+07	3.592E+07
Urban_LowD_Impervious	1.347E+07	2.425E+07

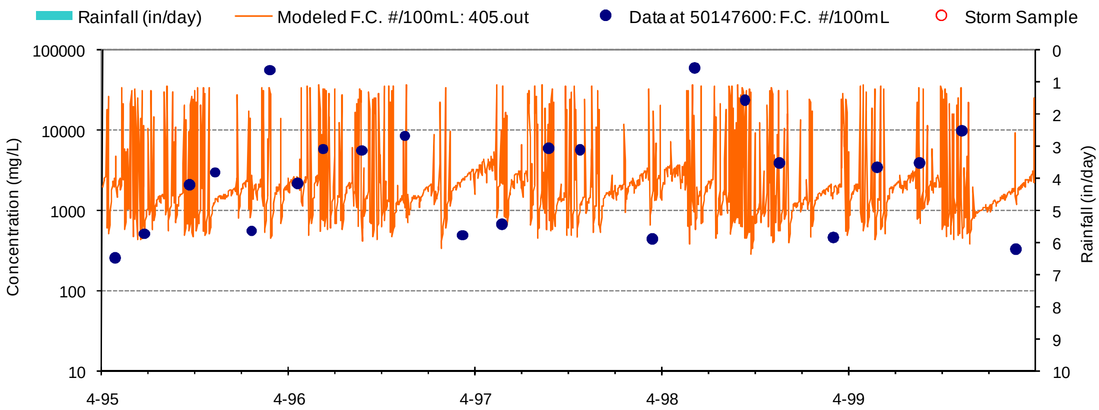

Figure 4-7. Water quality calibration at USGS 50147600: Río Culebrinas near San Sebastián, Puerto Rico.

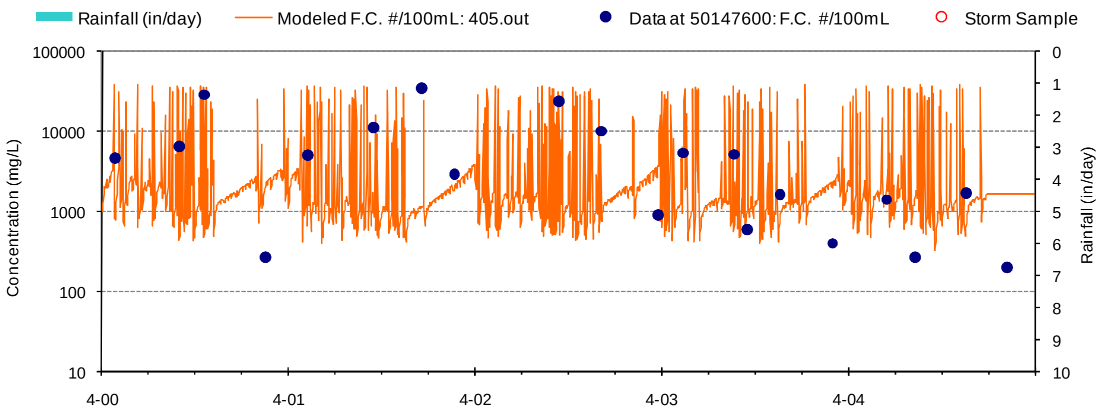

Figure 4-8. Water quality validation at USGS station 50147600: Río Culebrinas near San Sebastián, Puerto Rico.

Overall, the water quality calibration at this location shows that the LSPC model well represents the Río Culebrinas watershed. The observed seasonal trends for bacteria are represented by the model, and simulation data between monitoring points captures expected variability from rainfall events and dry periods where point sources might have increased influence. There is a very large range of observed fecal coliform bacteria concentrations. The model captures most of this variability, although a few of the data observed are higher and some are lower. Although there are always inherent limitations on modeling of fecal coliform bacteria, the water quality calibration is considered successful.

4.2 Tidal Prism Model

The daily fecal coliform bacteria loads representing all source contributions were introduced to a tidal prism model to predict fecal coliform bacteria levels over time in the tidal portion of the Río Culebrinas watershed. The concept of the tidal prism model is shown in Figure 4-9. In the Río Culebrinas system, the ebb (Q_b) and flood (Q_o) of the tide moves water between locations exchanging and mixing with other water. Apart from this, the amount of freshwater discharge into the embayment (Q_f) is also one of the dominant influences on the transport of fecal coliform bacteria.

The tidal prism method of estimating in-stream fecal coliform bacteria concentrations uses the volume of the waterbody and adjusts for tidal flushing, freshwater inflow and bacteria load (L_f), and bacteria decay (k) to establish the existing conditions in the estuary. The conceptual and mathematical components of the tidal prism model are further described in Appendix A.

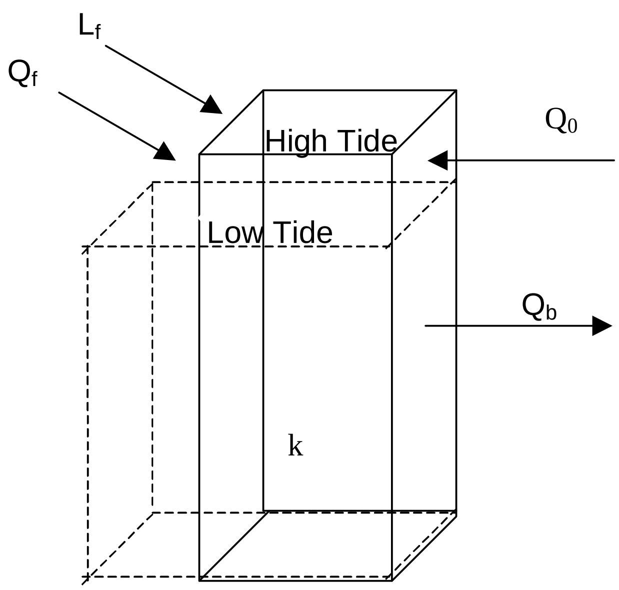

Figure 4-9. Tidal prism model concept.

The tidal portion of the Río Culebrinas was estimated on the basis of data obtained from the USGS. These data estimate the inland extent of the salt wedge, or water of higher salinity than the watershed runoff. The USGS developed preliminary estimates of saltwater intrusion in coastal rivers on the basis of local tide variation data(San Juan, PR station [NOAA/NOS # 9755371]). However, it is acknowledged that these shapefiles are static and do not reflect seasonal patterns. Figure 4-10 illustrates the inland extent of high-salinity water according to USGS data. These data were used to estimate the volume of the tidal prism domain, in conjunction with the Rosgen method of stream geometry estimation, as discussed in Section 4.1.2.1.

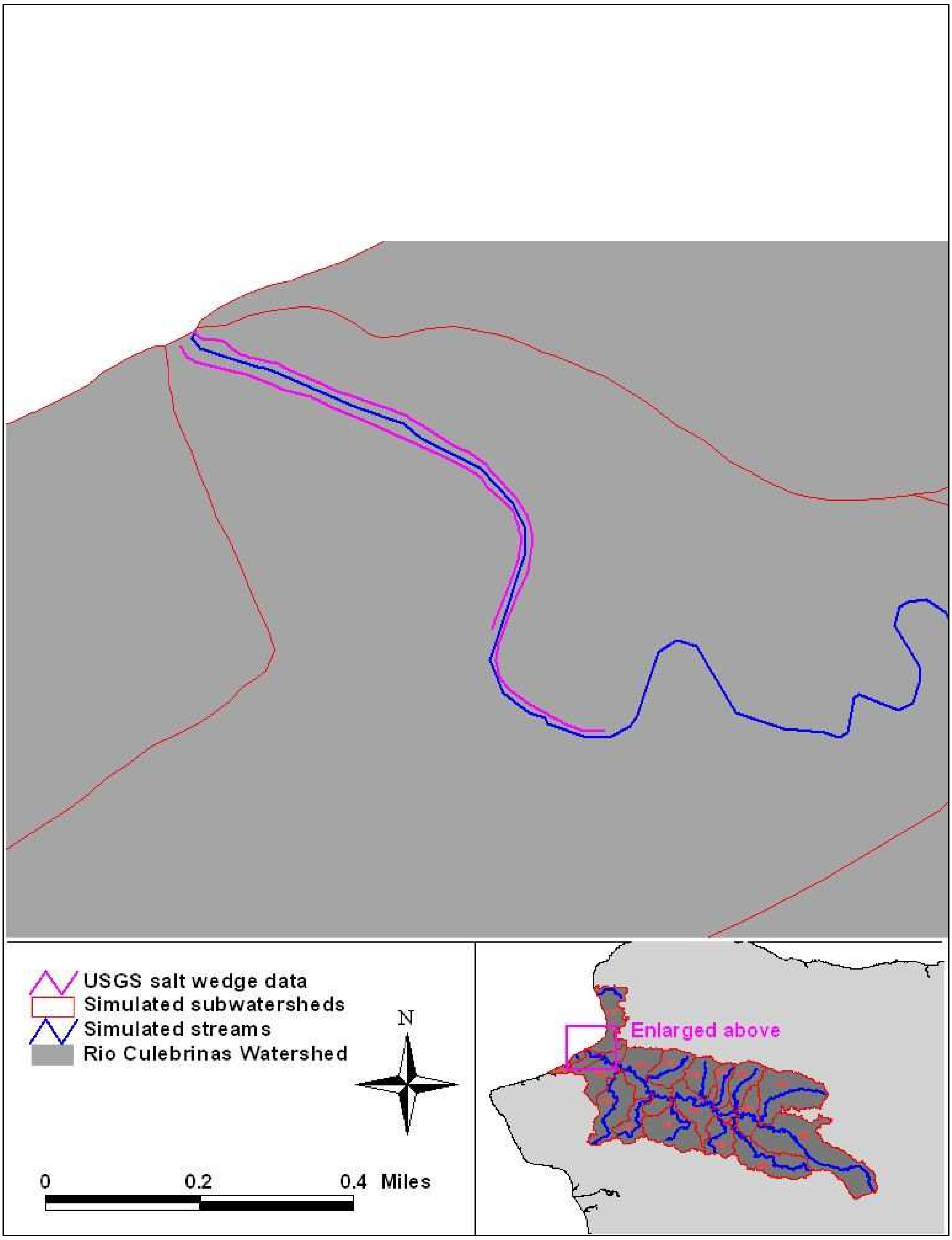

Figure 4-10. USGS Data used to estimate the extent of saltwater intrusion and tidal influence in the Río Culebrinas system.

4.3 Assumptions and Limitations

Some of the major underlying assumptions for this analysis include the following:

- The watersheds delineated were based on topographic data and available stream and channel coverages. Data regarding flow diversions to or from other watersheds were not available and therefore not considered in the analysis.
- Regeneration of fecal coliform bacteria is not a significant source.
- After the model was calibrated and validated using representative flows and concentrations for permitted facilities, the permitted facilities' flows and concentrations were changed to reflect their permit limits. This was the model run that was compared against the TMDL targets. This is a worst-case scenario of permitted facilities loading.
- All the estimated flows and loads from failing septic systems are assumed to be discharged to the streams. This is a conservative assumption in that it is expected that a portion of these loads will not be able to gain access to the stream reaches.
- The average rate of decay for fecal coliform bacteria (0.7 ^{1}/day) does not vary seasonally or by meteorological conditions. This is a conservative assumption, because the die-off rate will probably be higher in the warm waters of this watershed.
- Bacteria concentrations estimated by the tidal prism model contains the assumption that the volume is fully mixed and that bacteria concentrations are horizontally and vertically averaged.

A number of limitations were inherent in the analytical process because of the approach selected. These limitations are identified below. Although these limitations are present, the approach followed successfully resulted in identifying the TMDL. If additional data are collected for the Río Culebrinas watershed, many of these limitations can be addressed.

- The comparison between ambient data and tidal prism results was rudimentary in nature because of the infrequency of data collection and resulting simplistic methodology.
- Population estimates for the watershed were calculated using 2000 Census block data for Puerto Rico.

5 TMDL CALCULATION AND ALLOCATIONS

A TMDL for a given pollutant and waterbody is composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for both nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is represented by the equation

$$TMDL = \sum WLAs + \sum LAs + MOS$$

The TMDL is the total amount of pollutant that can be assimilated by the receiving waterbody while still achieving the TMDL target. In TMDL development, allowable loadings from pollutant sources that cumulatively amount to no more than the TMDL must be established; this provides the basis to establish water quality-based controls. TMDLs can be expressed on a mass loading basis (e.g., bacteria counts per day) or as a concentration in accordance with 40 CFR 130.2(l).

5.1 Numeric Target for Fecal Coliform Bacteria

The TMDL target for the Río Culebrinas watershed is a dual target; a geomean of 200 colonies/100 mL or less, and 400 colonies/100 mL or less, not to be exceeded more than 20 percent of the time. This target was selected on the basis of the water quality criteria discussed in Section 2.2. Watershed and tidal segment concentrations were not allowed to exceed these limits for the TMDL condition.

Compliance with the TMDL target was evaluated using the results of the LSPC and tidal prism models. The daily time series of in-stream fecal coliform bacteria concentrations were reduced until 80 percent of values were below 400 colonies/100 mL. Then, a moving 5-day geomean of concentrations on consecutive days was calculated. These values were reduced until none of the calculated geomeans were above 200 colonies/100 mL.

The weather data from the time period of 1998–2000 were used in the model to derive the allocations. This time period exhibited both extremes with respect to precipitation, and Figure 5-1 shows annual precipitation at *San Sebastián 2 WNW, Puerto Rico* (Station number PR8881) for the years 1980–2004. The years selected for calibration and those used for the TMDL allocations are also identified. Calibration years and TMDL allocation years were selected to address data availability and to encompass critical precipitation conditions and thus flow conditions in the watershed. The year 1998 experienced hurricane Georges and provides the wettest one for consideration in the calibration/validation period and the second wettest year in the entire data set available. The year 2000 was the driest one in the calibration/validation period and the third driest year in the entire data set. The year 1999 was a relatively average one with respect to precipitation. As discussed in Section 3.2, the critical condition in the Río Culebrinas watershed occurs during both high- and low-flow periods. Therefore, an allocation scenario time period that encompassed both conditions within the calibrated and validated modeling timescale was needed for this TMDL. The reason for selecting a relatively short allocation period was to make the allocations more efficient. The allocation process is iterative and performed in a top-down manner. Assessment units upstream were evaluated first. The sources were reduced until the in-stream concentrations met the TMDL targets, then the next downstream AU was evaluated, and so on. The most stringent target was the 5-day geomean of 200 c/100ml. The final step of the allocations was to evaluate the TMDL targets for all AUs for the entire modeling period. All AUs met the required TMDL targets. The critical condition occurs when a large storm follows a very long dry period. During the dry period, the fecal coliform concentrations are elevated because the load from failing septics and point sources are less diluted, and once the storm arrives and generates runoff, the first flush of the bacteria that accumulated on the ground from non-point sources and MS4s is added to the stream.

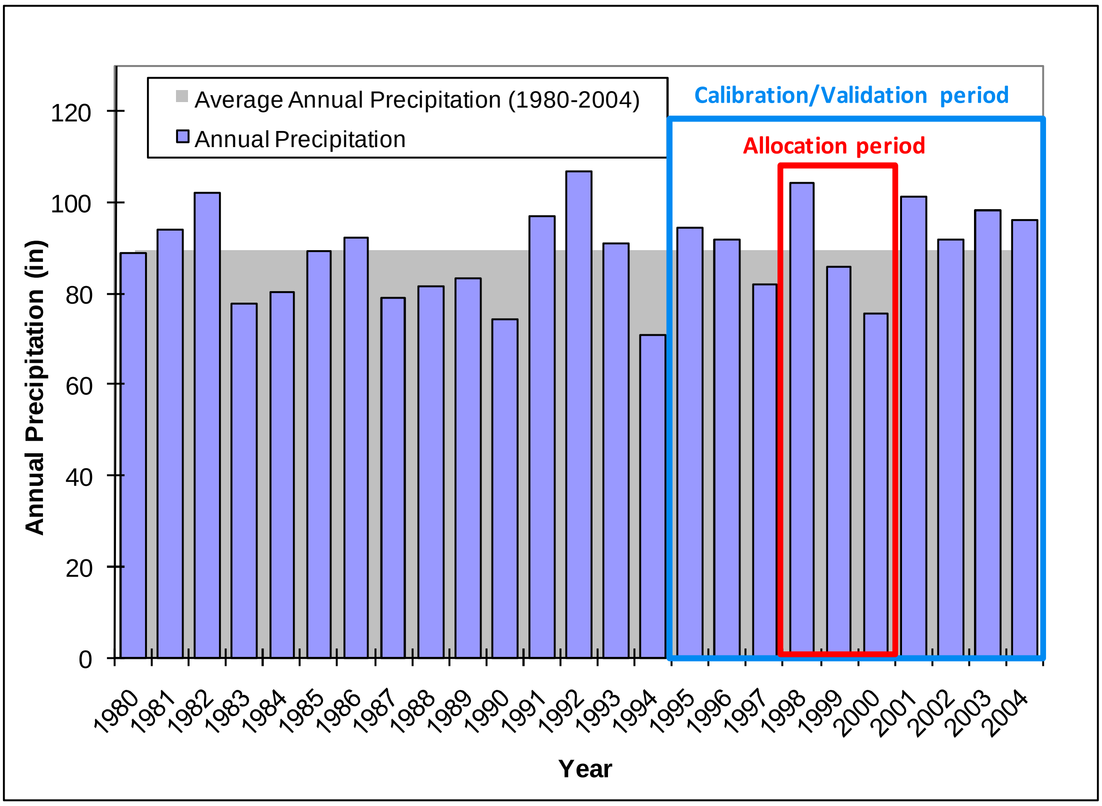

Figure 5-1. Precipitation patterns, 1980–2004 and selected allocation period for the TMDL.

For the watershed as a whole, a 98.9 percent reduction in bacteria loading met these targets in the Río Culebrinas system. Therefore, this is the reduction required to meet the TMDL. The allocations for the bacteria sources are discussed below.

5.2 Margin of Safety

There are two methods for incorporating the MOS (USEPA 1991):

- Implicitly incorporate the MOS using conservative model assumptions to develop allocations

- Explicitly specify a portion of the total TMDL as the MOS and use the remainder for allocations

For the Río Culebrinas system, an implicit MOS was incorporated in several ways. Throughout the TMDL development process, conservative assumptions were made to address the implicit component of the MOS (see list of assumptions in Section 4.2). In addition, an explicit 10 percent MOS was included in the fecal coliform bacteria loads from LA components of the TMDL. The TMDL targets described in Section 5.1 were selected on the basis of the water quality standards discussed previously.

5.3 Fecal Coliform Bacteria TMDLs

The fecal coliform bacteria TMDLs for the Río Culebrinas watershed were developed using the LSPC model, and targets were based on existing water quality criteria, as discussed in Section 2.2. The existing and TMDL bacteria loads for the Río Culebrinas watershed were generated from the calibrated LSPC model. The target TMDL values for bacteria were calculated by iteratively adjusting loading rate input until simulated in-stream concentrations achieved water quality standards. A maximum geomean (at least five samples) in-stream concentration of 200 colonies/100 mL of fecal coliform bacteria, with no more than 20 percent of the samples exceeding 400 colonies/100 mL were used as TMDL endpoints, which directly represent the criteria discussed in Section 2.2. Figure 5-2 illustrates compliance with the water quality targets under TMDL conditions. The target of a maximum geomean (at least five samples) in-stream concentration of 200 colonies/100 mL of fecal coliform bacteria was the most stringent one.

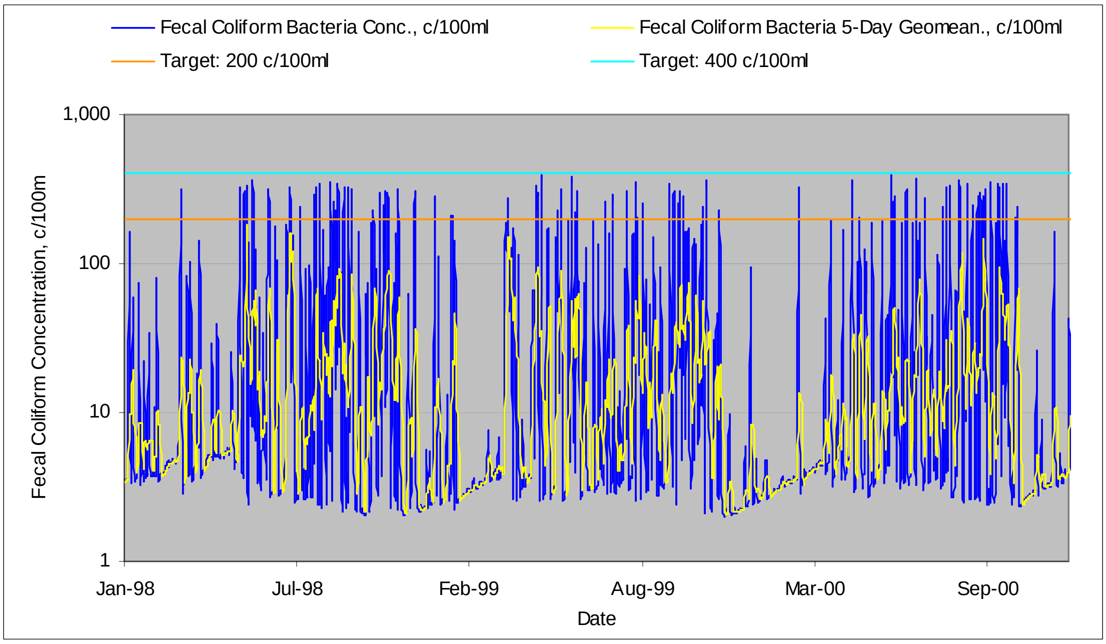

Figure 5-2. Example of daily and 5-day geomean time series under TMDL conditions for Río Culebrinas outlet (Reach 401).

Figure 5-3 identifies the assessment units in the watershed and provides a linkage between modeled subwatersheds and the larger assessment units. Tables 5-1 and 5-2 present baseline and TMDL summaries, respectively, for each of the assessment units.

One assessment unit for which a TMDL was developed within the Río Culebrinas watershed were not included in Puerto Rico's 2008 section 303(d) list of impaired waterbodies. Assessment unit PRWQ95E is not listed as impaired in the 2008 section 303(d) list of impaired waters (Figure 5-3). In addition, four unnamed assessment units (named *Unnamed 1*, *Unnamed 2*, *Unnamed 3*, and *Unnamed 4* for this TMDL analysis) were not included on the list of impaired waters. However, because these assessment units are in the Río Culebrinas watershed, they were simulated in the LSPC model. On the basis of modeling results, water quality in these five assessment units does not meet water quality standards, and thus TMDLs were calculated for these units as well.

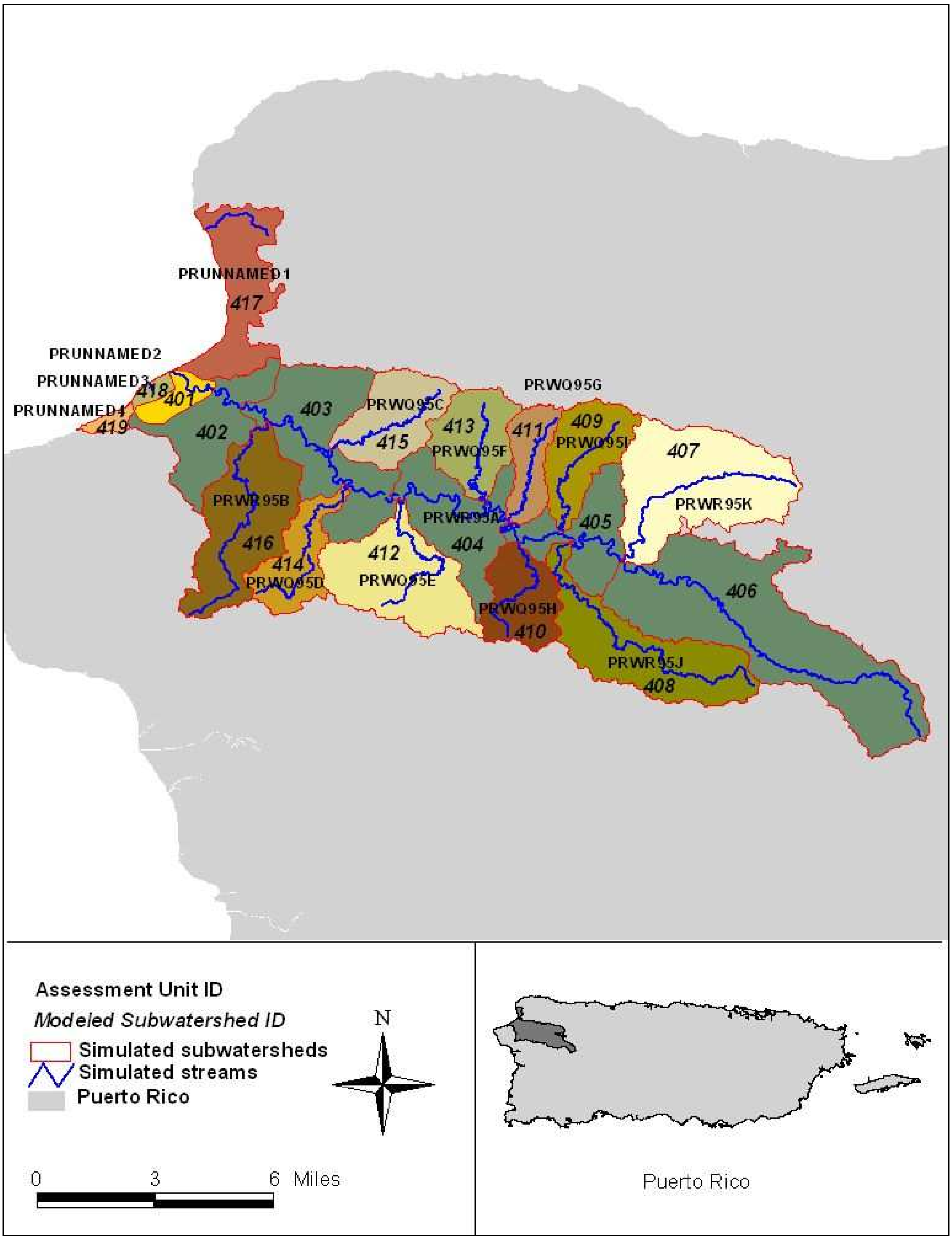

Figure 5-3. Allocation units and modeled subwatersheds in the Río Culebrinas watershed.

The baseline loads presented for septics in Table 5-1 are the sum of the estimated septics load from Table 2-7 for all subwatersheds that compose the assessment unit. The baseline loads presented for NPDES permits in Table 5-1 are the sum of the permitted loads from Table 2-2 for all facilities in the subwatersheds that compose the assessment unit. The baseline loads presented for MS4 permits in Table 5-1 are the sum of the estimated loads from all MS4 areas in the subwatersheds that compose the assessment unit (see Table 2-3).

The TMDL loads presented for septics in

Table 5-2 are based on a complete elimination of failing septics load to the streams (i.e. by fixing the failing septic systems so that they perform adequately). The TMDL loads presented for NPDES permits in Table 5-1 are the sum of the WLAs from Table 5-4 for all facilities in the subwatersheds that compose the assessment unit. The TMDL loads presented for MS4 permits in Table 5-2 are the sum of the WLAs from all MS4 areas in the subwatersheds that compose the assessment unit, see Table 5-3.

Table 5-1. Baseline summary by assessment unit

	Landuse	PRUNNAMED1	PRUNNAMED2	PRUNNAMED3	PRUNNAMED4	PRWQ95C	PRWQ95D	PRWQ95E	PRWQ95F	PRWQ95G	PRWQ95H	PRWQ95I	PRWR95A	PRWR95B	PRWR95J	PRWR95K
		(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)
Nonpoint Sources	Agriculture	3.49E+11	0.00E+00	0.00E+00	0.00E+00	7.89E+12	3.04E+14	6.61E+14	2.15E+12	3.01E+12	3.40E+14	3.82E+12	1.15E+15	1.84E+14	4.99E+14	1.37E+13
	Barren	4.72E+09	5.23E+08	9.26E+07	3.39E+08	3.49E+08	1.02E+08	9.72E+07	1.39E+08	2.15E+07	0.00E+00	7.43E+07	2.24E+09	3.92E+08	5.43E+07	2.28E+08
	Forest	1.75E+13	1.81E+12	2.74E+11	1.03E+12	9.75E+12	1.74E+13	3.71E+13	7.17E+12	5.10E+12	1.34E+13	1.03E+13	1.52E+14	3.33E+13	3.23E+13	1.72E+13
	Pasture	1.34E+15	7.64E+14	2.51E+14	1.79E+14	2.57E+15	9.51E+14	3.27E+15	3.52E+15	1.97E+15	2.35E+15	3.37E+15	2.00E+16	2.58E+15	4.60E+15	8.35E+15
	Urban High Density	1.84E+10	4.04E+09	4.48E+09	4.59E+08	0.00E+00	0.00E+00	2.37E+09	6.38E+07	0.00E+00	0.00E+00	0.00E+00	9.76E+09	3.53E+06	0.00E+00	3.29E+08
	Urban Low Density	0.00E+00	0.00E+00	1.61E+06	0.00E+00	0.00E+00	8.40E+10	1.24E+12	4.48E+10	1.32E+10	2.26E+11	3.58E+11	3.01E+12	2.25E+09	7.28E+11	1.33E+11
	Water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wetland	2.38E+11	1.31E+12	2.78E+11	2.13E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Septics	1.29E+14	2.68E+13	1.02E+13	2.00E+13	6.81E+13	2.50E+13	4.31E+13	3.76E+13	2.07E+13	2.14E+13	2.32E+13	3.61E+14	1.01E+14	3.16E+13	7.88E+13
Permitted Point Sources	NPDES	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.04E+13	0.00E+00	0.00E+00	1.93E+11
	Urban MS4	9.37E+12	5.90E+11	1.85E+11	1.14E+12	3.62E+12	1.23E+12	8.43E+11	2.62E+12	2.12E+12	1.24E+12	1.65E+12	2.35E+13	5.03E+12	2.36E+12	6.21E+12
Total baseline load		1.50E+15	7.95E+14	2.62E+14	2.01E+14	2.66E+15	1.30E+15	4.01E+15	3.57E+15	2.00E+15	2.73E+15	3.41E+15	2.17E+16	2.90E+15	5.17E+15	8.47E+15

Table 5-2. TMDL summary by assessment unit

	Landuse	PRUNNAMED1	PRUNNAMED2	PRUNNAMED3	PRUNNAMED4	PRWQ95C	PRWQ95D	PRWQ95E	PRWQ95F	PRWQ95G	PRWQ95H	PRWQ95I	PRWR95A	PRWR95B	PRWR95J	PRWR95K
		(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)	(#/yr)
LA	Agriculture	1.75E+09	0.00E+00	0.00E+00	0.00E+00	3.95E+10	6.08E+11	1.32E+12	1.07E+10	1.51E+10	1.02E+12	1.91E+10	5.76E+12	5.53E+11	1.50E+12	6.86E+10
	Barren	4.72E+09	5.23E+08	9.26E+07	3.39E+08	3.49E+08	1.02E+08	9.72E+07	1.39E+08	2.15E+07	0.00E+00	7.43E+07	2.24E+09	3.92E+08	5.43E+07	2.28E+08
	Forest	1.75E+13	1.81E+12	2.74E+11	1.03E+12	9.75E+12	1.74E+13	3.71E+13	7.17E+12	5.10E+12	1.34E+13	1.03E+13	1.52E+14	3.33E+13	3.23E+13	1.72E+13
	Pasture	6.68E+12	3.82E+12	1.25E+12	8.94E+11	1.29E+13	1.90E+12	6.54E+12	1.76E+13	9.83E+12	7.04E+12	1.68E+13	9.96E+13	7.75E+12	1.38E+13	4.18E+13
	Urban High Density	9.17E+07	2.02E+07	2.24E+07	2.29E+06	0.00E+00	0.00E+00	4.74E+06	3.18E+05	0.00E+00	0.00E+00	0.00E+00	4.89E+07	1.06E+04	0.00E+00	1.65E+06
	Urban Low Density	0.00E+00	0.00E+00	8.06E+03	0.00E+00	0.00E+00	1.68E+08	2.48E+09	2.24E+08	6.58E+07	6.79E+08	1.79E+09	1.50E+10	6.76E+06	2.18E+09	6.67E+08
	Water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wetland	2.38E+11	1.31E+12	2.78E+11	2.13E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Septics[1]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
WLA[4]	NPDES[2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.70E+12	0.00E+00	0.00E+00	1.93E+10
	Urban MS4	4.68E+10	2.95E+09	9.26E+08	5.68E+09	1.81E+10	2.45E+09	1.68E+09	1.31E+10	1.06E+10	3.72E+09	8.26E+09	1.18E+11	1.51E+10	7.09E+09	3.11E+10
MOS	Margin of Safety[3]	2.72E+12	7.71E+11	2.00E+11	2.17E+11	2.52E+12	2.21E+12	5.00E+12	2.75E+12	1.66E+12	2.38E+12	3.01E+12	2.91E+13	4.62E+12	5.29E+12	6.57E+12
TMDL	Total Maximum Daily Load	2.72E+13	7.71E+12	2.00E+12	2.17E+12	2.52E+13	2.21E+13	5.00E+13	2.75E+13	1.66E+13	2.38E+13	3.01E+13	2.91E+14	4.62E+13	5.29E+13	6.57E+13
	Percent Reductions	98.28%	98.18%	99.03%	99.24%	98.92%	99.05%	98.30%	98.76%	99.23%	99.17%	99.13%	99.12%	98.66%	98.41%	98.98%

[1]Based on a 100% reduction in bacteria loading from failing septic systems.
[2]Based on a reduction in facility permit limits to 200 colonies/100 mL, or ambient water quality standards.
[3]A 10% explicit Margin of Safety (MOS) was applied to the load capacity.
[4]The individual WLAs are found in Tables 5-3 and 5-4.

5.4 Load Allocations

The LA is the portion in the TMDL that is assigned to nonpoint sources. Tables 5-1 and 5-2 show the total loads by land use type and assessment unit. These loads are inclusive of MS4 loads. For this TMDL, the MS4 bacteria loads were subtracted from the nonpoint source LA and reallocated as WLAs. The remaining LAs are presented in Tables 5-1 and 5-2. For additional information regarding MS4 loads, see the next section.

On the basis of the analysis performed, the primary nonpoint source contributions to the Río Culebrinas system are from the land surface. Source-based reductions were arrived at through an iterative process of examining bacteria reduction possibilities by varying bacteria loads from each source to the system and ensuring that the TMDL target was met. Specifically, nonpoint source loads were reduced by assessment unit until fecal coliform bacteria concentrations in that segment met the TMDL targets described in Section 5.3.

LAs were performed using a *top-down* reduction methodology. This methodology entails applying reductions to headwaters first, until waters in these subwatersheds meet the TMDL target. This method has the effect of also reducing in-stream concentrations in downstream subwatersheds by discharging waters of higher quality to subsequent reaches in the simulated network. These waters then serve to dilute fecal coliform bacteria loads that enter downstream.

However, this methodology sometimes requires large reductions in headwater subbasins. This occurs when significant sources of a pollutant exist in that watershed and diluting flows from upstream reaches are not available. Larger reductions are required in these watersheds to meet the TMDL target. Large reductions in excess of 90 percent are sometimes required in areas where excessive in-stream pollutant concentrations have been observed.

For example, Figures 4-7 and 4-8 show a water quality calibration where in-stream measurements in excess of 20,000 colonies/100 mL have been observed. The geometric mean water quality standard for fecal coliform bacteria is 200 colonies/100 mL, so a simplistic reduction from 20,000 colonies to 200 colonies would require a 99 percent reduction. This example is presented to provide the magnitude of the impairment and justify the reductions shown in Tables 5-1 and 5-2.

The LAs are separated by land use and separated from septic loads, which are also considered a component of the LA.

5.5 Wasteload Allocations

Federal regulations (40 CFR 130.7) require TMDLs to include individual WLAs for each point source. In addition, EPA's stormwater permitting regulations require municipalities to obtain permit coverage for all stormwater discharges from urban MS4s. A November 22, 2002, EPA Memorandum from Robert Wayland and James Hanlon, Water Division

Directors (http://www.epa.gov/boston/npdes/stormwater/) clarified existing regulatory requirements for MS4s connected with TMDLs. The key points are the following:

- NPDES-regulated MS4 discharges must be included in the WLA of the TMDL and may not be addressed by the LA component of TMDL.
- The stormwater allotment can be a gross allotment and does not need to be apportioned to specific outfalls.
- Industrial stormwater permits need to reflect technology-based and water quality based requirements.

In accordance with this memorandum, MS4s within the Río Culebrinas watershed were treated as point sources for TMDL and NPDES permitting purposes, and the bacteria loading generated within the boundary of an MS4 area was assigned a WLA in addition to the WLA for the point source dischargers. There are also four point source facilities with four outfalls, and one MS4 community in the Río Culebrinas watershed, all requiring WLAs. The components of the WLA are summarized below.

WLA: MS4 Municipalities
In the Río Culebrinas watershed, stormwater bacteria loads are covered under the Phase II NPDES Stormwater Program and were considered wasteloads at this time. Runoff from residential areas and UAs during storm events can be a significant fecal coliform bacteria source, delivering bacteria to the waterbody. EPA's stormwater permitting regulations require public entities to obtain NPDES permit coverage for stormwater discharges from MS4s in specified UAs. Table 5-3 presents a summary of the MS4 components. Although there is one census UA covered under MS4, it overlaps with both assessment units and counties; hence, there are 23 total MS4 components.

WLA: Permitted Facilities
For the permitted facilities, the fecal coliform bacteria WLAs were calculated using a concentration of 200 colonies/100 mL and the facilities' current permitted flow. Table 5-4 presents the baseline load, WLAs, and the percent reductions required to meet the TMDL targets. The baseline load is calculated using the facilities' current permitted flow and concentration. The percent reduction is the reduction from baseline to TMDL conditions.

Table 5-3. Bacteria loads for the MS4 component of the WLA

Urbanized Area	County	UA Code	Assessment Unit	Baseline (#/day FC Bacteria)	WLA (#/day FC Bacteria)	Percent Reduction
Aguadilla-Isabela-San Sebastian, PR	Aguada	631	PRUNNAMED1	2.21E+09	1.1027E+07	99.5%
Aguadilla-Isabela-San Sebastian, PR	Aguadilla	631	PRUNNAMED1	2.35E+10	1.1720E+08	99.5%
Aguadilla-Isabela-San Sebastian, PR	Aguada	631	PRUNNAMED2	1.62E+09	8.0762E+06	99.5%
Aguadilla-Isabela-San Sebastian, PR	Aguada	631	PRUNNAMED3	5.08E+08	2.5369E+06	99.5%
Aguadilla-Isabela-San Sebastian, PR	Aguada	631	PRUNNAMED4	3.12E+09	1.5575E+07	99.5%
Aguadilla-Isabela-San Sebastian, PR	Moca	631	PRWQ95C	9.91E+09	4.9488E+07	99.5%
Aguadilla-Isabela-San Sebastian, PR	Aguada	631	PRWQ95D	1.76E+09	3.5233E+06	99.8%
Aguadilla-Isabela-San Sebastian, PR	Moca	631	PRWQ95D	1.60E+09	3.1943E+06	99.8%
Aguadilla-Isabela-San Sebastian, PR	Moca	631	PRWQ95E	2.31E+09	4.6040E+06	99.8%
Aguadilla-Isabela-San Sebastian, PR	Moca	631	PRWQ95F	7.18E+09	3.5891E+07	99.5%
Aguadilla-Isabela-San Sebastian, PR	Moca	631	PRWQ95G	3.56E+09	1.7814E+07	99.5%
Aguadilla-Isabela-San Sebastian, PR	San Sebastian	631	PRWQ95G	2.24E+09	1.1225E+07	99.5%
Aguadilla-Isabela-San Sebastian, PR	Moca	631	PRWQ95H	1.73E+09	5.1982E+06	99.7%
Aguadilla-Isabela-San Sebastian, PR	San Sebastian	631	PRWQ95H	1.66E+09	4.9968E+06	99.7%
Aguadilla-Isabela-San Sebastian, PR	San Sebastian	631	PRWQ95I	4.53E+09	2.2636E+07	99.5%
Aguadilla-Isabela-San Sebastian, PR	Aguada	631	PRWR95A	1.10E+10	5.4939E+07	99.5%
Aguadilla-Isabela-San Sebastian, PR	Aguadilla	631	PRWR95A	4.30E+09	2.1494E+07	99.5%
Aguadilla-Isabela-San Sebastian, PR	Moca	631	PRWR95A	2.41E+10	1.2023E+08	99.5%
Aguadilla-Isabela-San Sebastian, PR	San Sebastian	631	PRWR95A	2.51E+10	1.2554E+08	99.5%
Aguadilla-Isabela-San Sebastian, PR	Aguada	631	PRWR95B	1.37E+10	4.1178E+07	99.7%
Aguadilla-Isabela-San Sebastian, PR	Moca	631	PRWR95B	5.24E+07	1.5731E+05	99.7%
Aguadilla-Isabela-San Sebastian, PR	San Sebastian	631	PRWR95J	6.47E+09	1.9416E+07	99.7%
Aguadilla-Isabela-San Sebastian, PR	San Sebastian	631	PRWR95K	1.70E+10	8.5126E+07	99.5%
			TOTALS:	1.69E+11	7.8107E+08	**99.5%**

Table 5-4. Individual NPDES permitted facility WLAs

NPDES Permit	Facility Name	Latitude	Longitude	Assessment Unit	Permitted (#/day FC Bacteria)	WLA (#/day FC Bacteria)	WLA Conc. (#/100mL)	Percent Reduction
PR0020851	Prasa San Sebastian	1820100	-6659480	PRWR95A	3.03E+10	3.03E+09	200	90%
PR0023981	Prasa WTP San Sebastian	1819260	-6658400	PRWR95A	4.58E+09	2.29E+09	200	50%
PR0025551	Prasa San Sebastian WWTP	1820480	-6701050	PRWR95A	5.30E+08	5.30E+07	200	90%
PR0024317	Hoyamala Ward Secondary School	1821220	-6657190	PRWR95K	7.57E+10	7.57E+09	200	90%
				TOTALS:	1.11E+11	1.29E+10		

6 REASONABLE ASSURANCE AND TMDL IMPLEMENTATION

6.1 Reasonable Assurance

There is reasonable assurance that the goals of these TMDLs can be met with proper watershed planning, implementing pollution reduction of the best management practices (BMPs), and strong political and financial mechanisms. Reasonable assurance that the TMDLs established will require a comprehensive, adaptive approach that addresses the following:

- Nonpoint source pollution including failing septic systems
- Existing and future sources
- Regulatory and voluntary approaches

TMDLs represent an attempt to quantify the pollutant load that can be present in a waterbody and still ensure attainment and maintenance of water quality standards. These TMDLs identify the necessary overall load reductions for fecal coliform bacteria causing use impairments and distributes those reduction goals to the appropriate sources. Reaching the reduction goals established by these TMDLs will occur through nonpoint source controls to achieve LAs and the NPDES and permits to achieve WLAs.

The nonpoint source controls can be implemented through a number of existing programs such as section 319 of the Clean Water Act commonly referred to as the Nonpoint Source Program. This program can help with installing BMPs that prevent or reduce nonpoint source pollution to a level compatible with water quality goals.

According to 40 CFR 122.44(d)(1)(vii)(B), the effluent limitations for an NPDES permit must be consistent with the assumptions and requirements of any available WLA for the discharge prepared by the state and approved by EPA. Furthermore, EPA has authority to object to issuance of an NPDES permit that is inconsistent with WLAs established for that point source. This applies to traditional point sources as well as more diffuse sources such as permitted MS4 systems.

6.2 Implementation

These TMDLs are based on attaining an in-stream geomean fecal coliform bacteria concentration of 200 colonies/100 mL (minimum five samples) and a dual target of no more than 20 percent of samples exceeding 400 colonies/100 mL (see Section 2.2). The TMDLs in this report meet these standards, have been calculated at each assessment unit pour point, and require between 73.6 percent and 99.0 percent reductions in fecal coliform bacteria loading to meet the standard. The TMDL implementation plan focuses on increased reductions from existing sources of fecal coliform bacteria. Managing future sources, such as new development, falls under the category of watershed planning.

Effective watershed planning is a critical component for meeting water quality standards in the future. It is recognized that implementing watershed management strategies has already occurred to some extent in the watershed. However, to meet the targeted load reductions, additional implementation practices must occur in the future.

Several critical questions should be addressed during the TMDL implementation phase. These are presented as a basis for evaluating an implementation strategy and to ensure that adequate resources are provided to meet the fecal coliform bacteria reduction goals specified in Section 5. Some of the key programmatic questions and answers are listed below, these include the following:

How much fecal coliform bacteria must be reduced?

Section 5 identifies the necessary fecal coliform bacteria load reductions for the entire watershed, listed by assessment unit and source as calculated as part of this TMDL analysis. To meet the current water quality standards, assessment units must reduce fecal coliform bacteria load by a range of between 98.3 percent and 99.3 percent.

Do programs and organizations exist to address the reductions from nonpoint sources?

An effective management plan must address the capability of local, territorial, and federal programs to implement the management strategies recommended in this implementation plan. Identifying and assigning actions to appropriate organizations is part of implementation. Some of those organizations might include EPA, PREQB, Puerto Rico Natural Resource Conservation Service, University of Puerto Rico Agricultural Extension Offices, local watershed associations and environmental groups.

What monitoring information would help to meet the necessary reductions?

This TMDL presents sources of fecal coliform bacteria loading based on in-stream monitoring, modeling results, and land use data. Further data collection regarding specific sources can be used to refine the management plan. For example, septic failure rates were assumed to be uniform throughout the watershed because of a lack of data or log of failures. Further data collection to refine the failure rate in the watershed could be performed to verify the assumed failure rate and assist in focusing BMP implementation more effectively. For assumptions and limitations with respect to these TMDLs, see Section 4.3.

How should load reductions be prioritized?

While there are variations in the percent reductions necessary to achieve TMDL compliance by assessment unit, pollutant load is fairly evenly distributed throughout the watershed. Thus, the following management recommendations are for the watershed as a whole.

6.2.1 Management Plan: Agricultural Areas

Agriculture includes farming of plant crops and animal husbandry. Because large areas of land are devoted to these activities, they have a significant impact on water quality and water resources. Agricultural effects on water resources generally involve several types of pollutants: (1) Nutrients, (2) Pesticides, (3) Bacteria and Viruses, (4) Sediments, and (5) Erosion. For the purposes of this management plan, reductions of bacteria will be the primary focus of management recommendations. However, because many of the same management practices will also contribute to load reductions in other pollutants, implementing proposed fecal coliform bacteria reducing management measures would contribute to improved overall water quality within the watershed. To improve water quality, farmers can apply a variety of measures to minimize runoff of potentially harmful materials (e.g., animal wastes) from agricultural lands into adjacent streams and, ultimately, surface waters in the watershed.

6.2.1.1 Implementation: Agricultural Areas

To achieve realistic reductions in fecal coliform bacteria load and concentrations in the watershed, the following framework is provided:

1. Using GIS land use data and animal census data, locate and identify the most significant farming activities and source areas with the highest potential fecal coliform bacteria load.
2. Develop a suite of educational, technical and financial resources to address the issues deemed most significant, including the following:
    - Develop a schedule for implementation of pilot scale and demonstration projects and monitor the results.
    - Reassess implementation schedule as a result of monitoring results and revise program accordingly.
    - Implement actions on lower priority land uses and activities as higher priority areas are completed, assessed, and begin to come into compliance.

It is recognized that current programs have been implemented in recent years to address the goal of reducing fecal coliform bacteria loading to receiving waters. However, on the basis of in-stream monitoring and modeling results, additional BMP implementation must occur to meet the load reductions specified in this TMDL.

6.2.1.2 Recommended BMPs: Agricultural Areas

Education should occur on a variety of levels and target decision makers (elected officials, heads of agencies, and political appointees), farm owners and farm workers, and the general public. The importance of protecting natural resources and the effect of nonpoint source pollution must be communicated effectively, focusing on linkages between healthy natural resources, clean drinking water, and a strong economy.

Public education and outreach activities and materials can take on a variety of forms, depending on the target audience:

- Decision makers need general information on the effects of nonpoint source pollution, how nonpoint source pollution affects the environment, ways of controlling nonpoint source pollution, and how the adverse effects of nonpoint source pollution affect the economy and aesthetics of the region.

- Farmers need detailed information on how to select and implement proper nonstructural and structural BMPs, operate and maintain structural BMPs, recognize the limitations of the land and obtain the maximum sustainable yield within those limitations, manage land properly, and develop and implement control plans.
- The general public needs to understand the linkages between their actions, nonpoint source pollution, and degradation of the natural environment.
- Education programs should be tailored to the specific needs of the community, the needs of the farmers, and the education level of the target audiences.

An effective strategy for public education and outreach regarding agricultural nonpoint source pollution should include the following:

- Developing a commission or similar mechanism for coordinating educational policy for the region
- Community education programs
- Field demonstrations and follow-up site visits
- School and community workshops
- Outreach and extension programs, including courses for farm workers
- Using media (TV, radio, videos, and such)
- Require school environmental education curriculum
- Developing outreach materials such as fact sheets, guidance documents, and courses for decision makers, farmers, and the general public
- Educating political and policy leaders in the watershed
- Designate one responsible or lead coordinating agency
- Economic incentives for implementing education programs

Achieving the successful implementation of BMPs by farmers hinges on demonstrating to them that adopting such practices can save money, resources, and time.
Education and outreach programs should focus on working with farmers and others to implement the following BMPs, which emphasize reducing fecal coliform bacteria loading:

Keep Livestock Out of Water. By cutting off the access of livestock to streams, ponds, and rivers with fencing, animal contact with waterborne bacteria is reduced and animal discharge of bacteria is minimized.

Provide Alternative Watering Holes. To deter livestock grazing, farmers must provide an alternative source of drinking water for their livestock.

Disposal of Dead Livestock. Dead livestock should be disposed of properly to reduce the potential for ground and surface water contamination from pathogens. They should be removed from streams or fields and isolated until disposal is possible. Proper disposal methods include composting and incineration. Incineration facilities require more detailed planning and need to be developed under the consultation of local, territorial, and national authorities to ensure proper construction, operation, and maintenance.

Divert Runoff Water. Diverting clean water around a feedlot prevents the excessive erosion of manure solids from the lot and increases the effectiveness of settling basins or other solid-liquid separation equipment. Prevent rainwater from entering the feedlot by using gutters and downspouts to handle water coming from building rooftops.

Manure Management. A complete manure management system involves collection, storage (temporary or long-term), and ultimate disposal or use. A manure management plan should establish fertilizer plans to use manure effectively.

Store Livestock Wastes Properly. Waste storage structures should not be near surface waters. Also, farmers should take special precautions when storing waste in earthen structures to prevent wastes from seeping through the bottom of the basin to adjacent surface waters or groundwater. Manure storage areas should be covered when possible.

Composting Manure. This practice is an aerobic process of controlled biodegradation of animal wastes that reduces pathogens and stabilizes nutrients. It is a highly cost-effective technique of managing wastes, producing a valuable commodity, and reducing potential for water resource contamination. Composting requires active management to produce a useful soil amendment.

Filter Strips. These are vegetated zones around a confined animal facility or active cropland that trap sediments, organic wastes and other pollutants in stormwater runoff. Farmers must regularly maintain them to function effectively. Constructed wetlands in low-lying areas can also serve a similar purpose.

Heavy Use Area Protections. This practice involves constructing hard surfaces in heavily used areas. Materials for construction can be concrete, asphalt, compacted gravel or compacted earth, depending on the waste management objectives. Hardening areas of heavy use prevents or slows their physical degradation and facilitates the collection and use of animal wastes, the latter being vital to protecting water resources.

Manure Stacking Areas. These areas are temporary locations for storing animal wastes in a field before application. Their purpose is to supplement constructed storage facility volumes or to await favorable conditions for field application.

Manure Storage Facilities. This BMP involves using permanent structures for temporarily storing animal wastes. They also capture polluted runoff and are therefore a useful means of preventing or minimizing transport of contaminants and sediments to surface waters.

Manure and Waste Utilization Plans. These are plans that formulate an approach to recycling animal wastes to benefit crop production while ensuring environmental quality.

They can be used in conjunction with nutrient management plans to minimize the amount of commercial fertilizer applied to cropland.

Other BMPs that might be useful in managing animal wastes include the following:

- Using waste storage ponds and waste treatment lagoons
- Reusing runoff water or manure for agricultural crops or plantings
- Contracting with commercial rendering or disposal services

Reducing Wastewater and Runoff from Confined Animal Facility. This involves limiting surface water runoff and discharge from confined animal facilities to adjacent streams or the river. This can be done by storing both the facility wastewater and the stormwater runoff and managing the stored runoff and pollutants through an appropriate waste use system. Some BMPs for reducing animal facility runoff include the following:

- Using dikes, diversions, and grassed waterways
- Protecting heavy use areas
- Using lined waterways or outlets
- Managing roof runoff and runoff from paved areas
- Terracing slopes
- Using waste storage ponds or waste storage structures such as waste treatment lagoons
- Reusing runoff water or manure for agricultural crops or plantings
- Waste use and recycling
- Providing a composting facility
- Using commercial rendering or disposal services
- Incinerating wastes
- Using approved burial sites
- Using structures to trap sediments and associated pollutants (sediment basin, water and sediment control basin)
- Using vegetated filter strips and constructed wetlands to trap sediments and associated pollutants

Grazing Management. This BMP protects water resources by managing livestock range, pasture, and other grazing lands to reduce erosion, sedimentation, and transport of pollutants in the following ways:

- Using deferred grazing and planned grazing to allow water resources and land to recover from intensive use that can damage water quality
- Proper grazing use
- Proper woodland grazing
- Pasture and hayland management

- Using pipelines, wells, ponds, drinking water troughs or tanks to water livestock instead of natural streams or ponds
- Spring development

Irrigation Water Management. This BMP reduces nonpoint pollution of surface and groundwaters caused by irrigation. Such measures include the following:

- Irrigation water management and scheduling
- Using irrigation water-measuring devices
- Soil and crop water use data
- Irrigation system, drip or trickle
- Irrigation system, sprinkler
- Irrigation system, surface and subsurface
- Irrigation system, tailwater recovery
- Irrigation field ditch
- Irrigation land leveling
- Filter strip
- Surface drainage field ditch
- Subsurface drain
- Water table control
- Controlled drainage
- Backflow prevention practices

Financial Incentives. Financial incentives should be a component of the agricultural management plan. Grants and government programs could be directed to farmers for implementing BMPs. For example, government agencies could implement manure-recycling programs by purchasing manure from livestock farmers and storing the manure properly until it can be donated as fertilizer. Other cost sharing measures should be offered to provide incentive for BMP implementation.

6.2.2 Management Plan: Urban Areas

Land development and construction activities typically involve clearing and removing vegetation, grading the land surface, excavating earth, removing and importing soil, constructing impervious structures using man-made building materials, installing utilities, constructing septic or sewer systems, building roads, and landscaping. Such activities also affect water quality by removing protective vegetation, stormwater runoff from cleared areas and lawns, spilling paint or other compounds, dust from construction materials, and fertilizers and pesticides used in landscaping.

Existing urban land uses contribute to nonpoint source pollutant loading from a variety of sources and activities, including increased flow and wash off of accumulated pollutants from impervious surfaces, accelerated upland and channel erosion, pet waste, sanitary sewer overflows and combined sewer overflows, and failing septic systems.

6.2.2.1 Implementation: Urban Areas

To achieve realistic reductions in fecal coliform bacteria load and concentration in the watershed, the following framework is provided:

1. A program should be developed to assess the discrete effects of permitted (MS4s) and non-permitted loads from urban areas.
2. Using GIS land use data, locate and identify the most significant land use source areas with the highest potential load.
3. Develop a suite of educational, technical, and financial resources to address the issues deemed most significant, including the following:
    - Develop a schedule for implementation of ordinances, pilot scale and demonstration projects and monitor the results
    - Reassess implementation schedule as a result of monitoring results and revise program accordingly
    - Implement actions on lower priority sources as higher priorities are completed, assessed, and come into compliance

6.2.2.2 Recommended BMPs: Urban Areas

BMPs for urban land uses are designed to reduce the effects of these sources on surface waters. After implementing BMPs, their effectiveness should be evaluated in relation to prescribed WLAs (MS4s), and future permit conditions will be established with a goal of water quality standard compliance. Typical measures for construction sites include sediment traps and basins; sediment fences; wind erosion controls; and sediment, chemical, and nutrient control. Although these BMPs target sediment, bacteria are also targeted inherently because bacteria sources can be associated with sediment. Because urbanization is ongoing, it is useful to consider BMPs that address existing UAs as well as future growth. Therefore, BMPs for urban land uses should be considered in three phases of development: Pre-Construction (or Planning), Construction, and Post-Construction.

Education focused on urban residents, businesses, and decision makers is essential to the success of BMPs. As with agricultural BMPs, public education and outreach activities can take on a variety of forms, depending on the target audience.

- Decision makers and residents need general information on the effects of nonpoint source pollution, how nonpoint source pollution affects the environment, ways of controlling nonpoint source pollution, and how the adverse effects of nonpoint source pollution affect the economy and aesthetics of the region.
- Businesses and commercial users need detailed and focused information on how to select and implement proper nonstructural and structural BMPs, operate and maintain structural BMPs, manage land properly, and develop and implement erosion and sediment control plans.
- Education programs should be tailored to the specific needs of the community and the education level of the target audiences.

An effective strategy for public education and outreach regarding urban nonpoint source pollution should include the following:

- Developing a commission or similar mechanism for coordinating educational policy for the region
- Community education programs
- Field demonstrations and follow-up site visits
- School and community workshops
- Outreach and extension programs, including courses for commercial, industrial and residential users
- Using media (TV, radio, videos, and others)
- Required school environmental education curriculum
- Developing outreach materials such as fact sheets, guidance documents, and courses for decision makers, residents, businesses and the general public
- Educating political and policy leaders in the Watershed
- Appointing one responsible or lead coordinating agency
- Economic incentives for implementing education programs

Achieving the successful implementation of BMPs by citizens hinges on demonstrating to them that adopting such practices can save money, resources, and time. Education and outreach programs can focus on working with citizens and others to implement the following BMPs.

<u>Pre-Construction (Planning) Phase:</u>

Develop a spill response plan that clearly outlines procedures to be followed if an accidental spill occurs on-site during construction (e.g., sewer line damage).

Plan access roads to reduce stream crossings to minimize the amount of sediment-associated pollutants that wash into tributaries.

<u>Construction Phase</u>:

Locate on-site pollutant sources away from drainage courses to prevent pollutants from being washed into drainage courses and streams during rainfall events.

Install sedimentation basins to collect stormwater runoff from construction activities.

Install anchored mulch (especially on slopes greater than 5 percent and concentrated flow areas such as diversions and waterway channels). Examples of mulch include mats, chemical mulches and organic mulches (hay, wood chips, shredded corn stalks).

Sediment barriers (hay bales, silt fencing) that are installed along the slope contour (at the same elevation) with ends flared uphill successfully capture runoff.

Minimize soil disturbance at construction projects in areas with steep slopes and close proximity to surface waters need to minimize the amount of road access and exposed soil.

Construct entrance pads at construction sites.

Vehicle washing keeps sediment and soil on-site.

Post-Construction Phase:

Vegetated filter strips are areas of land with natural or planted vegetation designed to receive overland sheet runoff from upgradient development. The primary function of the strips is to remove pollutants from the flow before it reaches surface water.

Grassed swales are shallow, vegetated, man-made ditches designed so that the bottom elevation is above the groundwater table to allow runoff to infiltrate into the ground.

Grassed waterways (wide, shallow channels lined with sod) are often used as outlets for runoff from terraces.

Extended detention ponds are structures that are designed to temporarily hold stormwater for up to 24 hours, a period long enough to allow for settling of particulates. These ponds are normally dry between storm events, but may have a shallow marsh in the detention area.

Wet ponds are designed to have a permanent pool of water with additional capacity to detain stormwater. The pool prevents the resuspension of sediments in the pond from previous storm events. Wet ponds can achieve a high degree of pollutant removal and peak stormwater discharge reduction.

Constructed wetlands are engineered systems designed to replicate some of the beneficial functions of natural wetlands to treat and contain stormwater runoff pollutants and reduce peak flow. Constructed wetlands are complex systems and require careful planning if they are to function properly.

Infiltration practices including ponds and trenches are designed to allow stormwater runoff to collect and permeate into the ground. By infiltrating the runoff, pollutants will be retained in the soil. However, a major drawback to infiltration practices is their high maintenance requirements.

6.2.3 Management Plan: Septic Systems

Fecal coliform loads from septic systems represent approximately 10% of the total load in the Culebrinas system. Approximately 67% and 29% of the population is serviced by on-site septic systems and latrine systems, respectively. These systems effectively remove fecal coliform bacteria when properly installed and maintained as fecal coliform bacteria naturally die off while the effluent percolates through the soil to the groundwater. These systems fail when there is a discharge of waste to the soil surface where it is available for washoff into surface waters.

Failing septic systems can deliver high bacteria loads to surface waters, depending on the proximity of the discharge to a waterbody and the timing of rainfall events. Septic system failures typically occur in older systems that are not adequately maintained with periodic sewage pump-outs.

6.2.3.1 Implementation: Septic Systems

Strategies for septic system management include:

- surveying and testing programs to identify failing septic systems;
- education on proper maintenance of septic systems;
- encouragement to make repairs; and
- studies to evaluate alternatives.

Septic failures are often not evident, and identification of failing septic systems should represent a significant portion of the implementation plan. As failed systems are identified, repairs or alternative systems can be encouraged and incorporated.

Public education regarding proper use and maintenance of septic systems is also important in the implementation process. A significant number of septic failures may be prevented if proper maintenance is conducted. Therefore, a public awareness component should be employed.

Septic alternative studies may provide sufficient information to assist in evaluating alternatives to septic systems. Suitability studies for selecting appropriate septic systems (latrines vs. septic tanks or leachfields) can be developed based on soil type and other physical characteristics that may provide selection criteria.

6.2.3.2 Recommended BMPs: Septic Systems

If additional septic system reductions/controls beyond those outlined earlier are necessary, studies are recommended to be undertaken to assess the reduction of fecal coliform as a result of the proposed septic system alternatives. PREQB in consultation with local governments should determine whether additional treatment requirements such as clustered treatment and/or on-site upgrades, or sewering with centralized treatment and discharge out of the watersheds are necessary to achieve these TMDLs.

BMP pollutant removal efficiencies for septic systems are largely dependent on site-specific characteristics that dictate the design and placement of these features. Therefore, recommendations for BMPs should be made on a case by case basis, or clustered depending on the type of management.

6.2.4 Effectiveness of Proposed Watershed Management Measures

The potential effectiveness of the suggested management measures will largely depend on the watershed-wide implementation success as well as the effectiveness of the individual practices. The amount of research conducted on the efficiency of BMPs in reducing pollutant transport to receiving waters has grown steadily in recent years.

However, land use-based BMP pollutant removal efficiencies are largely dependent on site-specific characteristics that dictate the design and placement of these features. Efficiency data based on local BMP implementation projects should be reviewed rather than literature values or regional efficiency data to guide the implementation process. Based on accurate pollutant removal estimates, an informed strategy for attainment of the TMDL can be developed, implemented, and verified by future monitoring.

Recommended future monitoring locations include the existing calibration location (USGS 50147600; see Figure 3-1), and at the discharge point of each assessment unit (see Figure 5-3). Monitoring at the calibration station would provide a continuous flow record that would provide historical data and ongoing record during TMDL implementation process. Monitoring conducted at assessment unit pour points will provide estimates of implementation.

While ideally all subwatersheds should be monitored at their discharge points, limited resources may be available to establish year round sampling at all of these locations. If resources are unavailable, it is suggested that year round data collection should focus on locations listed in **Error! Reference source not found.** and shown in Figure 6-1. Detailed identifying information for these stations is included in Table 6-2. Details of recommended stations to focus water quality monitoring efforts per watershed. A summary of currently available fecal coliform bacteria data for the recommended locations (for dates after 1/1/1980) is included in Table 6-3. Summary of available fecal coliform bacteria data (from 1/1/1980 onwards) for recommended stations.

The recommended stations were selected based on their location and availability of long term data. It is recommended that future monitoring be focused on weather conditions (dry weather vs. wet weather) and flow regime (low flows, high flows, and average flows).

Flow in the stream should be measured concurrently and weather condition should be noted. The current sampling schedule for these stations is 3 times a year, an increase in the frequency of sampling is recommended. Fecal coliform bacteria samples will be collected by trained personnel and tested by a certified laboratory. The analysis method should be the following: Fecal coliform bacteria, M-FC MF (0.7 micron) method, water, colonies per 100 milliliters.

Additionally, it would be useful to monitor fecal coliform concentrations during the rising, peak and recession of the streamflow hydrograph for a storm that occurs after a period of dry weather. This would allow for an evaluation of the surface accumulation and washoff rates of fecal coliform bacteria. This special monitoring effort could be done once a year.

In addition to fecal coliform bacteria and flow, several other water quality parameters should normally be sampled and the data recorded by trained volunteers. These include pH, dissolved oxygen, biological oxygen demand (BOD), temperature, conductivity, and turbidity. Observations regarding the condition of the stream and adjacent areas should be made.

Table 6-1. Recommended stations to focus water quality monitoring efforts per watershed

Agency	Site No.	Station name	Municipality
USGS	50147050	RÍO CULEBRINAS AT COLINAS VERDES, PR	San Sebastian
USGS	50147600	RÍO CULEBRINAS NR SAN SEBASTIAN, PR	San Sebastian
USGS	50149100	RÍO CULEBRINAS NR AGUADA, PR	Aguadilla

Table 6-2. Details of recommended stations to focus water quality monitoring efforts per watershed

Agency	Site no	Latitude	Longitude	Elevation, ft	Drainage area, mi^2
USGS	50147050	18.33317225	-67.00101169	164.0	16.8
USGS	50147600	18.34550467	-67.04406799	65.6	58.2
USGS	50149100	18.39883520	-67.16073620	13.1	97.0

Table 6-3. Summary of available fecal coliform bacteria data (from 1/1/1980 onwards) for recommended stations

Site No.	Count	Min date	Max date	Min conc. c/100ml	Ave conc. c/100ml	Max conc. c/100ml
50147050	2	3/6/2007	8/30/2007	5,700	18,850	32,000
50147600	76	1/29/1980	3/17/2009	6	64,007	3,800,000
50149100	74	1/17/1980	3/18/2009	40	31,128	650,000

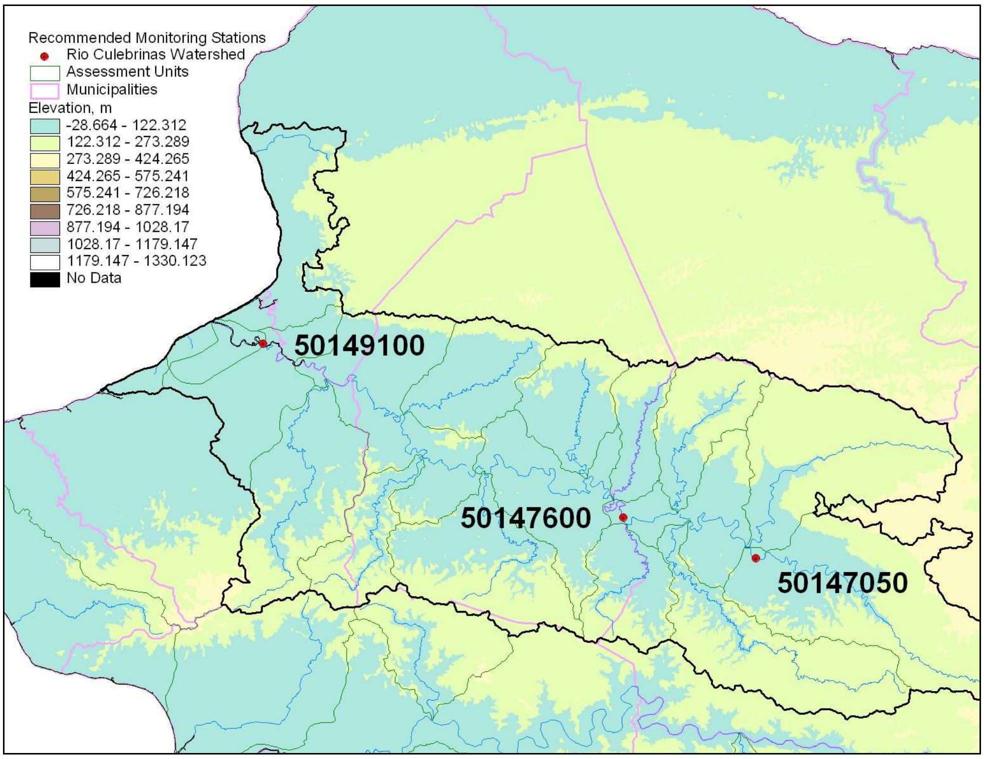

Figure 6-1. Recommended monitoring stations for the Río Culebrinas watershed

7 REFERENCES

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APPENDIX A: SANITARY SYSTEM TYPE

	Households, Census 1990			Percent		
Municipality	**Sanitary Sewers**	**Septics**	**Other**	**Sanitary Sewers**	**Septics**	**Other**
Aguada	3,223	7,722	908	27%	65%	8%
Aguadilla	10,592	9,359	810	51%	45%	4%
Lares	2,911	5,642	771	31%	61%	8%
Moca	2,667	7,030	757	26%	67%	7%
San Sebastian	4,385	8,317	834	32%	61%	6%

APPENDIX B: TIDAL PRISM MODEL

The tidal prism model assumes that a single control volume can represent a waterbody and that the pollutant is well-mixed in the waterbody system.

The mass balance of water can be written as follows (Guo and Lordi 2000):

$$\frac{dV}{dT} = (Q_0 - Q_b + Q_f) \qquad (1)$$

where

Q_0 is the quantity of water that enters the embayment on the flood tide through the ocean boundary (m^3 per tidal cycle)
Q_b is the quantity of mixed water that leaves the bay on the ebb tide that did not enter the bay on the previous flood tide (m^3 per tidal cycle)
Q_f is total freshwater input (m^3 per tidal cycle)
V is the volume of the bay (m^3)
T is the dominant tidal period (hours)

It is further assumed that Q_0 is the pure ocean water that did not flow out of the embayment on the previous ebb tide and that Q_b is the embayment water that did not enter into the system on the previous flood tide. The mass balance for the fecal coliform bacteria can then be written as follows:

$$V\frac{dC}{dT} = Q_0C_0 - Q_bC + L_f - kVC \qquad (2)$$

where

L_f ($Q_f . C_f$) is the loading from upstream in the tidal cycle
k is the fecal coliform bacteria decay rate (or a damped parameter for the net loss of fecal coliform bacteria)
C is fecal coliform bacteria concentration in the embayment
C_0 is the fecal coliform bacteria concentration from outside the embayment

In a steady-state condition, the mass balance equations for the water can be written as follows:

$$Q_b = Q_0 + Q_f \qquad (3)$$

A numerical solution for equation (2) can be developed for the fecal coliform bacteria concentration to simulate a time-variable result by substituting finite difference approximations for the derivatives. The fecal coliform bacteria concentration in the embayment can be calculated from equation (2) as follows:

$$Q_0C_0 - Q_bC^{i+1} + Q_fC_f - kVC^{i+1} = V\frac{C^{i+1} - C^i}{\Delta t} \qquad (4)$$

$$C^{i+1} = \frac{[\Delta t/V\,(Q_0C_0 + L_f) + C_i]}{[1 + \Delta t/V\,(Q_b + kV)]} \qquad (5)$$

The daily load can be estimated on the basis of the dominant tidal period in the area. The dominant tidal period was assumed to be approximately 12 hours. If fecal coliform bacteria concentration is in MPN/100 mL, the daily load (counts day^{-1}) can be estimated as follows:

$$Load = Load_T \times \frac{24}{12} \times 10000 \quad (6)$$

Because Q_0 (the quantity of water that enters the embayment on the flood tide through the ocean boundary) is unknown, it was determined indirectly.

Usually Q_0 is not known, and the only known quantity at the ocean boundary is the tidal range of the tidal embayment. A tidal range time series was computed for the dominant tidal period using observed hourly data from the San Juan, PR, station (NOAA/NOS # 9755371). From that, Q_T (the total ocean water entering the bay on the flood tide) can be calculated. Q_T can then be used to calculate Q_0 (the volume of new ocean water entering the embayment on the flood tide) by using the ocean tidal exchange ratio β:

$$Q_0 = \beta \cdot Q_T \quad (7)$$

where β is the exchange ratio, and Q_T is the total ocean water entering the bay on the flood tide. The numerical value of β is usually smaller than 1, and it represents the fraction of new ocean water entering the embayment.

In general, the exchange ratio values range from 0.3 to 0.7 (VDEQ 2005; Kuo et al. 1998; Shen et al. 2002). A value of 0.8 was used for the exchange ratio in the Río Culebrinas system. Once Q_0 is known, Q_b can be calculated from equation (3).

References

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APPENDIX C: LSPC CALIBRATED INPUT FILE

```
c-----------------------------------------------------------------------------------------
c LSPC -- Loading Simulation Program, C++
c Version 4.01 - Feb 22, 2007
c
c Designed and maintained by:
c    Tetra Tech, Inc.
c    10306 Eaton Place, Suite 340
c    Fairfax, VA 22030
c    (703) 385-6000
c-----------------------------------------------------------------------------------------
c LSPC MODEL INPUT FILE
c This input file was created at 11:32:48am on 02/06/2009
c-----------------------------------------------------------------------------------------
c0   general control
c
c   snowfg   if = 1 run snow module
c   pwatfg   if = 1 run pwater
c   sedfg    if = 1 run sediment
c   pqalfg   if = 1 run general quality
c   tempfg   if = 1 run temperature module
c   oxfg     if = 1 run DO-BOD module
c   nutfg    if = 1 run nutrients module
c   plkfg    if = 1 run plank module
c   phfg     if = 1 run pH-CO2 module
c   mstlfg   if = 1 run mstlay module
c   pestfg   if = 1 run pest module
c   nitrfg   if = 1 run nitr module
c   phosfg   if = 1 run phos module
c   tracfg   if = 1 run tracer module
c   mdasfg   if = 1 run mdas module
c   basefg   if = 0 run tmdl (reduction) mode
c            if = 1 run baseline mode
c   calibfg  if = 1 run calibration mode
c
c        snowfg   pwatfg   sedfg   pqalfg   tempfg   oxfg   nutfg   plkfg   phfg   mstlfg   pestfg   nitrfg
phosfg   tracfg   mdasfg   basefg   calibfg
         0        1        0       1        0        0      0       0       0      0        0
         0        0        0       0        0        1
c-----------------------------------------------------------------------------------------
c20  weather station name and path (file path specified in card 30)
c
c   wstnum     weather station id
c   filename   weather station file name
c   wst_desc   weather station name (notation)
c
c        wstnum   filename   wst_desc
         1        PR2801.air    COLOSO
         2        PR8881.air    SAN SEBASTIÁN 2 WNW
c-----------------------------------------------------------------------------------------
c30      output file path    input (weather) file path  (each must be a continuous string)
         D:\PR_Culebrinas_2009\LSPC\output\     D:\PR_Culebrinas_2009\LSPC\weather\
c-----------------------------------------------------------------------------------------
c35      point source file path    point source file name  (each must be a continuous string)
         D:\PR_Culebrinas_2009\LSPC\            LSPC_PR_Fecal_Culebrinas.mdb
c-----------------------------------------------------------------------------------------
c40      general watershed controls
c
c   nsubbasin   number of subwatersheds
c   nrchid      number of stream channels (corresponds with number of subwatersheds)
c   nrgid       number of stream groups to assign parameters
c   ndefid      number of land groups to assign parameters
c   ndeluid     maximum number of land use
c
c        nsws   nrch   nrgroup   nlgroup   nlandp
         19     19     1         1         10
c-----------------------------------------------------------------------------------------
c45  general output controls
c
c   Standard    Output standard model parameters
c   Snow        Output snow related parameters
c   Hydrology   Output hydrology related parameters
c   Sediment    Output sediment related parameters
c   GQUAL       Output general water quality related parameters
c   AGCHEM      Output agricultural water quality related parameters
c   RQUAL       Output biochemical water quality related parameters
c   Custom      Output user specified parameters
c   Landuse     Output landuse summary
c                                  if = 0 no output
c                                  if = 1 average annual output
c                                  if = 2 yearly output
c                                  if = 3 monthly output
c   Stream      Output stream summary
c                                  if = 0 no output
c                                  if = 1 average annual output
c                                  if = 2 yearly output
c                                  if = 3 monthly output
c   Threshold   Output threshold analysis summary
c                                  if = 0 no output
c                                  if = 1 average monthly output
c
c        Standard  Snow  Hydrology  Sediment  GQUAL  AGCHEM  RQUAL  Custom  Landuse  Stream  Threshold
         0         0     0          0         0      0       0      1       1        1       1
```

```
c-----------------------------------------------------------------------------------------
c46  user specified output parameter list
c
c  PRECP  AIRTMP SNOTMP SNOWF  RAINF  PRAIN  MELT  SNOWE WYIELD PACK   PACKF  PACKW  PACKI  PDEPTH COVINDX  NEGHTS
XLNMELT   RDENPKF   SKYCLEAR   SNOCOV DULLNESS   ALBEDO   PAKTEMP   DEWTMP SURS  UZS   LZS   AGWS  SURO  IFWO AGWO  PERO
TAET  PERC  INFIL GWI   IGWI  AGWI    DEP   AVDEP  HRAD  AVVEL  SAREA  VOLUME  RO TAU  WSSD  SCRSD  SOSED SOBER  SSEDC LSSED
LRSED LBEDDEP LDEPSCR   LROSED SQO    WASHQS SCRQS  SOQO   POQUAL SOQUAL IOQUAL   GOQUAL POQC CONC CONCOUT MATSQAL
MATIN  MATOUT  MATOSQAL  DOX  DOXMIN DOXMAX  DOXAV  DOXX   BOD  BODX  NO3  NO3X   TAM   TAMX   NO2   NO2X  PO4   PO4X  SNH4
SNH4X  SPO4  SPO4X  PHYTO  PHYTOX  PHYCLA  BENAL  ORN    ORNX   ORP    ORPX  ORC  ORCX  PH   ALK  TIC  TICX  CO2  CO2X   TEMP
MDASNH4   MDASNO3   MDASSO4   MDASDFe   MDASTFe   MDASDAl   MDASTAl   MDASpH   MDASACID   MDASALK   MDASOrgN  MDASH2O
MDASH  MDASCa  MDASCO3  MDASOrg  MDASNO2
          0         0         0         0         0         0         0         0         0         0         0
          0         0         0         0         0         0         0         0         0         0         0
          0         0         0         0         0         0         0         0         0         0         0
          0         0         0         0         0         0         0         0         0         0         0
          1         0         0         0         0         0         0         0         0         0         0
          0         0         0         0         0         0         0         0         0         0         0
          1         0         0         0         0         0         0         0         0         0         0
          0         0         0         0         0         0         0         0         0         0         0
          0         0         0         0         0         0         0         0         0         0         0
          0         0         0         0         0         0         0         0         0         0         0
          0         0         0         0         0         0         0         0         0         0         0
          0         0         0
c-----------------------------------------------------------------------------------------
c50  model simulation time period
c
c   mstart   model start day.
c   mend     model end day.
c   delt     time step in minutes.
c   mostart  model output start day.
c   moend    model output end day.
c   optlevel  if = 1 general output (daily)
c             if = 2 output per time interval (min)
c
c         mstart   mend    delt       mostart   moend   optlevel
          1/1/1996    12/31/2000   60        1/1/1998     12/31/2000    1
c-----------------------------------------------------------------------------------------
c60  group information
c
c   subbasin  subbasin id
c   defid    group parameter id
c   nwst     number of weather stations assigned to the watershed  (<=5)
c   for i = 1 up to 5
c    wsti = station id
c    wti = weighting to calculate input
c
c         subbasin  defid  nwst  wst1   wt1   wst2   wt2   wst3   wt3   wst4   wt4   wst5   wt5
          401       1         1         1         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          402       1         1         1         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          403       1         1         1         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          404       1         1         2         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          405       1         1         2         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          406       1         1         2         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          407       1         1         2         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          408       1         1         2         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          409       1         1         2         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          410       1         1         2         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          411       1         1         2         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          412       1         1         2         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          413       1         1         2         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          414       1         1         1         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          415       1         1         1         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          416       1         1         1         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          417       1         1         1         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          418       1         1         1         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
          419       1         1         1         1.000000   0         0.000000   0         0.000000   0         0.000000
          0         0.000000
c-----------------------------------------------------------------------------------------
c70  modeled land use names
c
c   deluid    landuse id
c   deluname   landuse name
c
c         deluid    deluname
          0         Water
```

```
            1           Forest
            2           Agriculture
            3           Pasture
            4           Wetland
            5           Barren
            6           Urban_HighD_Per
            7           Urban_LowD_Per
            8           Urban_HighD_Imp
            9           Urban_LowD_Imp
c------------------------------------------------------------------------------------------
c80  land use to stream routing
c
c   defid       landuse default group id
c   deluid      land use id
c   route_suro  fraction of surface runoff that routes to the stream (0-1)
c   route_ifwo  fraction of interflow outflow that routes to the stream (0-1)
c   route_agwo  fraction of groundwater outflow that routes to the stream (0-1)
c
c   Note: The remaining fraction is routed directly to the next downstream reach segment(s)
c
c  defid  deluid  route_suro  route_ifwo  route_agwo
            1           0           1.000000    1.000000    1.000000
            1           1           1.000000    1.000000    1.000000
            1           2           1.000000    1.000000    1.000000
            1           3           1.000000    1.000000    1.000000
            1           4           1.000000    1.000000    1.000000
            1           5           1.000000    1.000000    1.000000
            1           6           1.000000    1.000000    1.000000
            1           7           1.000000    1.000000    1.000000
            1           8           1.000000    1.000000    1.000000
            1           9           1.000000    1.000000    1.000000
c------------------------------------------------------------------------------------------
c90  land use information
c
c   subbasin   subbasin id
c   deluid     land use id
c   deluname   land use name
c   perimp     1 imperivous land (subsurface processes disabled)
c              2 pervious  land (subsurface processes activated)
c   area_ac    area (acres)
c   slsur      slope of overland flow plane (none)
c   lsur       length of overland flow plane (feet)
c
c  subbasin  deluid  deluname  perimp  area_ac  slsur  lsur
            401         0           Water       1           20.431000   0.071455    212.189681
            401         1           Forest      2           144.128000  0.071455    212.189681
            401         2           Agriculture 2           0.000000    0.071455    212.189681
            401         3           Pasture     2           477.466000  0.071455    212.189681
            401         4           Wetland     2           104.377000  0.071455    212.189681
            401         5           Barren      2           13.102000   0.071455    212.189681
            401         6           Urban_HighD_Per         2           18.321500   0.071455    212.189681
            401         7           Urban_LowD_Per          2           33.645000   0.071455    212.189681
            401         8           Urban_HighD_Imp         1           18.321500   0.071455    212.189681
            401         9           Urban_LowD_Imp          1           11.215000   0.071455    212.189681
            402         0           Water       1           35.587000   0.083696    211.851475
            402         1           Forest      2           336.293000  0.083696    211.851475
            402         2           Agriculture 2           5.116000    0.083696    211.851475
            402         3           Pasture     2           2063.804000 0.083696    211.851475
            402         4           Wetland     2           0.000000    0.083696    211.851475
            402         5           Barren      2           29.804000   0.083696    211.851475
            402         6           Urban_HighD_Per         2           66.057500   0.083696    211.851475
            402         7           Urban_LowD_Per          2           514.950000  0.083696    211.851475
            402         8           Urban_HighD_Imp         1           66.057500   0.083696    211.851475
            402         9           Urban_LowD_Imp          1           171.650000  0.083696    211.851475
            403         0           Water       1           69.164000   0.166499    229.883468
            403         1           Forest      2           1737.109000 0.166499    229.883468
            403         2           Agriculture 2           49.594000   0.166499    229.883468
            403         3           Pasture     2           2531.940000 0.166499    229.883468
            403         4           Wetland     2           0.000000    0.166499    229.883468
            403         5           Barren      2           18.459000   0.166499    229.883468
            403         6           Urban_HighD_Per         2           62.714500   0.166499    229.883468
            403         7           Urban_LowD_Per          2           770.757000  0.166499    229.883468
            403         8           Urban_HighD_Imp         1           62.714500   0.166499    229.883468
            403         9           Urban_LowD_Imp          1           256.919000  0.166499    229.883468
            404         0           Water       1           65.136000   0.189567    252.888974
            404         1           Forest      2           1230.479000 0.189567    252.888974
            404         2           Agriculture 2           48.241000   0.189567    252.888974
            404         3           Pasture     2           1898.961000 0.189567    252.888974
            404         4           Wetland     2           0.000000    0.189567    252.888974
            404         5           Barren      2           0.889000    0.189567    252.888974
            404         6           Urban_HighD_Per         2           1.000500    0.189567    252.888974
            404         7           Urban_LowD_Per          2           465.014250  0.189567    252.888974
            404         8           Urban_HighD_Imp         1           1.000500    0.189567    252.888974
            404         9           Urban_LowD_Imp          1           155.004750  0.189567    252.888974
            405         0           Water       1           47.611000   0.136521    239.248423
            405         1           Forest      2           775.569000  0.136521    239.248423
            405         2           Agriculture 2           30.035000   0.136521    239.248423
            405         3           Pasture     2           1575.387000 0.136521    239.248423
            405         4           Wetland     2           0.000000    0.136521    239.248423
            405         5           Barren      2           0.445000    0.136521    239.248423
            405         6           Urban_HighD_Per         2           3.893500    0.136521    239.248423
            405         7           Urban_LowD_Per          2           413.647500  0.136521    239.248423
            405         8           Urban_HighD_Imp         1           3.893500    0.136521    239.248423
```

405	9	Urban_LowD_Imp		1	137.882500	0.136521	239.248423
406	0	Water	1	3.336000	0.203212	255.255471	
406	1	Forest	2	6262.556000	0.203212	255.255471	
406	2	Agriculture	2	472.633000	0.203212	255.255471	
406	3	Pasture	2	2978.145000	0.203212	255.255471	
406	4	Wetland	2	0.000000	0.203212	255.255471	
406	5	Barren	2	4.448000	0.203212	255.255471	
406	6	Urban_HighD_Per		2	63.833500	0.203212	255.255471
406	7	Urban_LowD_Per		2	1142.994000	0.203212	255.255471
406	8	Urban_HighD_Imp		1	63.833500	0.203212	255.255471
406	9	Urban_LowD_Imp		1	380.998000	0.203212	255.255471
407	0	Water	1	1.780000	0.143174	357.159054	
407	1	Forest	2	1173.326000	0.143174	357.159054	
407	2	Agriculture	2	7.342000	0.143174	357.159054	
407	3	Pasture	2	4472.391000	0.143174	357.159054	
407	4	Wetland	2	0.000000	0.143174	357.159054	
407	5	Barren	2	4.894000	0.143174	357.159054	
407	6	Urban_HighD_Per		2	43.827500	0.143174	357.159054
407	7	Urban_LowD_Per		2	790.227000	0.143174	357.159054
407	8	Urban_HighD_Imp		1	43.827500	0.143174	357.159054
407	9	Urban_LowD_Imp		1	263.409000	0.143174	357.159054
408	0	Water	1	1.334000	0.189907	184.466129	
408	1	Forest	2	2109.077000	0.189907	184.466129	
408	2	Agriculture	2	255.268000	0.189907	184.466129	
408	3	Pasture	2	2353.228000	0.189907	184.466129	
408	4	Wetland	2	0.000000	0.189907	184.466129	
408	5	Barren	2	1.112000	0.189907	184.466129	
408	6	Urban_HighD_Per		2	0.000000	0.189907	184.466129
408	7	Urban_LowD_Per		2	440.938500	0.189907	184.466129
408	8	Urban_HighD_Imp		1	0.000000	0.189907	184.466129
408	9	Urban_LowD_Imp		1	146.979500	0.189907	184.466129
409	0	Water	1	2.666000	0.163403	278.266810	
409	1	Forest	2	687.602000	0.163403	278.266810	
409	2	Agriculture	2	1.999000	0.163403	278.266810	
409	3	Pasture	2	1761.329000	0.163403	278.266810	
409	4	Wetland	2	0.000000	0.163403	278.266810	
409	5	Barren	2	1.555000	0.163403	278.266810	
409	6	Urban_HighD_Per		2	0.666500	0.163403	278.266810
409	7	Urban_LowD_Per		2	287.760000	0.163403	278.266810
409	8	Urban_HighD_Imp		1	0.666500	0.163403	278.266810
409	9	Urban_LowD_Imp		1	95.920000	0.163403	278.266810
410	0	Water	1	0.000000	0.212883	240.936732	
410	1	Forest	2	880.821000	0.212883	240.936732	
410	2	Agriculture	2	175.542000	0.212883	240.936732	
410	3	Pasture	2	1211.240000	0.212883	240.936732	
410	4	Wetland	2	0.000000	0.212883	240.936732	
410	5	Barren	2	0.000000	0.212883	240.936732	
410	6	Urban_HighD_Per		2	0.000000	0.212883	240.936732
410	7	Urban_LowD_Per		2	209.650500	0.212883	240.936732
410	8	Urban_HighD_Imp		1	0.000000	0.212883	240.936732
410	9	Urban_LowD_Imp		1	69.883500	0.212883	240.936732
411	0	Water	1	0.667000	0.169881	217.736372	
411	1	Forest	2	336.130000	0.169881	217.736372	
411	2	Agriculture	2	1.556000	0.169881	217.736372	
411	3	Pasture	2	1015.058000	0.169881	217.736372	
411	4	Wetland	2	0.000000	0.169881	217.736372	
411	5	Barren	2	0.445000	0.169881	217.736372	
411	6	Urban_HighD_Per		2	3.890500	0.169881	217.736372
411	7	Urban_LowD_Per		2	293.780250	0.169881	217.736372
411	8	Urban_HighD_Imp		1	3.890500	0.169881	217.736372
411	9	Urban_LowD_Imp		1	97.926750	0.169881	217.736372
412	0	Water	1	1.557000	0.237282	234.542177	
412	1	Forest	2	2435.031000	0.237282	234.542177	
412	2	Agriculture	2	339.570000	0.237282	234.542177	
412	3	Pasture	2	1681.395000	0.237282	234.542177	
412	4	Wetland	2	0.000000	0.237282	234.542177	
412	5	Barren	2	2.001000	0.237282	234.542177	
412	6	Urban_HighD_Per		2	0.111000	0.237282	234.542177
412	7	Urban_LowD_Per		2	297.708000	0.237282	234.542177
412	8	Urban_HighD_Imp		1	0.111000	0.237282	234.542177
412	9	Urban_LowD_Imp		1	99.236000	0.237282	234.542177
413	0	Water	1	1.559000	0.163751	234.652718	
413	1	Forest	2	474.455000	0.163751	234.652718	
413	2	Agriculture	2	1.113000	0.163751	234.652718	
413	3	Pasture	2	1826.128000	0.163751	234.652718	
413	4	Wetland	2	0.000000	0.163751	234.652718	
413	5	Barren	2	2.894000	0.163751	234.652718	
413	6	Urban_HighD_Per		2	2.671500	0.163751	234.652718
413	7	Urban_LowD_Per		2	374.543250	0.163751	234.652718
413	8	Urban_HighD_Imp		1	2.671500	0.163751	234.652718
413	9	Urban_LowD_Imp		1	124.847750	0.163751	234.652718
414	0	Water	1	0.668000	0.233961	241.625057	
414	1	Forest	2	1329.892000	0.233961	241.625057	
414	2	Agriculture	2	182.290000	0.233961	241.625057	
414	3	Pasture	2	570.240000	0.233961	241.625057	
414	4	Wetland	2	0.000000	0.233961	241.625057	
414	5	Barren	2	2.448000	0.233961	241.625057	
414	6	Urban_HighD_Per		2	0.000000	0.233961	241.625057
414	7	Urban_LowD_Per		2	200.151750	0.233961	241.625057
414	8	Urban_HighD_Imp		1	0.000000	0.233961	241.625057
414	9	Urban_LowD_Imp		1	66.717250	0.233961	241.625057
415	0	Water	1	0.000000	0.165441	294.585124	
415	1	Forest	2	770.479000	0.165441	294.585124	

415	2	Agriculture	2	4.889000	0.165441	294.585124	
415	3	Pasture	2	1593.406000	0.165441	294.585124	
415	4	Wetland	2	0.000000	0.165441	294.585124	
415	5	Barren	2	8.667000	0.165441	294.585124	
415	6	Urban_HighD_Per		2	10.111500	0.165441	294.585124
415	7	Urban_LowD_Per		2	527.357250	0.165441	294.585124
415	8	Urban_HighD_Imp		1	10.111500	0.165441	294.585124
415	9	Urban_LowD_Imp		1	175.785750	0.165441	294.585124
416	0	Water	1	0.222000	0.255603	222.918030	
416	1	Forest	2	2529.108000	0.255603	222.918030	
416	2	Agriculture	2	109.642000	0.255603	222.918030	
416	3	Pasture	2	1538.326000	0.255603	222.918030	
416	4	Wetland	2	0.000000	0.255603	222.918030	
416	5	Barren	2	9.341000	0.255603	222.918030	
416	6	Urban_HighD_Per		2	12.565500	0.255603	222.918030
416	7	Urban_LowD_Per		2	726.573750	0.255603	222.918030
416	8	Urban_HighD_Imp		1	12.565500	0.255603	222.918030
416	9	Urban_LowD_Imp		1	242.191250	0.255603	222.918030
417	0	Water	1	59.803000	0.143947	350.000000	
417	1	Forest	2	1420.811000	0.143947	350.000000	
417	2	Agriculture	2	0.222000	0.143947	350.000000	
417	3	Pasture	2	849.019000	0.143947	350.000000	
417	4	Wetland	2	19.341000	0.143947	350.000000	
417	5	Barren	2	120.272000	0.143947	350.000000	
417	6	Urban_HighD_Per		2	292.121000	0.143947	350.000000
417	7	Urban_LowD_Per		2	530.886750	0.143947	350.000000
417	8	Urban_HighD_Imp		1	292.121000	0.143947	350.000000
417	9	Urban_LowD_Imp		1	176.962250	0.143947	350.000000
418	0	Water	1	0.000000	0.006166	304.944299	
418	1	Forest	2	31.384000	0.006166	304.944299	
418	2	Agriculture	2	0.000000	0.006166	304.944299	
418	3	Pasture	2	225.257000	0.006166	304.944299	
418	4	Wetland	2	31.830000	0.006166	304.944299	
418	5	Barren	2	3.339000	0.006166	304.944299	
418	6	Urban_HighD_Per		2	9.682500	0.006166	304.944299
418	7	Urban_LowD_Per		2	0.333750	0.006166	304.944299
418	8	Urban_HighD_Imp		1	9.682500	0.006166	304.944299
418	9	Urban_LowD_Imp		1	0.111250	0.006166	304.944299
419	0	Water	1	0.222000	0.119691	377.100472	
419	1	Forest	2	85.957000	0.119691	377.100472	
419	2	Agriculture	2	0.000000	0.119691	377.100472	
419	3	Pasture	2	116.527000	0.119691	377.100472	
419	4	Wetland	2	1.772000	0.119691	377.100472	
419	5	Barren	2	8.861000	0.119691	377.100472	
419	6	Urban_HighD_Per		2	51.507000	0.119691	377.100472
419	7	Urban_LowD_Per		2	13.624500	0.119691	377.100472
419	8	Urban_HighD_Imp		1	51.507000	0.119691	377.100472
419	9	Urban_LowD_Imp		1	4.541500	0.119691	377.100472

```
c-----------------------------------------------------------------------------------------
c92 SNOW-FLAGS
c defid    parameter group id
c deluid   landuse id
c iceflag  0 = Ice formation in the snow pack is not simulated
c          1 = Ice formation is simulated
c forest   0.0 - 1.0  Fraction of LAND covered by Forest (winter transpiration)
c              defid LUID ICEFLAG FOREST
c--------------------------------------------------------------------------------------------
c93 SNOW-PARM
c LAT      Latitude of the pervious land segment (PLS) - ENERGY BALANCE METHOD ONLY (degree)
c          Positive for the northern hemisphere, negative for southern
c MELEV    Mean elevation of LAND above sea level - ENERGY BALANCE METHOD ONLY (ft)
c SHADE    Fraction of LAND shaded from solar radiation (i.e. by trees) - ENERGY BALANCE METHOD ONLY
c SNOWCF   Precipitation-to-snow multiplier (accounts for poor gage-catch efficiency during snow)
c COVIND   Maximum snowpack (water equivalent) at which the entire LAND is covered with snow (in)
c              defid LUID     LAT    MELEV    SHADE    SNOWCF    COVIND
c--------------------------------------------------------------------------------------------
c94 SNOW-PARM2
c RDCSN    Density of cold, new snow relative to water (For snow falling at temps below freezing.
c          At higher temperatures the density of snow is adjusted)
c TSNOW    Air temperature below which precipitation will be snow, under saturated conditions (deg F)
c          Under non-saturated conditions the temperature is adjusted slightly.
c SNOEVP   Adapts sublimation equation to field conditions - ENERGY BALANCE METHOD ONLY
c CCFACT   Adapts snow condensation/convection melt equation to field conditions - ENERGY BALANCE METHOD ONLY
c MWATER   Maximum water content of the snow pack, in depth of water per depth of water.
c MGMELT   Maximum rate of snowmelt by ground heat, in depth of water per day (in/day)
c          This is the value which applies when the pack temperature is at the freezing point.
c              defid LUID    RDCSN    TSNOW    SNOEVP    CCFACT    MWATER    MGMELT
c--------------------------------------------------------------------------------------------
c96 SNOW-INIT
c  Pack-snow   Initial quantity of snow in the pack (water equivalent).
c  Pack-ice    Initial quantity of ice in the pack (water equivalent).
c  Pack-watr   Initial quantity of liquid water in the pack.
c  RDENPF      Density of the frozen contents (snow and ice) of the pack, relative to water.
c  DULL        Index of the dullness of the snow pack surface, from which albedo is estimated - ENERGY BALANCE METHOD ONLY
c  PAKTMP      Mean temperature of the frozen contents of the snow pack.
c
c  COVINX      Current snow pack depth (water equivalent) required to obtain complete areal coverage of LAND.
c              If the pack is less than this amount, areal coverage is prorated (PACKF/COVINX).
c  XLNMLT      Current remaining possible increment to ice storage in the pack.
c              Relevant when Ice formation is simulated (iceflag = 1)
c  SKYCLR      Fraction of sky which is assumed to be clear at the present time.
c              defid LUID Pack-snow  Pack-ice Pack-watr    RDENPF      DULL     PAKTMP
c--------------------------------------------------------------------------------------------
```

```
c100 pwat-parm1
c   pervious and impervious land hydrology control
c
c   (value of 0 = use constant pwat-parm4; 1 = use corresponding monthly variable card)
c
c   vcsfg   interception storage capacity                                    (card 150)
c   vuzfg   upper zone nominal storage                                                  (card 160)
c   vnnfg   manning's n for the overland flow plane            (card 170)
c   vifwfg  interflow inflow parameter                                                  (card 180)
c   vircfg  interflow recession constant                                     (card 190)
c   vlefg   lower zone evapotranspiration (e-t) parameter    (card 200)
c
c           vcsfg  vuzfg  vnnfg  vifwfg  vircfg  vlefg
            0      0      0      0       0       1
c-----------------------------------------------------------------------------------
c110 pwat-parm2
c
c   defid   parameter group id
c   deluid  landuse id
c   lzsn    lower zone nominal soil moisture storage (inches)
c   infilt  index to the infiltration capacity of the soil (in/hr)
c   kvary   variable groundwater recession (1/inches)
c   agwrc   base groundwater recession (none)
c
c           defid deluid lzsn     infilt    kvary     agwrc
            1     0      8.000000  0.200000  0.000000  0.990000
            1     1      8.000000  0.200000  0.000000  0.990000
            1     2      8.000000  0.200000  0.000000  0.990000
            1     3      8.000000  0.200000  0.000000  0.990000
            1     4      8.000000  0.200000  0.000000  0.990000
            1     5      8.000000  0.200000  0.000000  0.990000
            1     6      8.000000  0.200000  0.000000  0.990000
            1     7      8.000000  0.200000  0.000000  0.990000
            1     8      8.000000  0.200000  0.000000  0.990000
            1     9      8.000000  0.200000  0.000000  0.990000
c-----------------------------------------------------------------------------------
c120 pwat-parm3
c
c   defid   parameter group id
c   deluid  landuse id
c   petmax  air temperature below which e-t will is reduced (deg F)
c   petmin  air temperature below which e-t is set to zero (deg F)
c   infexp  exponent in the infiltration equation (none)
c   INFILD  ratio between the maximum and mean infiltration capacities over the PLS (none)
c   deepfr  fraction of groundwater inflow that will enter deep groundwater (none)
c   basetp  fraction of remaining potential e-t that can be satisfied from baseflow (none)
c   agwetp  fraction of remaining potential e-t that can be satisfied from active groundwater (none)
c
c           defid deluid  petmax    petmin    infexp    infild    deepfr    basetp    agwetp
            1     0       45.000000 35.000000 2.000000  2.000000  0.300000  0.070000  0.050000
            1     1       45.000000 35.000000 2.000000  2.000000  0.300000  0.070000  0.050000
            1     2       45.000000 35.000000 2.000000  2.000000  0.300000  0.070000  0.050000
            1     3       45.000000 35.000000 2.000000  2.000000  0.300000  0.070000  0.050000
            1     4       45.000000 35.000000 2.000000  2.000000  0.300000  0.070000  0.050000
            1     5       45.000000 35.000000 2.000000  2.000000  0.300000  0.070000  0.050000
            1     6       45.000000 35.000000 2.000000  2.000000  0.300000  0.070000  0.050000
            1     7       45.000000 35.000000 2.000000  2.000000  0.300000  0.070000  0.050000
            1     8       45.000000 35.000000 2.000000  2.000000  0.300000  0.070000  0.050000
            1     9       45.000000 35.000000 2.000000  2.000000  0.300000  0.070000  0.050000
c-----------------------------------------------------------------------------------
c130 pwat-parm4
c
c   defid   parameter group id
c   deluid  landuse id
c   cepsc   interception storage capacity (inches)
c   uzsn    upper zone nominal storage (inches)
c   nsur    Manning's n for the assumed overland flow plane (none)
c   intfw   interflow inflow parameter (none)
c   irc     interflow recession parameter (none)
c   lzetp   lower zone e-t parameter (none)
c
c           defid deluid  cepsc     uzsn      nsur      intfw     irc       lzetp
            1     0       0.300000  0.500000  0.200000  2.000000  0.600000  0.500000
            1     1       0.300000  0.500000  0.200000  2.000000  0.600000  0.500000
            1     2       0.300000  0.500000  0.200000  2.000000  0.600000  0.500000
            1     3       0.300000  0.500000  0.200000  2.000000  0.600000  0.500000
            1     4       0.300000  0.500000  0.200000  2.000000  0.600000  0.500000
            1     5       0.300000  0.500000  0.200000  2.000000  0.600000  0.500000
            1     6       0.300000  0.500000  0.200000  2.000000  0.600000  0.500000
            1     7       0.300000  0.500000  0.200000  2.000000  0.600000  0.500000
            1     8       0.300000  0.500000  0.200000  2.000000  0.600000  0.500000
            1     9       0.300000  0.500000  0.200000  2.000000  0.600000  0.500000
c-----------------------------------------------------------------------------------
c140 pwat-state1
c   initial conditions for the simulation
c
c   defid   parameter group id
c   deluid  landuse id
c   ceps    initial interception storage.
c   surs    initial surface (overland flow) storage.
c   uzs     initial upper zone storage.
c   ifws    initial interflow storage.
c   lzs     initial lower zone storage.
```

```
c   agws    initial active groundwater storage.
c   gwvs    initial index to groundwater slope.
c
c           defid deluid ceps    surs    uzs    ifws    lzs    agws    gwvs
            1      0     0.000000  0.000000  0.300000  0.000000  4.000000  1.000000  0.000000
            1      1     0.000000  0.000000  0.300000  0.000000  4.000000  1.000000  0.000000
            1      2     0.000000  0.000000  0.300000  0.000000  4.000000  1.000000  0.000000
            1      3     0.000000  0.000000  0.300000  0.000000  4.000000  1.000000  0.000000
            1      4     0.000000  0.000000  0.300000  0.000000  4.000000  1.000000  0.000000
            1      5     0.000000  0.000000  0.300000  0.000000  4.000000  1.000000  0.000000
            1      6     0.000000  0.000000  0.300000  0.000000  4.000000  1.000000  0.000000
            1      7     0.000000  0.000000  0.300000  0.000000  4.000000  1.000000  0.000000
            1      8     0.000000  0.000000  0.300000  0.000000  4.000000  1.000000  0.000000
            1      9     0.000000  0.000000  0.300000  0.000000  4.000000  1.000000  0.000000
c-------------------------------------------------------------------------------
c150 mon-interception storage (cepscm)
c   only required if vcsfg=1 in pwat-parm1 (see card 100)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec interception storage capacity at start of each month (inches)
c
c           defid deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c-------------------------------------------------------------------------------
c160 mon-upper zone nominal storage (uzsnm)
c   only required if vuzfg=1 in pwat-parm1 (see card 100)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec upper zone nominal storage at start of each month (inches)
c
c           defid deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c---------------------------------------------------------------------------------
c170 mon-Manning's roughness coefficient (nsurm)
c   only required if vnnfg=1 in pwat-parm1 (see card 100)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec Manning's roughness coefficient at start of each month (none)
c
c           defid deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c---------------------------------------------------------------------------------
c180 mon-interflow inflow parameter (intfwm)
c   only required if vifwfg=1 in pwat-parm1 (see card 100)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec interflow inflow parameter at start of each month (none)
c
c           defid deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c---------------------------------------------------------------------------------
c190 mon-interflow recession constant (ircm)
c   only required if vircfg=1 in pwat-parm1 (see card 100)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec interflow recession constant at start of each month (none)
c
c           defid deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c-------------------------------------------------------------------------------
c200 mon-lower zone evapotranspiration parameter (lzetpm)
c   only required if vlefg=1 in pwat-parm1 (see card 100)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec lower zone evapotranspiration parameter at start of each month (none)
c
c           defid deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
            1      0     0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000
            0.500000  0.500000  0.500000
            1      1     0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000
            0.500000  0.500000  0.500000
            1      2     0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000
            0.500000  0.500000  0.500000
            1      3     0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000
            0.500000  0.500000  0.500000
            1      4     0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000
            0.500000  0.500000  0.500000
            1      5     0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000
            0.500000  0.500000  0.500000
            1      6     0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000
            0.500000  0.500000  0.500000
            1      7     0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000
            0.500000  0.500000  0.500000
            1      8     0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000
            0.500000  0.500000  0.500000
            1      9     0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000  0.500000
            0.500000  0.500000  0.500000
c-------------------------------------------------------------------------------
c201   Irrigation Application Option Flags
cIrrigation flag decide whether to run irrigation
c
c   irrigfg   if = 1 run irrigation option
```

```
c   petfg     if = 1 use constant PET rather than time series from the air file
c   monVaryIrrig   if = 1 use monthly varying ET coefficient
c
c                  irrigfg             petfg  monVaryIrrig
                   0                   0                   0
c------------------------------------------------------------------------------------------
c202 Irrigation PET Value
c  defid       Group ID number.
c  petval      Constant PET value to calculate actual ET (in/hr)
c
c                  defid               petval
c------------------------------------------------------------------------------------------
c203 Irrigation Application Options
c  defid       Group ID number.
c  deluid      Landuse ID number
c  startmonth   startmonth of irrigation requirement
c  endmonth     endmonth of irrigation requirement
c  fraction1    fraction of irrigation requirement applied over the canopy.
c  fraction2    fraction of irrigation water applied directly to the soil surface.
c  fraction3    fraction of irrigation water applied to the upper soil zone via buried systems
c  fraction4    fraction of irrigation water likewise applied to the lower soil zone.
c  fraction5    fraction of irrigation water entering directly into the local groundwater, such as seepage irrigation.
c  etcoeff      Coefficient to calculate actual ET, based on PET.
c  etdays       Number of threshold days to calculate irrigation demand (pet*etcoeff - precip)
c            (if etdays = 0 then irrigation demand = pet * etcoeff)
c
c                  defid      deluid      startmonth    endmonth    fraction1    fraction2    fraction3    fraction4    fraction5    etcoeff    etdays
c------------------------------------------------------------------------------------------
c204 Monthly-variable ET coefficients
c  defid       Group ID number.
c  deluid      Landuse ID number
c  monetcs     Monthly-variable coefficient to calculate actual ET for Jan..Dec
c
c                  defid      deluid      monETCs1    monETCs2    monETCs3    monETCs4    monETCs5    monETCs6    monETCs7    monETCs8    monETCs9
                   monETCs10   monETCs11   monETCs12
c------------------------------------------------------------------------------------------
c205 Irrigation Withdrawal Options
c                  Irrigation withdrawal information for each watershed
c   subbasin    subbasin id
c   rchid       reach id from where water is withdrawn (if reach is does not exist then
c            etdemand is assumed to be satisfied from an external source)
c   irrigdep    depth of irrigation withdrawal pipe (ft)
c
c                  subbasin         rchid
c------------------------------------------------------------------------------------------
c250 general quality constituent control
c
c   defid    parameter group id
c   dwqid    general quality id
c   qname    name of qual (must be a continuous string)
c   qunit    units for quality constituent output (mg/l), (ug/l), or (#/100ml)
c   qsdfg    if = 0 no sediment associated qual
c                                    if = 1 sediment associated in pervious/impervious land (qsdfg should be > 0 in card 281)
c                                    if = 2 sediment associated in pervious/impervious land
c                                         and sediment associated qual is added to the dissolved part
c   gqsdfg   if = 0 general quality constituent
c          if = 1 general quality constituent simulated as a sediment (only one qual can be simulated as a sediment in each group)
c   qsofg    if = 1 then then accumulation and removal occur daily
c          if = 2 then then accumulation and removal occur every interval
c
c                  defid dwqid   qname  qunit  qsdfg  gqsdfg  qsofg
                   1          12          FECAL                   (#/100ml)     0          0          1
c---------------------------------------------------------------------------------------------------------
C255 subsurface quality control
c
c   (value of 0 = use constant qual-input; 1 = use corresponding monthly variable card)
c
c   vqofg      if = 1 the accumulation rate and limiting storage of QUALOF varies monthly   (cards 270, 271)
c   qsowfg      if = 1 the constituent is a QUALSURO (surface flow associated).
c   vsqcfg      if = 1 the concentration of this constituent in surface outflow varies monthly   (card 272)= 1 read table 272
c   qifwfg      if = 1 the constituent is a QUALIF (interflow associated).
c   viqcfg      if = 1 the concentration of this constituent in interflow outflow varies monthly   (card 273)= 1 read table 273
c   qagwfg      if = 1 the constituent is a QUALGW (groundwater associated).
c   vaqcfg      if = 1 the concentration of this constituent in groundwater outflow varies monthly (card 274)
c   adfglnd     if = 1 atmosperic deposition on land
c   maddfglnd   if = 1 atmosperic dry deposition varies monthly on land (card 275)
c   mawdfglnd   if = 1 atmosperic wet deposition varies monthly on land (card 276)
c
c                  vqofg  qsowfg  vsqcfg  qifwfg  viqcfg  qagwfg  vaqcfg  adfglnd  maddfglnd  mawdfglnd
                   1          1          1          1          1          1          1          1          0          0
c---------------------------------------------------------------------------------------------------------
C260  qual-input
c   storage on surface and nonseasonal parameters
c
c   defid   parameter group id
c   dwqid   general quality id
c   deluid  landuse id
c   sqo     initial storage of QUALOF on surface (lb or #)
c   potfw   washoff potency factor if qsdfg > 0, card 250 (lb or #)/ton-sediment
c   potfs   scour potency pactor if qsdfg > 0, card 250 (lb or #)/ton-sediment
c   potfc   background concentration potency pactor if qsdfg > 0, card 250 (lb or #)/ton-sediment
c   acqop   accumulation rate of QUALOF on surface (lb or #)/acre/day
c   sqolim  maximum storage of QUALOF on surface (lb or #)/acre
```

```
c   wsqop   rate of surface runoff that removes 90% of stored QUALOF per hour (in/hr)
c   soqc    concentration of constituent in surface outflow (mg/l), (ug/l), or (#/100ml)
c   ioqc    concentration of constituent in interflow outflow (mg/l), (ug/l), or (#/100ml)
c   aoqc    concentration of constituent in groundwater outflow (mg/l), (ug/l), or (#/100ml)
c   addc    atmospheric dry deposition flux (lb/acre/day or #/acre/day)
c   awdc    atmospheric wet deposition concentration (mg/l), (ug/l), or (#/100ml)
c
c           the units of the following parameters are as follow:
c           if in card 250, the unit is mg/l or ug/l, then M is lbs
c           if in card 250, the unit is #/100ml, then M is #, in this case the unit for
c           soqc, ioqc and aoqc should be #/100ml instead of mg/l
c
c           defid deluid dwqid  sqo   potfw   potfs  potfc  acqop  sqolim  wsqop  soqc  ioqc  aoqc  addc  awdc
            1     12     0      0.000000  0.000000  0.000000  0.000000  0.000000  0.000001  1.000000  0.000000
            0.000000  0.000000  0.000000  0.000000
            1     12     1      0.000000  0.000000  0.000000  0.000000  0.000000  0.000001  1.000000  0.000000
            0.000000  0.000000  0.000000  0.000000
            1     12     2      0.000000  0.000000  0.000000  0.000000  0.000000  0.000001  1.000000  0.000000
            0.000000  0.000000  0.000000  0.000000
            1     12     3      0.000000  0.000000  0.000000  0.000000  0.000000  0.000001  1.000000  0.000000
            0.000000  0.000000  0.000000  0.000000
            1     12     4      0.000000  0.000000  0.000000  0.000000  0.000000  0.000001  1.000000  0.000000
            0.000000  0.000000  0.000000  0.000000
            1     12     5      0.000000  0.000000  0.000000  0.000000  0.000000  0.000001  1.000000  0.000000
            0.000000  0.000000  0.000000  0.000000
            1     12     6      0.000000  0.000000  0.000000  0.000000  0.000000  0.000001  1.000000  0.000000
            0.000000  0.000000  0.000000  0.000000
            1     12     7      0.000000  0.000000  0.000000  0.000000  0.000000  0.000001  1.000000  0.000000
            0.000000  0.000000  0.000000  0.000000
            1     12     8      0.000000  0.000000  0.000000  0.000000  0.000000  0.000001  1.000000  0.000000
            0.000000  0.000000  0.000000  0.000000
            1     12     9      0.000000  0.000000  0.000000  0.000000  0.000000  0.000001  1.000000  0.000000
            0.000000  0.000000  0.000000  0.000000
c------------------------------------------------------------------------------------------
c270 mon-accumulation rate (monaccum)
c   only required if vqofg =1 (see card 255)
c
c   defid  parameter group id
c   dwqid  general quality id
c   deluid landuse id
c   jan-dec accumulation rate at start of each month (lb/acre/day)
c           if in card 250, the unit is #/100ml, the above unit should be #/acre/day
c
c           defid dwqid  deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
            1     12     0      0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
            0.000000  0.000000  0.000000  0.000000
            1     12     1      62633928.570000  62633928.570000  62633928.570000  62633928.570000
            62633928.570000  62633928.570000  62633928.570000  62633928.570000  62633928.570000
            62633928.570000  62633928.570000  62633928.570000
            1     12     2      7992384245.960000  7992384245.960000  7992384245.960000  7992384245.960000
            7992384245.960000  7992384245.960000  7992384245.960000  7992384245.960000  7992384245.960000
            7992384245.960000  7992384245.960000  7992384245.960000
            1     12     3      7992384245.960000  7992384245.960000  7992384245.960000  7992384245.960000
            7992384245.960000  7992384245.960000  7992384245.960000  7992384245.960000  7992384245.960000
            7992384245.960000  7992384245.960000  7992384245.960000
            1     12     4      62633928.570000  62633928.570000  62633928.570000  62633928.570000
            62633928.570000  62633928.570000  62633928.570000  62633928.570000  62633928.570000
            62633928.570000  62633928.570000  62633928.570000
            1     12     5      199575.350000  199575.350000  199575.350000  199575.350000
            199575.350000  199575.350000  199575.350000  199575.350000  199575.350000
            199575.350000  199575.350000  199575.350000
            1     12     6      19957534.800000  19957534.800000  19957534.800000  19957534.800000
            19957534.800000  19957534.800000  19957534.800000  19957534.800000  19957534.800000
            19957534.800000  19957534.800000  19957534.800000
            1     12     7      13471335.990000  13471335.990000  13471335.990000  13471335.990000
            13471335.990000  13471335.990000  13471335.990000  13471335.990000  13471335.990000
            13471335.990000  13471335.990000  13471335.990000
            1     12     8      19957534.800000  19957534.800000  19957534.800000  19957534.800000
            19957534.800000  19957534.800000  19957534.800000  19957534.800000  19957534.800000
            19957534.800000  19957534.800000  19957534.800000
            1     12     9      13471335.990000  13471335.990000  13471335.990000  13471335.990000
            13471335.990000  13471335.990000  13471335.990000  13471335.990000  13471335.990000
            13471335.990000  13471335.990000  13471335.990000
c------------------------------------------------------------------------------------
c271 mon-storage limit of quality constituent (monsqolim)
c   only required if vqofg = 1 (see card 255)
c
c   defid  parameter group id
c   dwqid  general quality id
c   deluid landuse id
c   jan-dec maximum storage at start of each month (lb/acre)
c           if in card 250, the unit is #/100ml, the above unit should be #/acre
c
c           defid dwqid  deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
            1     12     0      0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
            0.000000  0.000000  0.000000  0.000000
            1     12     1      112741071.430000  112741071.430000  112741071.430000  112741071.430000
            112741071.430000  112741071.430000  112741071.430000  112741071.430000  112741071.430000
            112741071.430000  112741071.430000  112741071.430000
            1     12     2      14386291642.740000  14386291642.740000  14386291642.740000  14386291642.740000
            14386291642.740000  14386291642.740000  14386291642.740000  14386291642.740000  14386291642.740000
            14386291642.740000  14386291642.740000  14386291642.740000
```

```
            1       12      3       14386291642.740000      14386291642.740000      14386291642.740000      14386291642.740000
            14386291642.740000      14386291642.740000      14386291642.740000      14386291642.740000      14386291642.740000
            14386291642.740000      14386291642.740000      14386291642.740000
            1       12      4       112741071.430000        112741071.430000        112741071.430000        112741071.430000
            112741071.430000        112741071.430000        112741071.430000        112741071.430000        112741071.430000
            112741071.430000        112741071.430000        112741071.430000
            1       12      5       359235.630000   359235.630000   359235.630000   359235.630000
            359235.630000   359235.630000   359235.630000   359235.630000   359235.630000
            359235.630000   359235.630000   359235.630000
            1       12      6       35923562.640000 35923562.640000 35923562.640000 35923562.640000
            35923562.640000 35923562.640000 35923562.640000 35923562.640000 35923562.640000
            35923562.640000 35923562.640000 35923562.640000
            1       12      7       24248404.780000 24248404.780000 24248404.780000 24248404.780000
            24248404.780000 24248404.780000 24248404.780000 24248404.780000 24248404.780000
            24248404.780000 24248404.780000 24248404.780000
            1       12      8       35923562.640000 35923562.640000 35923562.640000 35923562.640000
            35923562.640000 35923562.640000 35923562.640000 35923562.640000 35923562.640000
            35923562.640000 35923562.640000 35923562.640000
            1       12      9       24248404.780000 24248404.780000 24248404.780000 24248404.780000
            24248404.780000 24248404.780000 24248404.780000 24248404.780000 24248404.780000
            24248404.780000 24248404.780000 24248404.780000
c-----------------------------------------------------------------------------------
c272 mon-surfaceflow concentration (monsuroconc)
c   only required if vsqcfg = 1 (see card 255)
c
c   defid   parameter group id
c   dwqid   general quality id
c   deluid  landuse id
c   jan-dec concentration of constituent in surface flow at start of each month (mg/l), (ug/l), or (#/100ml)
c           if in card 250, the unit is #/100ml, the above unit should be #/100ml
c
c           defid dwqid  deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
            1       12      0       0.000000        0.000000        0.000000        0.000000        0.000000        0.000000        0.000000        0.000000
            0.000000        0.000000        0.000000        0.000000
            1       12      1       626.340000      626.340000      626.340000      626.340000      626.340000      626.340000      626.340000      626.340000
            626.340000      626.340000      626.340000      626.340000
            1       12      2       79923.840000 79923.840000 79923.840000 79923.840000 79923.840000 79923.840000 79923.840000 79923.840000
            79923.840000 79923.840000 79923.840000 79923.840000
            1       12      3       79923.840000 79923.840000 79923.840000 79923.840000 79923.840000 79923.840000 79923.840000 79923.840000
            79923.840000 79923.840000 79923.840000 79923.840000
            1       12      4       626.340000      626.340000      626.340000      626.340000      626.340000      626.340000      626.340000      626.340000
            626.340000      626.340000      626.340000      626.340000
            1       12      5       2.000000        2.000000        2.000000        2.000000        2.000000        2.000000        2.000000        2.000000
            2.000000        2.000000        2.000000        2.000000
            1       12      6       199.580000      199.580000      199.580000      199.580000      199.580000      199.580000      199.580000      199.580000
            199.580000      199.580000      199.580000      199.580000
            1       12      7       134.710000      134.710000      134.710000      134.710000      134.710000      134.710000      134.710000      134.710000
            134.710000      134.710000      134.710000      134.710000
            1       12      8       199.580000      199.580000      199.580000      199.580000      199.580000      199.580000      199.580000      199.580000
            199.580000      199.580000      199.580000      199.580000
            1       12      9       134.710000      134.710000      134.710000      134.710000      134.710000      134.710000      134.710000      134.710000
            134.710000      134.710000      134.710000      134.710000
c-----------------------------------------------------------------------------------
c273 mon-interflow concentration (moninterconc)
c   only required if viqcfg = 1 (see card 255)
c
c   defid   parameter group id
c   dwqid   general quality id
c   deluid  landuse id
c   jan-dec concentration of constituent in interflow at start of each month (mg/l), (ug/l), or (#/100ml)
c           if in card 250, the unit is #/100ml, the above unit should be #/100ml
c
c           defid dwqid  deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
            1       12      0       0.000000        0.000000        0.000000        0.000000        0.000000        0.000000        0.000000        0.000000
            0.000000        0.000000        0.000000        0.000000
            1       12      1       4.180000        4.180000        4.180000        4.180000        4.180000        4.180000        4.180000        4.180000
            4.180000        4.180000        4.180000        4.180000
            1       12      2       532.830000      532.830000      532.830000      532.830000      532.830000      532.830000      532.830000      532.830000
            532.830000      532.830000      532.830000      532.830000
            1       12      3       532.830000      532.830000      532.830000      532.830000      532.830000      532.830000      532.830000      532.830000
            532.830000      532.830000      532.830000      532.830000
            1       12      4       4.180000        4.180000        4.180000        4.180000        4.180000        4.180000        4.180000        4.180000
            4.180000        4.180000        4.180000        4.180000
            1       12      5       0.010000        0.010000        0.010000        0.010000        0.010000        0.010000        0.010000        0.010000
            0.010000        0.010000        0.010000        0.010000
            1       12      6       1.330000        1.330000        1.330000        1.330000        1.330000        1.330000        1.330000        1.330000
            1.330000        1.330000        1.330000        1.330000
            1       12      7       0.900000        0.900000        0.900000        0.900000        0.900000        0.900000        0.900000        0.900000
            0.900000        0.900000        0.900000        0.900000
            1       12      8       1.330000        1.330000        1.330000        1.330000        1.330000        1.330000        1.330000        1.330000
            1.330000        1.330000        1.330000        1.330000
            1       12      9       0.900000        0.900000        0.900000        0.900000        0.900000        0.900000        0.900000        0.900000
            0.900000        0.900000        0.900000        0.900000
c-----------------------------------------------------------------------------------
c274 mon-groundwater concentration (mongrndconc)
c   only required if vaqcfg = 1 (see card 255)
c
c   defid   parameter group id
c   dwqid   general quality id
c   deluid  landuse id
c   jan-dec concentration of constituent in groundwater at start of each month (mg/l), (ug/l), or (#/100ml)
c           if in card 250, the unit is #/100ml, the above unit should be #/100ml
c
```

```
c       defid dwqid  deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
        1       12      0       0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        0.000000  0.000000  0.000000  0.000000
        1       12      1       0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        0.000000  0.000000  0.000000  0.000000
        1       12      2       0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        0.000000  0.000000  0.000000  0.000000
        1       12      3       0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        0.000000  0.000000  0.000000  0.000000
        1       12      4       0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        0.000000  0.000000  0.000000  0.000000
        1       12      5       0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        0.000000  0.000000  0.000000  0.000000
        1       12      6       0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        0.000000  0.000000  0.000000  0.000000
        1       12      7       0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        0.000000  0.000000  0.000000  0.000000
        1       12      8       0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        0.000000  0.000000  0.000000  0.000000
        1       12      9       0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
        0.000000  0.000000  0.000000  0.000000
c------------------------------------------------------------------------------------------
c275 mon-atmospheric dry deposition flux
c  only required if maddfglnd = 1 (see card 255)
c
c  defid   parameter group id
c  dwqid   general quality id
c  deluid  landuse id
c  jan-dec flux of constituent in dry deposition at start of each month (lb/acre/day or #/acre/day)
c
c       defid dwqid  deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c------------------------------------------------------------------------------------------
c276 mon-atmospheric wet deposition concentration
c  only required if mawdfglnd = 1 (see card 255)
c
c  defid   parameter group id
c  dwqid   general quality id
c  deluid  landuse id
c  jan-dec concentration of constituent in atmospheric wet deposition at start of each month (mg/l), (ug/l), or (#/100ml)
c
c       defid dwqid  deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c------------------------------------------------------------------------------------------
C280 stream water quality control
c
c  adfgrch    if = 1 atmosperic deposition on reach (0 for no atmospheric deposition)
c  maddfgrch  if = 1 atmosperic dry deposition varies monthly on reach (card 282)
c  mawdfgrch  if = 1 atmosperic wet deposition varies monthly on reach (card 283)
c
c       adfgrch  maddfgrch  mawdfgrch
        0        0          0
c---------------------------------------------------------------------------------------------------------
c281 general quality constituent control
c
c  rgid     stream parameter group id
c  dwqid    general quality id
c  qsdfg    if = 0 no sediment associated qual
c                  if = 1 sediment associated in stream, adsorption/desorption of qual is simulated
c  iniCond  initial instream concentration at start of simulation by group (mg/l), (ug/l), or (#/100ml)
c  decay    general first-order instream loss rate of qual by reach group (1/day)
c  tcdecay  temperature correction coefficient for first-order decay of qual (min=1, max=2)
c  addc     atmospheric dry deposition flux (lb/acre/day or #/acre/day)
c  awdc     atmospheric wet deposition concentration (mg/l), (ug/l), or (#/100ml)
c  potber   scour potency pactor for stream bank erosion if qsdfg > 0, (lb or #)/ton-sediment
c
c       rgid  dwqid  qsdfg  iniCond  decay  tcdecay  addc  awdc  potber
        1       12      0       0.000000  0.700000  1.000000  0.000000  0.000000  0.000000
c---------------------------------------------------------------------------------------------------------
c282 mon-atmospheric dry deposition flux
c  only required if maddfgrch = 1 (see card 280)
c
c  rgid    reach group id
c  dwqid   general quality id
c  jan-dec flux of constituent in dry deposition at start of each month (lb/acre/day or #/acre/day)
c
c       rgid dwqid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c------------------------------------------------------------------------------------------
c283 mon-atmospheric wet deposition concentration
c  only required if mawdfgrch = 1 (see card 280)
c
c  rgid    reach group id
c  dwqid   general quality id
c  jan-dec concentration of constituent in atmospheric wet deposition at start of each month (mg/l), (ug/l), or (#/100ml)
c
c       defid dwqid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c------------------------------------------------------------------------------------------
c285 parameters for decay of contaminant adsorbed to sediment
c  only required if qsdfg > 0 (see card 281)
c
c  rgid      reach group id
c  dwqid     general quality id
c  addcpm1   decay rate for qual adsorbed to suspended sediment (/day)
c  addcpm2   temperature correction coefficient for decay of qual on suspended sediment (range from 1.0 to 2.0)
c  addcpm3   decay rate for qual adsorbed to bed sediment (/day)
```

```
c   addcpm4   temperature correction coefficient for decay of qual on bed sediment (range from 1.0 to 2.0)
c
c  rgid  dwqid   addcpm1   addcpm2   addcpm3   addcpm4
c-------------------------------------------------------------------------------------------
c286 adsorption coefficients of qual
c   only required if qsdfg > 0 (see card 281)
c
c   rgid      reach group id
c   dwqid     general quality id
c   adpm1     distribution coefficients for qual with suspended sand (l/mg)
c   adpm2     distribution coefficients for qual with suspended silt (l/mg)
c   adpm3     distribution coefficients for qual with suspended clay (l/mg)
c   adpm4     distribution coefficients for qual with bed sand (l/mg)
c   adpm5     distribution coefficients for qual with bed silt (l/mg)
c   adpm6     distribution coefficients for qual with bed clay (l/mg)
c
c  rgid  dwqid   adpm1   adpm2   adpm3   adpm4   adpm5   adpm6
c-------------------------------------------------------------------------------------------
c287 adsorption/desorption rate parameters
c   only required if qsdfg > 0 (see card 281)
c
c   rgid      reach group id
c   dwqid     general quality id
c   adpm1     transfer rates between adsorbed and desorbed states of qual with suspended sand (/day)
c   adpm2     transfer rates between adsorbed and desorbed states of qual with suspended silt (/day)
c   adpm3     transfer rates between adsorbed and desorbed states of qual with suspended clay (/day)
c   adpm4     transfer rates between adsorbed and desorbed states of qual with bed sand (/day)
c   adpm5     transfer rates between adsorbed and desorbed states of qual with bed silt (/day)
c   adpm6     transfer rates between adsorbed and desorbed states of qual with bed clay (/day)
c
c  rgid  dwqid   adpm1   adpm2   adpm3   adpm4   adpm5   adpm6
c-------------------------------------------------------------------------------------------
c288 adsorption/desorption temperature correction parameters
c   only required if qsdfg > 0 (see card 281)
c
c   rgid      reach group id
c   dwqid     general quality id
c   adpm1     temperature correction coefficients for adsorption/desorption on suspended sand (range from 1.0 to 2.0)
c   adpm2     temperature correction coefficients for adsorption/desorption on suspended silt (range from 1.0 to 2.0)
c   adpm3     temperature correction coefficients for adsorption/desorption on suspended clay (range from 1.0 to 2.0)
c   adpm4     temperature correction coefficients for adsorption/desorption on bed sand (range from 1.0 to 2.0)
c   adpm5     temperature correction coefficients for adsorption/desorption on bed silt (range from 1.0 to 2.0)
c   adpm6     temperature correction coefficients for adsorption/desorption on bed clay (range from 1.0 to 2.0)
c
c  rgid  dwqid   adpm1   adpm2   adpm3   adpm4   adpm5   adpm6
c-------------------------------------------------------------------------------------------
c289 initial concentrations on sediment
c   only required if qsdfg > 0 (see card 281)
c
c   rgid      reach group id
c   dwqid     general quality id
c   sqal1     initial concentrations of qual on suspended sand (concu/mg)
c   sqal2     initial concentrations of qual on suspended silt (concu/mg)
c   sqal3     initial concentrations of qual on suspended clay (concu/mg)
c   sqal4     initial concentrations of qual on bed sand (concu/mg)
c   sqal5     initial concentrations of qual on bed silt (concu/mg)
c   sqal6     initial concentrations of qual on bed clay (concu/mg)
c
c  rgid  dwqid   sqal1   sqal2   sqal3   sqal4   sqal5   sqal6
c-------------------------------------------------------------------------------------------
C310 soil-data
c   only required if nitrfg = 1 or phosfg = 1 (see card 0)
c   soil layer depths, bulk densities, and wilting point
c
c   defid     parameter group id
c   deluid    landuse id
c   dep_sl    depth of surface layer (in)
c   dep_ul    depth of upper layer (in)
c   dep_ll    depth of lower layer (in)
c   dep_gwl   depth of groundwater layer (in)
c   bd_sl     bulkdensity of surface layer (lb/ft3)
c   bd_ul     bulkdensity of upper layer (lb/ft3)
c   bd_ll     bulkdensity of lower layer (lb/ft3)
c   bd_gwl    bulkdensity of groundwater layer (lb/ft3)
c   wp_sl     wiltingpoint of surface layer (fraction)
c   wp_ul     wiltingpoint of upper layer (fraction)
c   wp_ll     wiltingpoint of lower layer (fraction)
c   wp_gwl    wiltingpoint of groundwater layer (fraction)
c
c  defid deluid  depth_sl   depth_ul   depth_ll   depth_gwl    bd_sl    bd_ul    bd_ll    bd_gwl    wp_sl    wp_ul    wp_ll    wp_gwl
c-------------------------------------------------------------------------------------------
C311  mstlay-parm
c   factors used to adjust solute leaching rates
c
c   defid   parameter group id
c   deluid  landuse id
c   slmpf   factor used to adjust solute percolation rate from the surface layer storage to the upper layer principal storage
c   ulpf    factor used to adjust solute percolation rate from the upper layer principal storage to the lower layer storage
c   llpf    factor used to adjust solute percolation rate from the lower layer storage to the active and inactive groundwater
c
c  defid   deluid  slmpf     ulpf     llpf
c-------------------------------------------------------------------------------------------
C312  mst-topstor
```

```
c   initial moisture storage in each topsoil layer
c
c   defid   parameter group id
c   deluid  landuse id
c   smstm   initial moisture content in the surface storage (lb/ac)
c   umstm   initial moisture content in the upper principal storage (lb/ac)
c   imstm   initial moisture content in the upper transitory (interflow) storages (lb/ac)
c
c  defid   deluid  smstm     umstm     imstm
c------------------------------------------------------------------------------------------
C313  mst-topflx
c   initial fractional fluxes in each topsoil layer
c
c   defid   parameter group id
c   deluid  landuse id
c   fso     initial values of the fractional fluxes of soluble chemicals through the topsoil layers of a PLS (/ivl)
c   fsp     initial values of the fractional fluxes of soluble chemicals through the topsoil layers of a PLS (/ivl)
c   fii     initial values of the fractional fluxes of soluble chemicals through the topsoil layers of a PLS (/ivl)
c   fup     initial values of the fractional fluxes of soluble chemicals through the topsoil layers of a PLS (/ivl)
c   fio     initial values of the fractional fluxes of soluble chemicals through the topsoil layers of a PLS (/ivl)
c
c  defid   deluid  fso     fsp     fii    fup     fio
c------------------------------------------------------------------------------------------
C314  mst-substor
c   initial moisture storage in each topsoil layer
c
c   defid   parameter group id
c   deluid  landuse id
c   lmstm   initial moisture storages in the lower layer (lb/ac)
c   amstm   initial moisture content in the active groundwater layers (lb/ac)
c
c  defid   deluid  lmstm     amstm
c------------------------------------------------------------------------------------------
C315  mst-subflx
c   initial fractional fluxes in each topsoil layer
c
c   defid   parameter group id
c   deluid  landuse id
c   flp     initial fractional fluxes of soluble chemicals through the subsoil layers (/ivl)
c   fldp    initial fractional fluxes of soluble chemicals through the subsoil layers (/ivl)
c   fao     initial fractional fluxes of soluble chemicals through the subsoil layers (/ivl)
c
c  defid   deluid  flp     fldp     fao
c------------------------------------------------------------------------------------------
C341 initial storage of nitrogen in the surface layer
c   only required if nitrfg = 1 (see card 0)
c
c   defid   parameter group id
c   deluid  landuse id
c   lorgn   initial storage of labile organic nitrogen (lb/acre)
c   amad    initial storage of adsorbed ammonium (lb/acre)
c   amsu    initial storage of solution ammonium (lb/acre)
c   no3     initial storage of nitrate (lb/acre)
c   pltn    initial storage of nitrogen stored in plants (lb/acre)
c   rorgn   initial storage of refractory organic nitrogen (lb/acre)
c
c  defid  deluid lorgn   amad    amsu    no3    pltn   rorgn
c------------------------------------------------------------------------------------------
C342 initial storage of nitrogen in the upper layer
c   only required if nitrfg = 1 (see card 0)
c
c   defid   parameter group id
c   deluid  landuse id
c   lorgn   initial storage of labile organic nitrogen (lb/acre)
c   amad    initial storage of adsorbed ammonium (lb/acre)
c   amsu    initial storage of solution ammonium (lb/acre)
c   no3     initial storage of nitrate (lb/acre)
c   pltn    initial storage of nitrogen stored in plants (lb/acre)
c   rorgn   initial storage of refractory organic nitrogen (lb/acre)
c
c  defid  deluid lorgn   amad    amsu    no3    pltn   rorgn
c------------------------------------------------------------------------------------------
C343 initial storage of nitrogen in the transitory layer
c   only required if nitrfg = 1 (see card 0)
c
c   defid   parameter group id
c   deluid  landuse id
c   iamsu   initial storage of solution ammonium (lb/acre)
c   ino3    initial storage of nitrate (lb/acre)
c   islon   initial storage of solution labile organic nitrogen  (lb/acre)
c   isron   initial storage of solution refractory organic nitrogen (lb/acre)
c   agpltn  initial storage of above-ground plant nitrogen (lb/acre)
c   littrn  initial storage of litter nitrogen (lb/acre)
c
c  defid  deluid iamsu   ino3    islon    isron    agpltn   littrn
c------------------------------------------------------------------------------------------
C344 initial storage of nitrogen in the lower layer
c   only required if nitrfg = 1 (see card 0)
c
c   defid   parameter group id
c   deluid  landuse id
c   lorgn   initial storage of labile organic nitrogen (lb/acre)
c   amad    initial storage of adsorbed ammonium (lb/acre)
```

```
c    amsu    initial storage of solution ammonium (lb/acre)
c    no3     initial storage of nitrate (lb/acre)
c    pltn    initial storage of nitrogen stored in plants (lb/acre)
c    rorgn   initial storage of refractory organic nitrogen (lb/acre)
c
c  defid  deluid lorgn   amad    amsu    no3    pltn   rorgn
c-------------------------------------------------------------------------------------------
C345 initial storage of nitrogen in the groundwater layer
c    only required if nitrfg = 1 (see card 0)
c
c    defid   parameter group id
c    deluid  landuse id
c    lorgn   initial storage of labile organic nitrogen (lb/acre)
c    amad    initial storage of adsorbed ammonium (lb/acre)
c    amsu    initial storage of solution ammonium (lb/acre)
c    no3     initial storage of nitrate (lb/acre)
c    pltn    initial storage of nitrogen stored in plants (lb/acre)
c    rorgn   initial storage of refractory organic nitrogen (lb/acre)
c
c  defid  deluid lorgn   amad    amsu    no3    pltn   rorgn
c-------------------------------------------------------------------------------------------
C361 initial phosphorus storage in the surface layer
c    only required if phosfg = 1 (see card 0)
c
c    defid   parameter group id
c    deluid  landuse id
c    orgp    initial storage of organic phosphorus (lb/acre)
c    p4ad    initial storage of adsorbed phosphate (lb/acre)
c    p4su    initial storage of solution phosphate (lb/acre)
c    pltp    initial storage of phosphorus stored in plants (lb/acre)
c
c  defid  deluid orgp   p4ad    p4su    pltp
c-------------------------------------------------------------------------------------------
C362 initial phosphorus storage in the upper layer
c    only required if phosfg = 1 (see card 0)
c
c    defid   parameter group id
c    deluid  landuse id
c    orgp    initial storage of organic phosphorus (lb/acre)
c    p4ad    initial storage of adsorbed phosphate (lb/acre)
c    p4su    initial storage of solution phosphate (lb/acre)
c    pltp    initial storage of phosphorus stored in plants (lb/acre)
c
c  defid  deluid orgp   p4ad    p4su    pltp
c-------------------------------------------------------------------------------------------
C363 initial phosphorus storage in the transitory layer
c    only required if phosfg = 1 (see card 0)
c
c    defid   parameter group id
c    deluid  landuse id
c    ip4su   initial storage of solution phosphate (lb/acre)
c
c  defid  deluid ip4su
c-------------------------------------------------------------------------------------------
C364 initial phosphorus storage in the lower layer
c    only required if phosfg = 1 (see card 0)
c
c    defid   parameter group id
c    deluid  landuse id
c    orgp    initial storage of organic phosphorus (lb/acre)
c    p4ad    initial storage of adsorbed phosphate (lb/acre)
c    p4su    initial storage of solution phosphate (lb/acre)
c    pltp    initial storage of phosphorus stored in plants (lb/acre)
c
c  defid  deluid orgp   p4ad    p4su    pltp
c-------------------------------------------------------------------------------------------
C365 initial phosphorus storage in the groundwater layer
c    only required if phosfg = 1 (see card 0)
c
c    defid   parameter group id
c    deluid  landuse id
c    orgp    initial storage of organic phosphorus (lb/acre)
c    p4ad    initial storage of adsorbed phosphate (lb/acre)
c    p4su    initial storage of solution phosphate (lb/acre)
c    pltp    initial storage of phosphorus stored in plants (lb/acre)
c
c  defid  deluid orgp   p4ad    p4su    pltp
c-------------------------------------------------------------------------------------------
c390 atmosphere to stream mapping (read if mdasfg = 1 and adfgrch = 1)
c
c    rgid    reach parameter group id
c    dwqid   general quality id
c    OrgN    organic nitrogen fraction in pqual
c    NH4S    ammonium solution fraction in pqual
c    NH4E    ammonium exchange fraction in  pqual
c    NO3     nitrate fraction in pqual
c    NO2     nitrite fraction in pqual
c    SO4     sulfate fraction in pqual
c
c                  defid dwqid   OrgN   NH4S   NH4E   NO3   NO2   SO4
c-------------------------------------------------------------------------------------------
c391 land surface to land sub-surface mapping (read if mdasfg =1)
c
```

```
c   defid   parameter group id
c   dwqid   general quality id
c   deluid  landuse id
c   OrgN    organic nitrogen fraction in pqual
c   NH4S    ammonium solution fraction in pqual
c   NH4E    ammonium exchange fraction in  pqual
c   NO3     nitrate fraction in pqual
c   NO2     nitrite fraction in pqual
c   SO4     sulfate fraction in pqual
c
c                   defid dwqid   deluid   OrgN   NH4S   NH4E   NO3   NO2   SO4
c-------------------------------------------------------------------------------------------
c392 land to stream mapping (read if mdasfg=1)
c
c   rgid    stream parameters group id
c   dwqid   general quality id
c   lutype  landuse type flow id (1 = impervious surfaceflow,
c           2 = pervious surfaceflow, 3 = pervious interflow, 4 = pervious groundflow)
c   PFe     Particulate iron fraction in pqual
c   DFe     Dissolved iron fraction in pqual
c   PAl     Particulate aluminum fraction in pqual
c   DAl     Dissolved aluminum fraction in pqual
c   CO3     CO3(2-) fraction in pqual
c
c                   rgid   dwqid    lutype   PFe   DFe   PAl   DAl   CO3
c-------------------------------------------------------------------------------------------
C393 calibration parameters for the surfcae layer
c   only required if mdasfg = 1 (see card 0)
c
c   defid   parameter group id
c   deluid  landuse id
c   crfg    chemical reaction flag
c           0  = no chemical reaction
c           1  = only nitrogen transformation
c           2  = full chemical reactions
c   kes     nitrogen transformation (NH4E to NH4S) rate (per day)
c   kse     nitrogen transformation (NH4S to NH4E) rate (per day)
c   k1      nitrogen transformation (NH4S to NO2) rate (per day)
c   k2      nitrogen transformation (NO2 to NO3) rate (per day)
c   k3      nitrogen transformation (plant uptake NO3) rate (per day)
c   k4      nitrogen transformation (plant uptake NH4S) rate (per day)
c   k6      nitrogen transformation (OrgN to NH4S) rate (per day)
c   kk6     nitrogen transformation (NH4S to OrgN) rate (per day)
c   kk8     nitrogen transformation (NO3 to OrgN) rate (per day)
c   K_Al    Aluminum solubility constant
c   Ks      selectivity coefficient
c   CaX     base saturation percentage (fraction)
c   THETA   temperature correction coefficient for nitrogen transformation for surface layer (range from 1.0 to 2.0)
c
c  defid deluid  crfg  kes   kse   k1   k2   k3   k4   k6   kk6   kk8  K_Al  Ks  CaX   theta
c-------------------------------------------------------------------------------------------
C394 calibration parameters for the upper layer
c   only required if mdasfg = 1 (see card 0)
c
c   defid   parameter group id
c   deluid  landuse id
c   crfg    chemical reaction flag
c           0  = no chemical reaction
c           1  = only nitrogen transformation and sulfate adsorption
c           2  = full chemical reactions
c   kes     nitrogen transformation (NH4E to NH4S) rate (per day)
c   kse     nitrogen transformation (NH4S to NH4E) rate (per day)
c   k1      nitrogen transformation (NH4S to NO2) rate (per day)
c   k2      nitrogen transformation (NO2 to NO3) rate (per day)
c   k3      nitrogen transformation (plant uptake NO3) rate (per day)
c   k4      nitrogen transformation (plant uptake NH4S) rate (per day)
c   k6      nitrogen transformation (OrgN to NH4S) rate (per day)
c   kk6     nitrogen transformation (NH4S to OrgN) rate (per day)
c   kk8     nitrogen transformation (NO3 to OrgN) rate (per day)
c   Km      maximum adsorbable amount of sulfate(mol/kg)
c   OneH    value to use to determine a half saturation
c   DESORP  desorption rate (per day)
c   K_Al    Aluminum solubility constant (log K_Al)
c   Ks      selectivity coefficient (Log Ks)
c   CaX     base saturation percentage (fraction)
c   PeakMon growing season peak month
c   THETA   temperature correction coefficient for nitrogen transformation for upper layer (range from 1.0 to 2.0)
c
c  defid deluid  crfg  kes   kse   k1   k2   k3   k4   k6   kk6   kk8   Km   OneH   DESORP  K_Al  Ks  CaX  PeakMon  theta
c-------------------------------------------------------------------------------------------
C395 calibration parameters for the lower layer
c   only required if mdasfg = 1 (see card 0)
c
c   defid   parameter group id
c   deluid  landuse id
c   crfg    chemical reaction flag
c           0  = no chemical reaction
c           1  = only nitrogen transformation and sulfate adsorption
c           2  = full chemical reactions
c   kes     nitrogen transformation (NH4E to NH4S) rate (per day)
c   kse     nitrogen transformation (NH4S to NH4E) rate (per day)
c   k1      nitrogen transformation (NH4S to NO2) rate (per day)
c   k2      nitrogen transformation (NO2 to NO3) rate (per day)
```

```
c   k3      nitrogen transformation (plant uptake NO3) rate (per day)
c   k4      nitrogen transformation (plant uptake NH4S) rate (per day)
c   k6      nitrogen transformation (OrgN to NH4S) rate (per day)
c   kk6     nitrogen transformation (NH4S to OrgN) rate (per day)
c   kk8     nitrogen transformation (NO3 to OrgN) rate (per day)
c   Km      maximum adsorbable amount of sulfate(mol/kg)
c   OneH    value to use to determine a half saturation
c   DESORP  desorption rate (per day)
c   K_Al    Aluminum solubility constant (Log K_Al)
c   Ks      selectivity coefficient (Log Ks)
c   CaX     base saturation percentage (fraction)
c   PeakMon growing season peak month
c   THETA   temperature correction coefficient for nitrogen transformation for lower layer (range from 1.0 to 2.0)
c
c  defid deluid  crfg  kes   kse   k1   k2   k3   k4   k6   kk6   kk8   Km   OneH   DESORP  K_Al  Ks  CaX  PeakMon  theta
c-------------------------------------------------------------------------------------------
C396 calibration parameters for the reach
c   only required if mdasfg = 1 (see card 0)
c
c   rgid    reach group id
c           0  = no chemical reaction
c           1  = only nitrogen transformation and sulfate adsorption
c           2  = full chemical reactions
c   k1      nitrogen transformation (NH4S to NO2) rate (per day)
c   k2      nitrogen transformation (NO2 to NO3) rate (per day)
c   k3      nitrogen transformation (NO3 to ?) rate (per day)
c   k6      nitrogen transformation (OrgN to NH4S) rate (per day)
c   kk1     sulfate transformation rate (per day)
c   FEK     metal (iron) dissolution constants
c   AlK     metal (alluminium) dissolution constants
c   PCO     co2 value (per day)
c   FR_3    precipitation rate for Ca(2+) (per day)
c   FR_4    precipitation rate for CO3(2-) (per day)
c   FR_5    precipitation rate for dissolved iron (per day)
c   FRP_5   precipitation rate for particulate iron (per day)
c   FR_8    precipitation rate for dissolved alluminium (per day)
c   FRP_8   precipitation rate for particulate alluminium (per day)
c   FR_9    precipitation rate for Org (per day)
c   THETA   temperature correction coefficient for nitrogen transformation for the stream (range from 1.0 to 2.0)
c
c  rgid   crfg  k1   k2   k3   k6   kk1  FEK   AlK  PCO   FR_3   FR_4   FR_5   FRP_5   FR_8   FRP_8   FR_9  theta
c-------------------------------------------------------------------------------------------
C397 initial storage in the top layer
c   only required if mdasfg = 1 (see card 0)
c
c   defid   parameter group id
c   deluid  landuse id
c   OrgN_S  initial storage of organic nitrogen in the surface layer (lb/acre)
c   OrgN_U  initial storage of organic nitrogen in the upper layer (lb/acre)
c   OrgN_I  initial storage of organic nitrogen in the transitory layer (lb/acre)
c   NH4S_S  initial storage of solution ammonium in the surface layer (lb/acre)
c   NH4S_U  initial storage of solution ammonium in the upper layer (lb/acre)
c   NH4S_I  initial storage of solution ammonium in the transitory layer (lb/acre)
c   NH4E_S  initial storage of exchange ammonium in the surface layer (lb/acre)
c   NH4E_U  initial storage of exchange ammonium in the upper layer (lb/acre)
c   NH4E_I  initial storage of exchange ammonium in the transitory layer (lb/acre)
c   NO3_S   initial storage of nitrate in the surface layer (lb/acre)
c   NO3_U   initial storage of nitrate in the upper layer (lb/acre)
c   NO3_I   initial storage of nitrate in the transitory layer (lb/acre)
c   NO2_S   initial storage of nitrite in the surface layer (lb/acre)
c   NO2_U   initial storage of nitrite in the upper layer (lb/acre)
c   NO2_I   initial storage of nitrite in the transitory layer (lb/acre)
c   SO4_S   initial storage of sulfate in the surface layer (lb/acre)
c   SO4_U   initial storage of sulfate in the upper layer (lb/acre)
c   SO4_I   initial storage of sulfate in the transitory layer (lb/acre)
c
c  defid  deluid OrgN_S  OrgN_U  OrgN_I  NH4S_S   NH4S_U   NH4S_I   NH4E_S   NH4E_U   NH4E_I   NO3_S   NO3_U   NO3_I   NO2_S  NO2_U  NO2_I
SO4_S   SO4_U   SO4_I
c-------------------------------------------------------------------------------------------
C398 initial storage in the sub layer
c   only required if mdasfg = 1 (see card 0)
c
c   defid   parameter group id
c   deluid  landuse id
c   OrgN_L  initial storage of organic nitrogen in the lower layer (lb/acre)
c   OrgN_A  initial storage of organic nitrogen in the groundwater layer (lb/acre)
c   NH4S_L  initial storage of solution ammonium in the lower layer (lb/acre)
c   NH4S_A  initial storage of solution ammonium in the groundwater layer (lb/acre)
c   NH4E_L  initial storage of exchange ammonium in the lower layer (lb/acre)
c   NH4E_A  initial storage of exchange ammonium in the groundwater layer (lb/acre)
c   NO3_L   initial storage of nitrate in the lower layer (lb/acre)
c   NO3_A   initial storage of nitrate in the groundwater layer (lb/acre)
c   NO2_L   initial storage of nitrite in the lower layer (lb/acre)
c   NO2_A   initial storage of nitrite in the groundwater layer (lb/acre)
c   SO4_L   initial storage of sulfate in the lower layer (lb/acre)
c   SO4_A   initial storage of sulfate in the groundwater layer (lb/acre)
c
c  defid  deluid OrgN_L   OrgN_A   NH4S_L    NH4S_A    NH4E_L    NH4E_A    NO3_L    NO3_A    NO2_L   NO2_A   SO4_L   SO4_A
c-------------------------------------------------------------------------------------------
C399 initial concentration in the stream
c   only required if mdasfg = 1 (see card 0)
c
c   defid parameter group id
```

```
c   OrgN  initial conc of organic nitrogen in the stream (mg/l)
c   H2O   initial conc of H2O in the stream (mg/l)
c   H     initial conc of H(+) in the stream (mg/l)
c   Ca    initial conc of Ca(2+) in the stream (mg/l)
c   CO3   initial conc of CO3(2-) in the stream (mg/l)
c   Fe    initial conc of Fe(3+) in the stream (mg/l)
c   NO3   initial conc of nitrate in the stream (mg/l)
c   NH4   initial conc of ammonium in the stream (mg/l)
c   Al    initial conc of aluminum in the stream (mg/l)
c   Org   initial conc of Torg in the stream (mg/l)
c   SO4   initial conc of sulfate in the stream (mg/l)
c   PF    initial conc of ParF in the stream (mg/l)
c   PA    initial conc of ParA in the stream (mg/l)
c   NO2   initial conc of nitrite in the stream (mg/l)
c
c  defid  OrgN  H2O  H  Ca  CO3  Fe  NO3  NH4  Al  Org  SO4  PF  PA  NO2
c------------------------------------------------------------------------------------------
c400 general channel information
c
c   admod   advection method (1 for dynamic mixing same as in HSPF and 2 for static mixing)
c   kc      crop factor associated with PEVT (used to back-calculate EVAP; EVAP = PEVT/kc)
c   sedber  stream bank erosion sediment (1 for on and 0 for off)
c   vconfg  a value of 1 for vconfg means that F(vol) (volume-dependent) outflow demand components are multiplied by a factor which is allowed to vary through the year.
c           These monthly adjustment factors are input in Table-type MON-CONVF in this section (card 401)
c
c               admod   kc   sedber   vconfg
                1               0.000000     0              0
c------------------------------------------------------------------------------------------
c401 monthly F(vol) adjustment factors
c   only required if vconfg = 1 (see card 400)
c
c   rgid     stream parameter group id
c   jan-dec  F(vol) adjustment factors at the start of each month
c
c rgid          jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c------------------------------------------------------------------------------------------
c405 channel routing network
c
c   rchid   reach id (same as subbasin id)
c   control output control switch for the corresponding reach
c           0 = will not write general output
c           1 = will write general output
c   NumOutlets number of downstream outlets
c   DSn     downstream outlets  DS1   Ds2  .... DSn
c
c   rchid   control   NumOutlets   DS1  DS2  ....... DSn
                401         1           1           -1
                402         1           1           401
                403         1           1           402
                404         1           1           403
                405         1           1           404
                406         1           1           405
                407         1           1           405
                408         1           1           405
                409         1           1           405
                410         1           1           405
                411         1           1           404
                412         1           1           404
                413         1           1           404
                414         1           1           403
                415         1           1           403
                416         1           1           403
                417         1           1           -1
                418         1           1           -1
                419         1           1           -1
c------------------------------------------------------------------------------------------
c410 reach geometry information
c
c   rchid   reach/lake id (same as subbasin id)
c   rgid    reach/lake group id
c   trgid   threshold reach/lake group id
c   lkfg    reach/lake flag (0 for reach otherwise lake)
c           lake flag = 1 (rectangular weir for internal option)
c           lake flag = 2 (triangular weir for internal option)
c           lake flag = 11 (BMP with rectangular weir for internal option)
c           lake flag = 12 (BMP with triangular weir for internal option)
c   idepth  reach/lake initial water depth (feet)
c   length  reach/lake length (miles)
c   depth   reach/lake bank full depth (feet)
c   width   reach/lake bankfull width (feet)
c   slope   reach longitudinal slope/lake infiltration rate (in/hr)
c   Mann    reach Manning's roughness coefficient/lake weir width (ft)
c   r1      reach ratio of bottom width to bank full width (bottom width = r1 * width)/lake orifice height (ft)
c   r2      reach side slope of flood plane/lake orifice diameter (ft)
c   w1      reach flood plane width factor (width of flood plane =w1*Width)/lake median particle size diameter, db50 (ft)
c   crat    ratio of maximum velocity to mean velocity in the RCHRES cross-section under typical flow conditions (greater than or equal to 1)
c   ks              the weighting factor for hydraulic routing (calibration)
c
c           rchid      rgid  trgid  lkfg      idepth      length   depth  width   slope    mann   r1    r2    w1   crat  ks
            401        1          1         0           5.577360    1.833734    5.577360    92.256096   0.001220    0.020000    0.200000
            0.500000   1.500000   1.500000  0.000000
            402        1          1         0           5.554394    1.583802    5.554394    91.780380   0.002080    0.020000    0.200000
            0.500000   1.500000   1.500000  0.000000
```

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            403      1         1         0         5.472374   8.094910   5.472374   89.884078   0.001670   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            404      1         1         0         5.016343   6.119326   5.016343   79.510188   0.002680   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            405      1         1         0         4.543908   6.302866   4.543908   69.162545   0.002390   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            406      1         1         0         3.392347   13.013975  3.392347   45.806530   0.019920   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            407      1         1         0         2.933035   6.980650   2.933035   37.292854   0.019010   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            408      1         1         0         2.732906   11.841498  2.732906   33.772555   0.009250   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            409      1         1         0         2.289998   4.993137   2.289998   26.298893   0.013260   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            410      1         1         0         2.217821   4.635320   2.217821   25.176859   0.018960   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            411      1         1         0         1.994726   4.457398   1.994726   21.682807   0.020870   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            412      1         1         0         2.664010   6.365792   2.664010   32.594748   0.017300   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            413      1         1         0         2.283437   4.719379   2.283437   26.190626   0.013070   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            414      1         1         0         2.168609   5.981917   2.168609   24.389467   0.019330   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            415      1         1         0         2.345772   4.879601   2.345772   27.237202   0.012070   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            416      1         1         0         2.713222   9.036441   2.713222   33.444475   0.016190   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            417      1         1         0         2.480285   2.273497   2.480285   29.425495   0.033190   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            418      1         1         0         1.223738   0.333677   1.223738   10.866010   0.002210   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
            419      1         1         0         1.246704   0.210149   1.246704   11.177686   0.014680   0.020000   0.200000
            0.500000 1.500000  1.500000  0.000000
c------------------------------------------------------------------------------------------
c413 reach cross-section information
c           rchid  x1     y1        x2        y2...
c------------------------------------------------------------------------------------------
c415 reach discharge-volume relationship
c
c  rchid   reach id
c  depth   water depth (feet)
c  area    water surface area (acres)
c  vol     water volume (ac-ft)
c  disch(1, 2, 3, ....noutflows)  outflows (cfs)
c
c           rchid  depth   area   vol   disch1   disch2   ....... dischN
c------------------------------------------------------------------------------------------
c420 general point source information
c
c  nPtSource   number of individual point sources
c  nPtQuals    number of point source quals
c
c nPtSource  nPtQuals
            23       1
c------------------------------------------------------------------------------------------
c425 point source
c  Qualindex  point source qual index
c  Qualname   point source qual name
c  Qualid        point source qual id
c  sqalfr        point source sediment associated qual fraction (0-1)
c
c Qualindex  Qualname  qualid
            1          FECAL     12        0.000000
c------------------------------------------------------------------------------------------
c430 point source withdrawal
c  subbasin  point source reach id
c  permit    point source permit
c  pipe      point source pipe
c  wd_target point source withdrawal target reach id
c
c subbasin  permit  pipe   wd_target
c------------------------------------------------------------------------------------------
c440 sediment parameters controls
c
c  crvfg   if crvfg is 1, erosion-related cover may vary throughout the year.
c          values are supplied in Table-type MON-COVER (card 453)
c  vsivfg  if vsivfg is 1, the rate of net vertical sediment input may vary throughout the year.
c          if vsivfg is 2, the vertical sediment input is added to the detached sediment storage only on days when no rainfall occurred during the previous day.
c          values are supplied in Table-type MON-NVSI (card 454)
c
c           crvfg    vsivfg
            0        0
c------------------------------------------------------------------------------------------
c450 sediment parameter group 1      (read if sedfg =1)
c
c  defid   parameter group id
c  deluid  landuse id
c  smpf    supporting management practice factor
c  krer    coefficient in the soil detachment equation
c  jrer    exponent in the soil detachment equation
c  affix   fraction by which detached sediment storage decreases each day as a result of
c          soil compaction. (/day)
```

```
c   cover   fraction of land surface which is shielded from rainfall erosion
c   nvsi    rate at which sediment enters detached storage from the atmosphere (lb/ac/day)
c           negative value may be used to simulate removal by human activity or wind
c   kser    coefficient in the detached sediment washoff equation
c   jser    exponent in the detached sediment washoff equation
c   kger    coefficient in the matrix soil scour equation, which simulates gully erosion
c   jger    exponent in the matrix soil scour equation, which simulates gully erosion
c   accsdp  rate at which solids accumulate on the land surface (used in impervious land)
c   remsdp  fraction of solids storage which is removed each day when there is no runoff,
c           for example, because of street sweeping (used in impervious land)
c
c                 defid deluid  smpf  krer  jrer  affix  cover   nvsi  kser  jser  kger  jger  accsdp remsdp
c-------------------------------------------------------------------------------------------
c451 sediment parameter group 2    (read if sedfg =1)
c
c   defid     parameter group id
c   deluid    landuse id
c   sed-suro  background concentration associated with surface flow (mg/l)
c   sed-ifwo  background concentration associated with interflow outflow (mg/l)
c   sed-agwo  background concentration associated with groundwater outflow (mg/l)
c   sand_p    fraction of sand in total sediments
c   sed_p     fraction of cohesive sediment class_i (silt,clay,......)
c
c   sand + silt + clay + ...... = 1
c   Background sediment load is added to total sediment from LAND prior to applying fractions
c
c                 defid deluid sed_suro   sed_ifwo   sed_agwo   sand_p   sed_p[1]   sed_p[2]   sed_p[3] ........sed_p[n]
c-------------------------------------------------------------------------------------------
c452 GQUAL-sediment to stream mapping (read if sediment as gqual)
c
c   defid   parameter group id
c   dwqid   general quality id
c   lutype  landuse type flow id (1 = impervious surfaceflow,
c           2 = pervious surfaceflow, 3 = pervious interflow, 4 = pervious groundflow)
c   sand    fraction of sand in total sediments
c   sed     fraction of cohesive sediment class_i (silt,clay,......)
c
c                 defid dwqid    lutype   sand   sed[1]   sed[2]   sed[3] ........sed[n]
c-------------------------------------------------------------------------------------------
c453 monthly erosion-related cover values
c   only required if crvfg = 1 (see card 440)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec erosion-related cover values at start of each month
c
c                 defid deluid   jan   feb   mar   apr   may   jun   jul   aug   sep   oct   nov   dec
c------------------------------------------------------------------------------------
c454 monthly net vertical sediment input
c   only required if vsivfg = 1 (see card 440)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec net vertical sediment input at start of each month (lb/acre/day)
c
c                 defid deluid   jan   feb   mar   apr   may   jun   jul   aug   sep   oct   nov   dec
c------------------------------------------------------------------------------------
c455 sed general parameters group 1
c   general sediment related parameters for instream transport
c
c   rgid     stream parameter group id
c   bedwid   bed width (ft) - this is constant for the entire simulation period
c   beddep   initial bed depth (ft)
c   por      porosity
c
c
c                 rgid  bedwid  beddep  por
c-------------------------------------------------------------------------------------------
c456 sediment class  parameters group
c   cohesive suspended sediment variables for instream transport
c
c   rgid     stream parameter group id
c   sed_id   cohesive sediment class id (silt, clay, .........)
c   sedflg   cohesive sediment flag indicating sediment class as a silt or clay (1 for silt and 2 for clay)
c   sedo     initial sediment conc in fluid phase (mg/liter)
c   sedbo    initial fraction of bed depth that is either clay (card 545) or silt (card 550)
c   d        effective diameter of the particles (in)
c   w        corresponding fall velocity of the particle in still water (in/s)
c   rho      density of the particles (gm/cm^3) - 2.65 is default for silica crystals
c   taucd    critical bed shear stress for deposition - generally taucd <= taucs (lb/ft^2)
c            if tau > taucd then no deposition
c            if tau < taucd then deposition rate approaches settling velocity, w
c   taucs    critical bed shear stress for scour (lb/ft^2)
c            if tau < taucs then no scour
c            if tau > taucs then scour steadily increases
c   m        erodibility coefficient of the sediment (lb/ft^2/day)
c
c
c                 rgid  sed_id  sedflg              sedo  sedbo  d   w  rho  taucd  taucs  m
c-------------------------------------------------------------------------------------------
c457 sediment parameter group 3    (read if sedfg = 1 and sedber = 1)
c
c   rchid   reach id
```

```
c   kber    coefficient for scour of the bank matrix soil (calibration)
c   jber    exponent for scour of the bank matrix soil (calibration)
c   qber    bank erosion flow threshold causing channel bank soil erosion (cfs)
c           if = -ve then threshold flow is at the bank full depth (cfs)
c   sand    fraction of sand in total bank erroded sediments
c   sed_n   fraction of cohesive sediment class_n (silt or clay)
c
c                 rchid   kber   jber   qber  sand  sed_1  sed_2  sed_3 ....sed_n
c------------------------------------------------------------------------------------------
c460 soil temperature control   (read if tempfg = 1)
c
c   msltfg  if = 1 monthly vary aslt and bslt parameters in surface flow temperature calculation
c   miftfg  if = 1 monthly vary aift and bift parameters in interflow temperature calculation
c   mgwtfg  if = 1 monthly vary agwt and bgwt parameters in ground water temperature calculation
c
c                 msltfg    miftfg     mgwtfg
c------------------------------------------------------------------------------------------
c461 Soil Temperature   (read if tempfg =1)
c
c   defid   parameter group id
c   deluid  landuse id
c   tsopfg  if = 0 compute subsurface temperatures using a mean departure from air temperature plus a smoothing factor
c           if = 1 compute subsurface temperature using regression
c           if = 2 the lower/gw layer temperature is a function of upper layer temperature instead of air temperature
c   aslt    surface layer temperature when the air temperature 0 degrees C
c   bslt    slope of the surface layer temperature regression equation
c   aift    mean difference between interflow temperature and air temperature (C)
c   bift    smoothing factor in the interflow temperature calculation
c   agwt    mean difference between groundwater temperature and air temperature (C)
c   bgwt    smoothing factor in the groundwater temperature calculation
c   islt    initial surface flow temperature (C)
c   iift    initial interflow temperature (C)
c   igwt    initial groundwater temperature (C)
c
c           y = a + b * x
c                 defid deluid  tsopfg   aslt   bslt   aift   bift   agwt  bgwt  islt  iift  igwt
c------------------------------------------------------------------------------------------
c462 mon-aslt
c   only required if tempfg = 1 and msltfg = 1 (see card 460)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec surface layer temperature when the air temperature 0 degrees C at start of each month (C)
c
c                 defid deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c------------------------------------------------------------------------------------
c463 mon-bslt
c   only required if tempfg = 1 and msltfg = 1 (see card 460)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec slope of the surface layer temperature regression equation at start of each month
c
c                 defid deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c------------------------------------------------------------------------------------
c464 mon-aift
c   only required if tempfg = 1 and miftfg = 1 (see card 460)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec mean difference between interflow temperature and air temperature at start of each month (C)
c
c                 defid deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c------------------------------------------------------------------------------------
c465 mon-bift
c   only required if tempfg = 1 and miftfg = 1 (see card 460)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec smoothing factor in the interflow temperature calculation at start of each month
c
c                 defid deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c------------------------------------------------------------------------------------
c466 mon-agwt
c   only required if tempfg = 1 and mgwtfg = 1 (see card 460)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec mean difference between groundwater temperature and air temperature at start of each month (C)
c
c                 defid deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c------------------------------------------------------------------------------------
c467 mon-bgwt
c   only required if tempfg = 1 and mgwtfg = 1 (see card 460)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec smoothing factor in the groundwater temperature calculation at start of each month
c
c                 defid deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c------------------------------------------------------------------------------------
c470 Temperature Parameters for Land Groups  (read if tempfg =1)
c
```

```
c   subbasin    subbasin id
c   melev           the mean watershed elevation (ft)
c   eldat       difference in elevation between watershed and the air temperature gage (ft)
c   rmelev      the mean RCHRES elevation (ft)
c   reldat      difference in elevation between the RCHRES and the air temperature gage (ft)
c              (positive if RCHRES is higher than the gage).
c
c                   subbasin   melev     eldat   rmelev     reldat
c-----------------------------------------------------------------------------------------
c475 Temperature Parameters for Stream Groups  (read if tempfg =1)
c
c   rgid    stream parameters group id
c   cfsaex  correction factor for solar radiation; fraction of RCHRES surface exposed to radiation
c   katrad  longwave radiation coefficient
c   kcond   conduction-convection heat transport coefficient
c   kevap   evaporation coefficient
c
c                   rgid   cfsaex    katrad     kcond     kevap
c-----------------------------------------------------------------------------------------
c500 land to stream mapping (read if oxfg =1)
c
c   rgid    stream parameters group id
c   dwqid   general quality id
c   lutype  landuse type flow id (1 = impervious surfaceflow,
c           2 = pervious surfaceflow, 3 = pervious interflow, 4 = pervious groundflow)
c   bod     bod fraction in pqual
c   nox     nitrate fraction in pqual
c   tam     total ammonia fraction in  pqual
c   snh4    particulate NH4-N fraction in pqual
c   po4     ortho-phosphorus fraction in pqual
c   spo4    particulate PO4-P fraction in pqual
c   orn     organic-nitrogen fraction in pqual
c   orp     organic-phosphorus fraction in pqual
c   orc     organic-carbon fraction in pqual
c
c                   rgid   dwqid    lutype   bod   nox   tam   snh4   po4   spo4   orn   orp   orc
c-----------------------------------------------------------------------------------------
c502 gases control   (read if oxfg =1)
c
c   midofg  if = 1 monthly very DO concentration in interflow
c   mico2fg if = 1 monthly very CO2 concentration in interflow
c   madofg  if = 1 monthly very DO concentration in ground water
c   maco2fg if = 1 monthly very CO2 concentration in ground water
c
c                   midofg     mico2fg     madofg      maco2fg
c-----------------------------------------------------------------------------------------
c503   DO-CO2 Control constant values (read if oxfg =1)
c
c   defid   parameter group id
c   deluid  landuse id
c   sdoxp   concentration of dissolved oxygen in surface flow (mg/l)
c   sco2p   concentration of dissolved CO2 in surface flow (mg/l)
c   idoxp   concentration of dissolved oxygen in interflow outflow (mg/l)
c   ico2p   concentration of dissolved CO2 in interflow outflow (mg/l)
c   adoxp   concentration of dissolved oxygen in active groundwater outflow (mg/l)
c   aco2p   concentration of dissolved CO2 in active groundwater outflow (mg/l)
c
c                   defid deluid   sdoxp    sco2p     idoxp    ico2p     adoxp    aco2p
c-----------------------------------------------------------------------------------------
c504 mon-DO (interflow)  mg C/l
c   only required if oxfg = 1 and midofg = 1 (see card 502)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec interflow dissolved oxygen concentration at start of each month (mg/l)
c
c                   defid deluid   jan   feb   mar   apr   may   jun   jul   aug   sep   oct   nov   dec
c-----------------------------------------------------------------------------------
c505 mon-DO (groundwater)
c   only required if oxfg = 1 and madofg = 1 (see card 502)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec groundwater dissolved oxygen concentration at start of each month (mg/l)
c
c                   defid deluid   jan   feb   mar   apr   may   jun   jul   aug   sep   oct   nov   dec
c-----------------------------------------------------------------------------------
c506 mon-CO2 (interflow)  mg C/l
c   only required if oxfg = 1 and mico2fg = 1 (see card 502)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec interflow carbon dioxide concentration at start of each month (mg/l)
c
c                   defid deluid   jan   feb   mar   apr   may   jun   jul   aug   sep   oct   nov   dec
c-----------------------------------------------------------------------------------------
c507 mon-CO2 (groundwater)
c   only required if oxfg = 1 and maco2fg = 1 (see card 502)
c
c   defid   parameter group id
c   deluid  landuse id
c   jan-dec groundwater carbon dioxide concentration at start of each month (mg/l)
c
```

```
c              defid deluid  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
c-------------------------------------------------------------------------------------
c510 DO/BOD control
c
c   benrfg   benthic release flag (for benthic related parameters)
c   reamfg   reaeration flag (for stream reaeration function)
c
c              benrfg    reamfg
c-------------------------------------------------------------------------------------
c511 ox-parm1
c
c   rgid    stream parameter group id
c   kbod20  bod decay rate at 20oC (1/hr)
c   tcbod   temperature adjustment coefficient for bod decay
c   kodset  bod settling rate (m/hr)
c   supsat  maximum allowable dissolved oxygen supersaturation (expressed as a multiple of the dissolved oxygen saturation concentration)
c   tcginv  temperature correction coefficient for surface gas invasion
c   reak    empirical constant in the equation used to calculate the reaeration coefficient (1/hr)
c   expred  exponent to depth in the reaeration coefficient equation
c   exprev  exponent to velocity in the reaeration coefficient equation
c   cforea  correction factor in the lake reaeration equation; it accounts for good or poor circulation characteristics
c
c              rgid  kbod20  tcbod  kodset  supsat  tcginv  reak  expred  exprev  cforea
c-------------------------------------------------------------------------------------
c512 ox-parm2
c
c   rgid       stream parameter group id
c   benod      benthal oxygen demand at 20 degrees C (with unlimited DO concentration) (mg/m2/hr)
c   tcben      temperature correction coefficient for benthal oxygen demand
c   expod      exponential factor in the dissolved oxygen term of the benthal oxygen demand equation
c   brbod      benthal release rate of BOD under aerobic conditions.(mg/m2/hr)
c   brbod_inc  increment to benthal release of BOD under anaerobic conditions. (mg/m2/hr)
c   expre1     the exponent in the DO term of the benthal BOD release equation
c
c              rgid  benod  tcben  expod  brbod  brbod_inc  exprel
c-------------------------------------------------------------------------------
c513 oxrx-initial conditions
c
c   rgid   stream parameter group id
c   dox    DO initial condition. (mg/l)
c   bod    BOD initial condition in water column. (mg/l)
c   satdo  Initial DO saturation concentration. (mg/l)
c
c              rgid  dox  bod  satdo
c-------------------------------------------------------------------------------
c514 ox-scour parms
c
c   rgid   stream parameter group id
c   scrvel threshold velocity above which the effect of scouring on benthal release rates is considered. (m/s)
c   scrmul multiplier by which benthal releases are increased during scouring.
c
c              rgid  scrvel  scrmul
c-------------------------------------------------------------------------------
c520 nutrients control
c
c   tamfg    total ammonia flag
c   no2fg    nitrite flag
c   po4fg    ortho-phosphorus flag
c   amvfg    ammonia volatilization flag
c   denfg    denitrification flag
c   adnhfg   NH4 adsorption flag
c   adpofg   PO4 adsorption flag
c   mphfg    monthly pH flag (not supported in this version)
c
c              tamfg  no2fg  po4fg  amvfg  denfg  adnhfg  adpofg  mphfg
c-------------------------------------------------------------------------------------
c521 nut-parm1
c
c   rgid    stream parameter group id
c   cvbo    conversion from milligrams biomass to milligrams oxygen (mg/mg)
c   cvbpc   conversion from biomass expressed as phosphorus to carbon (mols/mol)
c   cvbpn   conversion from biomass expressed as phosphorus to nitrogen (mols/mol)
c   bpcntc  percentage of biomass which is carbon (by weight)
c   ktam20  nitrification rate of ammonia at 20 degrees C (1/hr)
c   kno220  nitrification rate of nitrite at 20 degrees C (1/hr)
c   tcnit   temperature correction coefficient for nitrification
c   kno320  nitrate denitrification rate at 20 degrees C (1/hr)
c   tcden   temperature correction coefficient for denitrification
c   denoxt  dissolved oxygen concentration threshold for denitrification (mg/l)
c
c              rgid  cvbo  cvbpc  cvbpn  bpcntc  ktam20  kno220  tcnit  kno320  tcden  denoxt
c-------------------------------------------------------------------------------------
c522 nut-parm2
c
c   rgid        stream parameter group id
c   brtam_1     benthal release rate of ammonia under aerobic condition (mg/m2/hr)
c   brtam_2     benthal release rates of ammonia under anaerobic conditions (mg/m2/hr)
c   brpo4_1     benthal release rate of ortho-phosphorus under aerobic condition (mg/m2/hr)
c   brpo4_2     benthal release rate of ortho-phosphorus under anaerobic condition (mg/m2/hr)
c   bnh4(1-3)   constant bed concentrations of ammonia-N adsorbed to sand, silt, and clay (mg/kg)
c   bpo4(1-3)   constant bed concentrations of ortho-phosphorus-P adsorbed to sand, silt, and clay (mg/kg)
c
c              rgid  brtam_1  brtam_2  brpo4_1  brpo4_2  bnh4_1  bnh4_2  bnh4_3  bpo4_1  bpo4_2  bpo4_3
```

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c-----------------------------------------------------------------------------------
c523 nut-parm3
c
c   rgid        stream parameter group id
c   anaer       concentration of dissolved oxygen below which anaerobic conditions are assumed to exist (mg/l)
c   adnhpm(1-3)  adsorption coefficients (Kd) for ammonia-N adsorbed to sand, silt, and clay (cm3/g)
c   adpopm(1-3)  adsorption coefficients for ortho-phosphorus-P adsorbed to sand, silt, and clay (cm3/g)
c   expnvg      exponent in the gas layer mass transfer coefficient equation for NH3 volatilization
c   expnvl      exponent in the liquid layer mass transfer coefficient equation for NH3 volatilization
c
c              rgid  anaer   adnhpm_1  adnhpm_2  adnhpm_3  adpopm_1  adpopm_2  adpopm_3  expnvg  expnvl
c-----------------------------------------------------------------------------------
c524 nut-initial conditions
c
c   rgid       stream parameter group id
c   no3        initial concentration of nitrate (mg/l)
c   tam        initial concentration of total ammonia (mg/l)
c   no2        initial concentration of nitrite (as N) (mg/l)
c   po4        initial concentration of ortho-phosphorus (as P) (mg/l)
c   snh4(1-3)  initial suspended concentrations of ammonia-N adsorbed to sand, silt, and clay (mg/kg)
c   spo4(1-3)  initial suspended concentrations of ortho-phosphorus-P adsorbed to sand, silt, and clay (mg/kg)
c
c              rgid  no3  tam  no2  po4  snh4_1  snh4_2  snh4_3  spo4_1  spo4_2  spo4_3
c-----------------------------------------------------------------------------------
c530 plank flags
c
c   phyfg   phytoplankton flag
c   zoofg   zooplankton flag
c   balfg   benthic algae flag
c   sdltfg  influence of sediment washload on light extinction flag
c   amrfg   ammonia retardation of nitrogen-limited growth flag
c   decfg   linkage between carbon dioxide and phytoplankton growth flag
c   nsfg    ammonia is included as part of available nitrogen supply in nitrogen limited growth calculations
c   orefg   indicates the oref parameter in card 534 as a flowrate (if = 0) otherwise velocity
c
c              phyfg  zoofg  balfg  sdltfg  amrfg  decfg  nsfg  orefg
c------------------------------------------------------------------------------------------
c531 plank-parm1
c
c   rgid    stream parameter group id
c   ratclp  ratio of chlorophyll A content of biomass to phosphorus content
c   nonref  non-refractory fraction of algae and zooplankton biomass
c   litsed  multiplication factor to total sediment concentration to determine sediment contribution to light extinction (l/mg/ft)
c   alnpr   fraction of nitrogen requirements for phytoplankton growth that is satisfied by nitrate
c   extb    base extinction coefficient for light (1/m)
c   malgr   maximum unit algal growth rate (1/hr)
c
c              rgid   ratclp  nonref  litsed  alnpr  extb   malgr
c------------------------------------------------------------------------------------------
c532 plank-parm2
c
c   rgid    stream parameter group id
c   cmmlt   Michaelis-Menten constant for light limited growth (lay/min)
c   cmmn    nitrate Michaelis-Menten constant for nitrogen limited growth (mg/l)
c   cmmnp   nitrate Michaelis-Menten constant for phosphorus limited growth (mg/l)
c   cmmp    phosphate Michaelis-Menten constant for phosphorus limited growth (mg/l)
c   talgrh  temperature above which algal growth ceases (C)
c   talgrl  temperature below which algal growth ceases (C)
c   talgrm  temperature below which algal growth is retarded (C)
c
c              rgid   cmmlt   cmmn   cmmnp   cmmp   talgrh  talgrl  talgrm
c-----------------------------------------------------------------------------------
c533 plank-parm3
c
c   rgid   stream parameter group id
c   alr20  algal unit respiration rate at 20 degrees C (1/hr)
c   aldh   high algal unit death rate (1/hr)
c   aldl   low algal unit death rate (1/hr)
c   oxald  increment to phytoplankton unit death rate due to anaerobic conditions (1/hr)
c   naldh  inorganic nitrogen concentration below which high algal death rate occurs (as nitrogen) (mg/l)
c   paldh  inorganic phosphorus concentration below which high algal death rate occurs (as phosphorus) (mg/l)
c
c              rgid   alr20   aldh   aldl   oxald   naldh   paldh
c-----------------------------------------------------------------------------------
c534 plank-parm4
c
c   rgid    stream parameter group id
c   phycon  constant inflow concentration of plankton from land to reach (mg/l)
c   seed    minimum concentration of plankton not subject to advection (i.e., at high flow) (mg/l)
c   mxstay  concentration of plankton not subject to advection at very low flow (mg/l)
c   oref    velocity/outflow at which the concentration of plankton not subject to advection is midway between SEED and MXSTAY, see card 530 (m/s or m3/s)
c   claldh  chlorophyll a concentration above which high algal death rate occurs (ug/l)
c   physet  phytoplankton settling rate (m/hr)
c   refset  settling rate for dead refractory organics (m/hr)
c   cfsaex  This factor is used to adjust the input solar radiation to make it applicable to the RCHRES;
c           for example, to account for shading of the surface by trees or buildings
c   mbal    maximum benthic algae density (as biomass) (mg/m2)
c   cfbalr  ratio of benthic algal to phytoplankton respiration rate
c   cfbalg  ratio of benthic algal to phytoplankton growth rate
c
c              rgid  phycon  seed  mxstay  oref  claldh  physet  refset  cfsaex  mbal  cfbalr  cfbalg
c-----------------------------------------------------------------------------------
c535 plank-initial conditions
```

```
c
c   rgid   stream parameter group id
c   phyto  initial phytoplankton concentration, as biomass (mg/l)
c   benal  initial benthic algae density, as biomass (mg/m2)
c   orn    initial dead refractory organic nitrogen concentration (mg/l)
c   orp    initial dead refractory organic phosphorus concentration (mg/l)
c   orc    initial dead refractory organic carbon concentration (mg/l)
c
c          rgid   phyto   benal  orn   orp   orc
c---------------------------------------------------------------------------------
c540 pH controls
c
c   phffg1   value of 0 indicates that the removal factor for total inorganic carbon is constant, given as phfrc1
c                                    a value of 1 indicates the monthly removal factors
c   phffg2   value of 0 indicates that the removal factor for dissolved carbon dioxide is constant, given as phfrc2
c        a value of 1 indicates the monthly removal factors
c   phfrc1   removal fraction for total inorganic carbon
c   phfrc2   removal fraction for dissolved carbon dioxide
c
c          phffg1   phffg2   phfrc1   phfrc2
c----------------------------------------------------------------------------------------
c541 pH-parm
c
c   rgid    stream parameter group id
c   phcnt        maximum number of iterations used to solve for the pH
c   alkcon       number of the conservative substance which is used to simulate alkalinity
c         Alkalinity must be simulated in order to obtain valid results
c   cfcinv       ratio of the carbon dioxide invasion rate to the oxygen reaeration rate
c   brco2_1      benthal release rate of CO2 (as carbon) for aerobic conditions (mg/m2/hr)
c   brco2_2 benthal release rate of CO2 (as carbon) for anaerobic conditions (mg/m2/hr)
c
c          rgid   phcnt   alkcon   cfcinv   brco2_1   brco2_2
c----------------------------------------------------------------------------------------
c542 pH-initial conditions
c
c   rgid          stream parameter group id
c   tic                         initial total inorganic carbon (mg/l)
c   co2                         initial carbon dioxide (as carbon) (mg/l)
c   ph                          initial pH
c
c          rgid   tic   co2   ph
c---------------------------------------------------------------------------------
c543 mon-tic (monthly removal fraction for total inorganic carbon)
c   only required if phfg = 1 and phffg1 = 1 (see card 502 and card 540)
c
c   rgid    stream parameter group id
c   jan-dec total inorganic carbon removal fraction at the start of each month
c
c rgid          jan   feb   mar   apr   may   jun   jul   aug   sep   oct   nov   dec
c----------------------------------------------------------------------------------------
c544 mon-co2 (monthly removal fraction for dissolved carbon dioxide)
c   only required if phfg = 1 and phffg2 = 1 (see card 502 and card 540)
c
c   rgid    stream parameter group id
c   jan-dec dissolved carbon dioxide removal fraction at the start of each month
c
c rgid          jan   feb   mar   apr   may   jun   jul   aug   sep   oct   nov   dec
c----------------------------------------------------------------------------------------
c600 TMDL control flags
c
c   ncpt       if > 0 then use point sources control card 660
c   ncland     if > 0 then use landuse control card 670
c            if = 1 then apply reduction to only surface output
c            if = 2 then apply reduction to total land output
c   ncrch      if > 0 then use reach control card 680 and 690
c   ntrgp      number of threshold groups in Card 410 and 610
c   ntnum      number of defined thresholds for analysis
c            if > 0 then use threshold control cards 605 and 610
c
c   ncpt  ncland  ncrch  ntrgp  ntnum
              23           2           0           1           3
c----------------------------------------------------------------------------------------
c605 TMDL threshold mapping (used if ntnum > 0 in card 600)
c
c   tnum      threshold ordinal number
c   tqsd      threshold qual (1 for dissolved only and 2 for total)
c   tcount    number of water quality constituent to aggregate
c   tqid      list of tqid to aggregate - number of tqid in list = tcount (GQUAL/RQUAL IDs)
c
c   tnum   tqsd    tcount   tqid1   tqid2   ....... tqidn
              1            2            1            12
              2            2            1            12
              3            2            1            12
c----------------------------------------------------------------------------------------
c610 TMDL threshold definitions (used if ntnum > 0 in card 600)
c
c   trgid     threshold reach group ID (corresponds to trgid on Card 410)
c   tnum      threshold number (corresponds to tnum on Card 605)
c   ttype     threshold type (possible values: 0, 1, 2, 3 or -1, -2, -3)
c            0 = no standard to be applied for the trgid
c            1 = instantaneous values > threshold
c            2 = arithmetic mean > threshold
c            3 = geometric mean > threshold
```

```
c           -1 = instantaneous values < threshold
c           -2 = arithmetic mean < threshold
c           -3 = geometric mean < threshold
c   tdays     number of days over model output is aggregated and/or is compared
c           if tdays = 0 then threshold becomes percent of time
c   jan-dec   twelve monthly values for threshold (for constant, use same value 12 times)
c           (units are same as in card 250)
c
c   examples: ttype  tdays  description/interpretation
c              1      1  at least one instantaneous value within a 1-day running period > threshold
c             -1      1  at least one instantaneous value within a 1-day running period < threshold
c              1      0  percent of time that instantaneous value > threshold
c              2      4  4-day running arithmetic mean > threshold
c              3     30  30-day running geometric mean > threshold (for previous 30-days)
c
c trgid  tnum   ttype  tdays  jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
            1           1           1           0           400.000000  400.000000  400.000000  400.000000  400.000000  400.000000  400.000000
            400.000000  400.000000  400.000000  400.000000  400.000000
            1           2           3           5           200.000000  200.000000  200.000000  200.000000  200.000000  200.000000  200.000000
            200.000000  200.000000  200.000000  200.000000  200.000000
            1           3           1           0           4000.000000 4000.000000 4000.000000 4000.000000 4000.000000 4000.000000 4000.000000
            4000.000000 4000.000000 4000.000000 4000.000000 4000.000000
c----------------------------------------------------------------------------------------
c660 TMDL point source control (used if ncpt > 0 on card 600)
c
c   rchid       reach id
c   permit      point source index (level1)
c   pipe        point source index qualifier (level2)
c   reduction   reduction of pollutant from point source (in fraction)
c
c  rchid   permit   pipe   reduction_flow...reduction_qual1...reduction_qual2...reduction_qualn
            401         septics_401  1           0.000000    0.000000
            402         septics_402  1           0.000000    0.000000
            403         septics_403  1           0.000000    0.000000
            404         septics_404  1           0.000000    0.000000
            405         PR0025551    1           0.000000    0.000000
            405         septics_405  1           0.000000    0.000000
            406         PR0020851    1           0.000000    0.000000
            406         PR0023981    1           0.000000    0.000000
            406         septics_406  1           0.000000    0.000000
            407         PR0024317    1           0.000000    0.000000
            407         septics_407  1           0.000000    0.000000
            408         septics_408  1           0.000000    0.000000
            409         septics_409  1           0.000000    0.000000
            410         septics_410  1           0.000000    0.000000
            411         septics_411  1           0.000000    0.000000
            412         septics_412  1           0.000000    0.000000
            413         septics_413  1           0.000000    0.000000
            414         septics_414  1           0.000000    0.000000
            415         septics_415  1           0.000000    0.000000
            416         septics_416  1           0.000000    0.000000
            417         septics_417  1           0.000000    0.000000
            418         septics_418  1           0.000000    0.000000
            419         septics_419  1           0.000000    0.000000
c-------------------------------------------------------------------------------------------
c670 TMDL land-based control (used if ncland > 0 on card 600)
c
c   subbasin   subwatershed id
c   deluid     land use id
c   luname     land use name
c   reduction  reduction of pollutant from corresponding landuse and subwatershed
c
c           subbasin  deluid pluname  reduction
            401         0           Water       0.000000    0.000000
            401         1           Forest      0.000000    0.000000
            401         2           Agriculture 0.000000    0.000000
            401         3           Pasture     0.000000    0.000000
            401         4           Wetland     0.000000    0.000000
            401         5           Barren      0.000000    0.000000
            401         6           Urban_HighD_Per         0.000000    0.000000
            401         7           Urban_LowD_Per          0.000000    0.000000
            401         8           Urban_HighD_Imp         0.000000    0.000000
            401         9           Urban_LowD_Imp          0.000000    0.000000
            402         0           Water       0.000000    0.000000
            402         1           Forest      0.000000    0.000000
            402         2           Agriculture 0.000000    0.000000
            402         3           Pasture     0.000000    0.000000
            402         4           Wetland     0.000000    0.000000
            402         5           Barren      0.000000    0.000000
            402         6           Urban_HighD_Per         0.000000    0.000000
            402         7           Urban_LowD_Per          0.000000    0.000000
            402         8           Urban_HighD_Imp         0.000000    0.000000
            402         9           Urban_LowD_Imp          0.000000    0.000000
            403         0           Water       0.000000    0.000000
            403         1           Forest      0.000000    0.000000
            403         2           Agriculture 0.000000    0.000000
            403         3           Pasture     0.000000    0.000000
            403         4           Wetland     0.000000    0.000000
            403         5           Barren      0.000000    0.000000
            403         6           Urban_HighD_Per         0.000000    0.000000
            403         7           Urban_LowD_Per          0.000000    0.000000
            403         8           Urban_HighD_Imp         0.000000    0.000000
            403         9           Urban_LowD_Imp          0.000000    0.000000
```

404	0	Water	0.000000	0.000000	
404	1	Forest	0.000000	0.000000	
404	2	Agriculture	0.000000	0.000000	
404	3	Pasture	0.000000	0.000000	
404	4	Wetland	0.000000	0.000000	
404	5	Barren	0.000000	0.000000	
404	6	Urban_HighD_Per		0.000000	0.000000
404	7	Urban_LowD_Per		0.000000	0.000000
404	8	Urban_HighD_Imp		0.000000	0.000000
404	9	Urban_LowD_Imp		0.000000	0.000000
405	0	Water	0.000000	0.000000	
405	1	Forest	0.000000	0.000000	
405	2	Agriculture	0.000000	0.000000	
405	3	Pasture	0.000000	0.000000	
405	4	Wetland	0.000000	0.000000	
405	5	Barren	0.000000	0.000000	
405	6	Urban_HighD_Per		0.000000	0.000000
405	7	Urban_LowD_Per		0.000000	0.000000
405	8	Urban_HighD_Imp		0.000000	0.000000
405	9	Urban_LowD_Imp		0.000000	0.000000
406	0	Water	0.000000	0.000000	
406	1	Forest	0.000000	0.000000	
406	2	Agriculture	0.000000	0.000000	
406	3	Pasture	0.000000	0.000000	
406	4	Wetland	0.000000	0.000000	
406	5	Barren	0.000000	0.000000	
406	6	Urban_HighD_Per		0.000000	0.000000
406	7	Urban_LowD_Per		0.000000	0.000000
406	8	Urban_HighD_Imp		0.000000	0.000000
406	9	Urban_LowD_Imp		0.000000	0.000000
407	0	Water	0.000000	0.000000	
407	1	Forest	0.000000	0.000000	
407	2	Agriculture	0.000000	0.000000	
407	3	Pasture	0.000000	0.000000	
407	4	Wetland	0.000000	0.000000	
407	5	Barren	0.000000	0.000000	
407	6	Urban_HighD_Per		0.000000	0.000000
407	7	Urban_LowD_Per		0.000000	0.000000
407	8	Urban_HighD_Imp		0.000000	0.000000
407	9	Urban_LowD_Imp		0.000000	0.000000
408	0	Water	0.000000	0.000000	
408	1	Forest	0.000000	0.000000	
408	2	Agriculture	0.000000	0.000000	
408	3	Pasture	0.000000	0.000000	
408	4	Wetland	0.000000	0.000000	
408	5	Barren	0.000000	0.000000	
408	6	Urban_HighD_Per		0.000000	0.000000
408	7	Urban_LowD_Per		0.000000	0.000000
408	8	Urban_HighD_Imp		0.000000	0.000000
408	9	Urban_LowD_Imp		0.000000	0.000000
409	0	Water	0.000000	0.000000	
409	1	Forest	0.000000	0.000000	
409	2	Agriculture	0.000000	0.000000	
409	3	Pasture	0.000000	0.000000	
409	4	Wetland	0.000000	0.000000	
409	5	Barren	0.000000	0.000000	
409	6	Urban_HighD_Per		0.000000	0.000000
409	7	Urban_LowD_Per		0.000000	0.000000
409	8	Urban_HighD_Imp		0.000000	0.000000
409	9	Urban_LowD_Imp		0.000000	0.000000
410	0	Water	0.000000	0.000000	
410	1	Forest	0.000000	0.000000	
410	2	Agriculture	0.000000	0.000000	
410	3	Pasture	0.000000	0.000000	
410	4	Wetland	0.000000	0.000000	
410	5	Barren	0.000000	0.000000	
410	6	Urban_HighD_Per		0.000000	0.000000
410	7	Urban_LowD_Per		0.000000	0.000000
410	8	Urban_HighD_Imp		0.000000	0.000000
410	9	Urban_LowD_Imp		0.000000	0.000000
411	0	Water	0.000000	0.000000	
411	1	Forest	0.000000	0.000000	
411	2	Agriculture	0.000000	0.000000	
411	3	Pasture	0.000000	0.000000	
411	4	Wetland	0.000000	0.000000	
411	5	Barren	0.000000	0.000000	
411	6	Urban_HighD_Per		0.000000	0.000000
411	7	Urban_LowD_Per		0.000000	0.000000
411	8	Urban_HighD_Imp		0.000000	0.000000
411	9	Urban_LowD_Imp		0.000000	0.000000
412	0	Water	0.000000	0.000000	
412	1	Forest	0.000000	0.000000	
412	2	Agriculture	0.000000	0.000000	
412	3	Pasture	0.000000	0.000000	
412	4	Wetland	0.000000	0.000000	
412	5	Barren	0.000000	0.000000	
412	6	Urban_HighD_Per		0.000000	0.000000
412	7	Urban_LowD_Per		0.000000	0.000000
412	8	Urban_HighD_Imp		0.000000	0.000000
412	9	Urban_LowD_Imp		0.000000	0.000000
413	0	Water	0.000000	0.000000	
413	1	Forest	0.000000	0.000000	
413	2	Agriculture	0.000000	0.000000	

413	3	Pasture	0.000000	0.000000	
413	4	Wetland	0.000000	0.000000	
413	5	Barren	0.000000	0.000000	
413	6	Urban_HighD_Per		0.000000	0.000000
413	7	Urban_LowD_Per		0.000000	0.000000
413	8	Urban_HighD_Imp		0.000000	0.000000
413	9	Urban_LowD_Imp		0.000000	0.000000
414	0	Water	0.000000	0.000000	
414	1	Forest	0.000000	0.000000	
414	2	Agriculture	0.000000	0.000000	
414	3	Pasture	0.000000	0.000000	
414	4	Wetland	0.000000	0.000000	
414	5	Barren	0.000000	0.000000	
414	6	Urban_HighD_Per		0.000000	0.000000
414	7	Urban_LowD_Per		0.000000	0.000000
414	8	Urban_HighD_Imp		0.000000	0.000000
414	9	Urban_LowD_Imp		0.000000	0.000000
415	0	Water	0.000000	0.000000	
415	1	Forest	0.000000	0.000000	
415	2	Agriculture	0.000000	0.000000	
415	3	Pasture	0.000000	0.000000	
415	4	Wetland	0.000000	0.000000	
415	5	Barren	0.000000	0.000000	
415	6	Urban_HighD_Per		0.000000	0.000000
415	7	Urban_LowD_Per		0.000000	0.000000
415	8	Urban_HighD_Imp		0.000000	0.000000
415	9	Urban_LowD_Imp		0.000000	0.000000
416	0	Water	0.000000	0.000000	
416	1	Forest	0.000000	0.000000	
416	2	Agriculture	0.000000	0.000000	
416	3	Pasture	0.000000	0.000000	
416	4	Wetland	0.000000	0.000000	
416	5	Barren	0.000000	0.000000	
416	6	Urban_HighD_Per		0.000000	0.000000
416	7	Urban_LowD_Per		0.000000	0.000000
416	8	Urban_HighD_Imp		0.000000	0.000000
416	9	Urban_LowD_Imp		0.000000	0.000000
417	0	Water	0.000000	0.000000	
417	1	Forest	0.000000	0.000000	
417	2	Agriculture	0.000000	0.000000	
417	3	Pasture	0.000000	0.000000	
417	4	Wetland	0.000000	0.000000	
417	5	Barren	0.000000	0.000000	
417	6	Urban_HighD_Per		0.000000	0.000000
417	7	Urban_LowD_Per		0.000000	0.000000
417	8	Urban_HighD_Imp		0.000000	0.000000
417	9	Urban_LowD_Imp		0.000000	0.000000
418	0	Water	0.000000	0.000000	
418	1	Forest	0.000000	0.000000	
418	2	Agriculture	0.000000	0.000000	
418	3	Pasture	0.000000	0.000000	
418	4	Wetland	0.000000	0.000000	
418	5	Barren	0.000000	0.000000	
418	6	Urban_HighD_Per		0.000000	0.000000
418	7	Urban_LowD_Per		0.000000	0.000000
418	8	Urban_HighD_Imp		0.000000	0.000000
418	9	Urban_LowD_Imp		0.000000	0.000000
419	0	Water	0.000000	0.000000	
419	1	Forest	0.000000	0.000000	
419	2	Agriculture	0.000000	0.000000	
419	3	Pasture	0.000000	0.000000	
419	4	Wetland	0.000000	0.000000	
419	5	Barren	0.000000	0.000000	
419	6	Urban_HighD_Per		0.000000	0.000000
419	7	Urban_LowD_Per		0.000000	0.000000
419	8	Urban_HighD_Imp		0.000000	0.000000
419	9	Urban_LowD_Imp		0.000000	0.000000

```
c-------------------------------------------------------------------------------------------
c680 TMDL reach control (used if ncrch > 0 on card 600)
c
c   rchid        controlled reach id
c   outlet       controlled reach outlet id
c   limit-flow   flow limit from the corresponding reach (cfs)
c   limit_pol    concentration limit of pollutant from the corresponding reach (mg/l or ug/l or #/100ml)
c
c  rchid   outlet   limit_flow   limit_qual1...limit_qual2...limit_qualn
c-------------------------------------------------------------------------------------------
c690 TMDL reach control (used if ncrch > 0 on card 600)
c
c   rchid        controlled reach id
c   outlet       controlled reach outlet id
c   reduction    reduction of pollutant from the corresponding reach (fraction)
c                reduction in outflow will also reduce the pollutant mass from the outflow and
c                any defined reduction to pollutant will be the additional
c
c  rchid   outlet   reduction_flow...reduction_qual1...reduction_qual2...reduction_qualn
c-------------------------------------------------------------------------------------------
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APPENDIX D: SUBBASIN LAND USE AREA

Subbasin	Assessment Unit Code	Assessment Unit Name	Landuse Code	Landuse Description	Area (Acres)
401	PRUNNAMED2	UNNAMED 2	0	Water	20.431
401	PRUNNAMED2	UNNAMED 2	1	Forest	144.128
401	PRUNNAMED2	UNNAMED 2	2	Agriculture	0
401	PRUNNAMED2	UNNAMED 2	3	Pasture	477.466
401	PRUNNAMED2	UNNAMED 2	4	Wetland	104.377
401	PRUNNAMED2	UNNAMED 2	5	Barren	13.102
401	PRUNNAMED2	UNNAMED 2	6	Urban_HighD_Per	18.3215
401	PRUNNAMED2	UNNAMED 2	7	Urban_LowD_Per	33.645
401	PRUNNAMED2	UNNAMED 2	8	Urban_HighD_Imp	18.3215
401	PRUNNAMED2	UNNAMED 2	9	Urban_LowD_Imp	11.215
402	PRWR95A	RIO CULEBRINAS	0	Water	35.587
402	PRWR95A	RIO CULEBRINAS	1	Forest	336.293
402	PRWR95A	RIO CULEBRINAS	2	Agriculture	5.116
402	PRWR95A	RIO CULEBRINAS	3	Pasture	2063.804
402	PRWR95A	RIO CULEBRINAS	4	Wetland	0
402	PRWR95A	RIO CULEBRINAS	5	Barren	29.804
402	PRWR95A	RIO CULEBRINAS	6	Urban_HighD_Per	66.0575
402	PRWR95A	RIO CULEBRINAS	7	Urban_LowD_Per	514.95
402	PRWR95A	RIO CULEBRINAS	8	Urban_HighD_Imp	66.0575
402	PRWR95A	RIO CULEBRINAS	9	Urban_LowD_Imp	171.65
403	PRWR95A	RIO CULEBRINAS	0	Water	69.164
403	PRWR95A	RIO CULEBRINAS	1	Forest	1737.109
403	PRWR95A	RIO CULEBRINAS	2	Agriculture	49.594
403	PRWR95A	RIO CULEBRINAS	3	Pasture	2531.94
403	PRWR95A	RIO CULEBRINAS	4	Wetland	0
403	PRWR95A	RIO CULEBRINAS	5	Barren	18.459
403	PRWR95A	RIO CULEBRINAS	6	Urban_HighD_Per	62.7145
403	PRWR95A	RIO CULEBRINAS	7	Urban_LowD_Per	770.757
403	PRWR95A	RIO CULEBRINAS	8	Urban_HighD_Imp	62.7145
403	PRWR95A	RIO CULEBRINAS	9	Urban_LowD_Imp	256.919
404	PRWR95A	RIO CULEBRINAS	0	Water	65.136
404	PRWR95A	RIO CULEBRINAS	1	Forest	1230.479
404	PRWR95A	RIO CULEBRINAS	2	Agriculture	48.241
404	PRWR95A	RIO CULEBRINAS	3	Pasture	1898.961
404	PRWR95A	RIO CULEBRINAS	4	Wetland	0
404	PRWR95A	RIO CULEBRINAS	5	Barren	0.889
404	PRWR95A	RIO CULEBRINAS	6	Urban_HighD_Per	1.0005
404	PRWR95A	RIO CULEBRINAS	7	Urban_LowD_Per	465.01425
404	PRWR95A	RIO CULEBRINAS	8	Urban_HighD_Imp	1.0005
404	PRWR95A	RIO CULEBRINAS	9	Urban_LowD_Imp	155.00475
405	PRWR95A	RIO CULEBRINAS	0	Water	47.611
405	PRWR95A	RIO CULEBRINAS	1	Forest	775.569
405	PRWR95A	RIO CULEBRINAS	2	Agriculture	30.035
405	PRWR95A	RIO CULEBRINAS	3	Pasture	1575.387
405	PRWR95A	RIO CULEBRINAS	4	Wetland	0
405	PRWR95A	RIO CULEBRINAS	5	Barren	0.445
405	PRWR95A	RIO CULEBRINAS	6	Urban_HighD_Per	3.8935
405	PRWR95A	RIO CULEBRINAS	7	Urban_LowD_Per	413.6475
405	PRWR95A	RIO CULEBRINAS	8	Urban_HighD_Imp	3.8935

Subbasin	Assessment Unit Code	Assessment Unit Name	Landuse Code	Landuse Description	Area (Acres)
405	PRWR95A	RIO CULEBRINAS	9	Urban_LowD_Imp	137.8825
406	PRWR95A	RIO CULEBRINAS	0	Water	3.336
406	PRWR95A	RIO CULEBRINAS	1	Forest	6262.556
406	PRWR95A	RIO CULEBRINAS	2	Agriculture	472.633
406	PRWR95A	RIO CULEBRINAS	3	Pasture	2978.145
406	PRWR95A	RIO CULEBRINAS	4	Wetland	0
406	PRWR95A	RIO CULEBRINAS	5	Barren	4.448
406	PRWR95A	RIO CULEBRINAS	6	Urban_HighD_Per	63.8335
406	PRWR95A	RIO CULEBRINAS	7	Urban_LowD_Per	1142.994
406	PRWR95A	RIO CULEBRINAS	8	Urban_HighD_Imp	63.8335
406	PRWR95A	RIO CULEBRINAS	9	Urban_LowD_Imp	380.998
407	PRWR95K	RIO GUATEMALA	0	Water	1.78
407	PRWR95K	RIO GUATEMALA	1	Forest	1173.326
407	PRWR95K	RIO GUATEMALA	2	Agriculture	7.342
407	PRWR95K	RIO GUATEMALA	3	Pasture	4472.391
407	PRWR95K	RIO GUATEMALA	4	Wetland	0
407	PRWR95K	RIO GUATEMALA	5	Barren	4.894
407	PRWR95K	RIO GUATEMALA	6	Urban_HighD_Per	43.8275
407	PRWR95K	RIO GUATEMALA	7	Urban_LowD_Per	790.227
407	PRWR95K	RIO GUATEMALA	8	Urban_HighD_Imp	43.8275
407	PRWR95K	RIO GUATEMALA	9	Urban_LowD_Imp	263.409
408	PRWR95J	RIO SONADOR	0	Water	1.334
408	PRWR95J	RIO SONADOR	1	Forest	2109.077
408	PRWR95J	RIO SONADOR	2	Agriculture	255.268
408	PRWR95J	RIO SONADOR	3	Pasture	2353.228
408	PRWR95J	RIO SONADOR	4	Wetland	0
408	PRWR95J	RIO SONADOR	5	Barren	1.112
408	PRWR95J	RIO SONADOR	6	Urban_HighD_Per	0
408	PRWR95J	RIO SONADOR	7	Urban_LowD_Per	440.9385
408	PRWR95J	RIO SONADOR	8	Urban_HighD_Imp	0
408	PRWR95J	RIO SONADOR	9	Urban_LowD_Imp	146.9795
409	PRWQ95I	QUEBRADA SALADA	0	Water	2.666
409	PRWQ95I	QUEBRADA SALADA	1	Forest	687.602
409	PRWQ95I	QUEBRADA SALADA	2	Agriculture	1.999
409	PRWQ95I	QUEBRADA SALADA	3	Pasture	1761.329
409	PRWQ95I	QUEBRADA SALADA	4	Wetland	0
409	PRWQ95I	QUEBRADA SALADA	5	Barren	1.555
409	PRWQ95I	QUEBRADA SALADA	6	Urban_HighD_Per	0.6665
409	PRWQ95I	QUEBRADA SALADA	7	Urban_LowD_Per	287.76
409	PRWQ95I	QUEBRADA SALADA	8	Urban_HighD_Imp	0.6665
409	PRWQ95I	QUEBRADA SALADA	9	Urban_LowD_Imp	95.92
410	PRWQ95H	QUEBRADA GRANDE DE LA MAJAGUA	0	Water	0
410	PRWQ95H	QUEBRADA GRANDE DE LA MAJAGUA	1	Forest	880.821
410	PRWQ95H	QUEBRADA GRANDE DE LA MAJAGUA	2	Agriculture	175.542
410	PRWQ95H	QUEBRADA GRANDE DE LA MAJAGUA	3	Pasture	1211.24

Subbasin	Assessment Unit Code	Assessment Unit Name	Landuse Code	Landuse Description	Area (Acres)
410	PRWQ95H	QUEBRADA GRANDE DE LA MAJAGUA	4	Wetland	0
410	PRWQ95H	QUEBRADA GRANDE DE LA MAJAGUA	5	Barren	0
410	PRWQ95H	QUEBRADA GRANDE DE LA MAJAGUA	6	Urban_HighD_Per	0
410	PRWQ95H	QUEBRADA GRANDE DE LA MAJAGUA	7	Urban_LowD_Per	209.6505
410	PRWQ95H	QUEBRADA GRANDE DE LA MAJAGUA	8	Urban_HighD_Imp	0
410	PRWQ95H	QUEBRADA GRANDE DE LA MAJAGUA	9	Urban_LowD_Imp	69.8835
411	PRWQ95G	QUEBRADA EL SALTO	0	Water	0.667
411	PRWQ95G	QUEBRADA EL SALTO	1	Forest	336.13
411	PRWQ95G	QUEBRADA EL SALTO	2	Agriculture	1.556
411	PRWQ95G	QUEBRADA EL SALTO	3	Pasture	1015.058
411	PRWQ95G	QUEBRADA EL SALTO	4	Wetland	0
411	PRWQ95G	QUEBRADA EL SALTO	5	Barren	0.445
411	PRWQ95G	QUEBRADA EL SALTO	6	Urban_HighD_Per	3.8905
411	PRWQ95G	QUEBRADA EL SALTO	7	Urban_LowD_Per	293.78025
411	PRWQ95G	QUEBRADA EL SALTO	8	Urban_HighD_Imp	3.8905
411	PRWQ95G	QUEBRADA EL SALTO	9	Urban_LowD_Imp	97.92675
412	PRWQ95E	QUEBRADA YAGRUMA	0	Water	1.557
412	PRWQ95E	QUEBRADA YAGRUMA	1	Forest	2435.031
412	PRWQ95E	QUEBRADA YAGRUMA	2	Agriculture	339.57
412	PRWQ95E	QUEBRADA YAGRUMA	3	Pasture	1681.395
412	PRWQ95E	QUEBRADA YAGRUMA	4	Wetland	0
412	PRWQ95E	QUEBRADA YAGRUMA	5	Barren	2.001
412	PRWQ95E	QUEBRADA YAGRUMA	6	Urban_HighD_Per	0.111
412	PRWQ95E	QUEBRADA YAGRUMA	7	Urban_LowD_Per	297.708
412	PRWQ95E	QUEBRADA YAGRUMA	8	Urban_HighD_Imp	0.111
412	PRWQ95E	QUEBRADA YAGRUMA	9	Urban_LowD_Imp	99.236
413	PRWQ95F	QUEBRADA LASALLE	0	Water	1.559
413	PRWQ95F	QUEBRADA LASALLE	1	Forest	474.455
413	PRWQ95F	QUEBRADA LASALLE	2	Agriculture	1.113
413	PRWQ95F	QUEBRADA LASALLE	3	Pasture	1826.128
413	PRWQ95F	QUEBRADA LASALLE	4	Wetland	0
413	PRWQ95F	QUEBRADA LASALLE	5	Barren	2.894
413	PRWQ95F	QUEBRADA LASALLE	6	Urban_HighD_Per	2.6715
413	PRWQ95F	QUEBRADA LASALLE	7	Urban_LowD_Per	374.54325
413	PRWQ95F	QUEBRADA LASALLE	8	Urban_HighD_Imp	2.6715
413	PRWQ95F	QUEBRADA LASALLE	9	Urban_LowD_Imp	124.84775
414	PRWQ95D	QUEBRADA LAS MARIAS	0	Water	0.668
414	PRWQ95D	QUEBRADA LAS MARIAS	1	Forest	1329.892
414	PRWQ95D	QUEBRADA LAS MARIAS	2	Agriculture	182.29
414	PRWQ95D	QUEBRADA LAS MARIAS	3	Pasture	570.24
414	PRWQ95D	QUEBRADA LAS MARIAS	4	Wetland	0
414	PRWQ95D	QUEBRADA LAS MARIAS	5	Barren	2.448
414	PRWQ95D	QUEBRADA LAS MARIAS	6	Urban_HighD_Per	0
414	PRWQ95D	QUEBRADA LAS MARIAS	7	Urban_LowD_Per	200.15175

Subbasin	Assessment Unit Code	Assessment Unit Name	Landuse Code	Landuse Description	Area (Acres)
414	PRWQ95D	QUEBRADA LAS MARIAS	8	Urban_HighD_Imp	0
414	PRWQ95D	QUEBRADA LAS MARIAS	9	Urban_LowD_Imp	66.71725
415	PRWQ95C	QUEBRADA GRANDE	0	Water	0
415	PRWQ95C	QUEBRADA GRANDE	1	Forest	770.479
415	PRWQ95C	QUEBRADA GRANDE	2	Agriculture	4.889
415	PRWQ95C	QUEBRADA GRANDE	3	Pasture	1593.406
415	PRWQ95C	QUEBRADA GRANDE	4	Wetland	0
415	PRWQ95C	QUEBRADA GRANDE	5	Barren	8.667
415	PRWQ95C	QUEBRADA GRANDE	6	Urban_HighD_Per	10.1115
415	PRWQ95C	QUEBRADA GRANDE	7	Urban_LowD_Per	527.35725
415	PRWQ95C	QUEBRADA GRANDE	8	Urban_HighD_Imp	10.1115
415	PRWQ95C	QUEBRADA GRANDE	9	Urban_LowD_Imp	175.78575
416	PRWR95B	RIO CANAS	0	Water	0.222
416	PRWR95B	RIO CANAS	1	Forest	2529.108
416	PRWR95B	RIO CANAS	2	Agriculture	109.642
416	PRWR95B	RIO CANAS	3	Pasture	1538.326
416	PRWR95B	RIO CANAS	4	Wetland	0
416	PRWR95B	RIO CANAS	5	Barren	9.341
416	PRWR95B	RIO CANAS	6	Urban_HighD_Per	12.5655
416	PRWR95B	RIO CANAS	7	Urban_LowD_Per	726.57375
416	PRWR95B	RIO CANAS	8	Urban_HighD_Imp	12.5655
416	PRWR95B	RIO CANAS	9	Urban_LowD_Imp	242.19125
417	PRUNNAMED1	UNNAMED 1	0	Water	59.803
417	PRUNNAMED1	UNNAMED 1	1	Forest	1420.811
417	PRUNNAMED1	UNNAMED 1	2	Agriculture	0.222
417	PRUNNAMED1	UNNAMED 1	3	Pasture	849.019
417	PRUNNAMED1	UNNAMED 1	4	Wetland	19.341
417	PRUNNAMED1	UNNAMED 1	5	Barren	120.272
417	PRUNNAMED1	UNNAMED 1	6	Urban_HighD_Per	292.121
417	PRUNNAMED1	UNNAMED 1	7	Urban_LowD_Per	530.88675
417	PRUNNAMED1	UNNAMED 1	8	Urban_HighD_Imp	292.121
417	PRUNNAMED1	UNNAMED 1	9	Urban_LowD_Imp	176.96225
418	PRUNNAMED3	UNNAMED 3	0	Water	0
418	PRUNNAMED3	UNNAMED 3	1	Forest	31.384
418	PRUNNAMED3	UNNAMED 3	2	Agriculture	0
418	PRUNNAMED3	UNNAMED 3	3	Pasture	225.257
418	PRUNNAMED3	UNNAMED 3	4	Wetland	31.83
418	PRUNNAMED3	UNNAMED 3	5	Barren	3.339
418	PRUNNAMED3	UNNAMED 3	6	Urban_HighD_Per	9.6825
418	PRUNNAMED3	UNNAMED 3	7	Urban_LowD_Per	0.33375
418	PRUNNAMED3	UNNAMED 3	8	Urban_HighD_Imp	9.6825
418	PRUNNAMED3	UNNAMED 3	9	Urban_LowD_Imp	0.11125
419	PRUNNAMED4	UNNAMED 4	0	Water	0.222
419	PRUNNAMED4	UNNAMED 4	1	Forest	85.957
419	PRUNNAMED4	UNNAMED 4	2	Agriculture	0
419	PRUNNAMED4	UNNAMED 4	3	Pasture	116.527
419	PRUNNAMED4	UNNAMED 4	4	Wetland	1.772
419	PRUNNAMED4	UNNAMED 4	5	Barren	8.861
419	PRUNNAMED4	UNNAMED 4	6	Urban_HighD_Per	51.507
419	PRUNNAMED4	UNNAMED 4	7	Urban_LowD_Per	13.6245

Subbasin	Assessment Unit Code	Assessment Unit Name	Landuse Code	Landuse Description	Area (Acres)
419	PRUNNAMED4	UNNAMED 4	8	Urban_HighD_Imp	51.507
419	PRUNNAMED4	UNNAMED 4	9	Urban_LowD_Imp	4.5415