Precipitation-Runoff and Streamflow-Routing Models for the Willamette River Basin, Oregon

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95–4284

Prepared in cooperation with
OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY

Cover photograph. Cottonwood seeds float on the Willamette River looking upstream between Harrisburg and Eugene (at river mile 169), June 24, 1993. (Photograph by Dennis A. Wentz, U.S. Geological Survey.)

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By ANTONIUS LAENEN and JOHN C. RISLEY

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1997

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CONVERSION FACTORS

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
inch	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

Temperature in degrees Celsius (^oC) may be converted to degrees Fahrenheit (^oF) as follows:

$$^oF = (1.8\ ^oC) + 32$$

Temperature in degrees Fahrenheit (^oF) may be converted to degrees Celsius (C) as follows:

$$C = (^oF-32)/1.8$$

Sea level: In this report “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

GLOSSARY

Acronym definitions (all other acronyms used in this report are parameters used in the Precipitation-Runoff Modeling System [PRMS] and definitions can be found in Appendix 3.)

Acronym	Description
ADCP	Acoustic Doppler Current Profiler, used to measure streamflow.
AML	Arc Macro Language, used in executing ARC commands.
ANNIE	A computer program for interactive hydrologic analyses and data management.
ARC-INFO	Geographic Information System by ESRI, Inc., ARC is the interactive spatial data processing program, and INFO is the relational data-base program.
ASCII	American Standard Code for Information Interchange.
BLTM (CBLTM)	Branched Lagrangian Transport Model, a computer model that simulates the transport of water-quality constituents.
DAFLOW	Diffusion Analogy Flow model, a one-dimensional unsteady-state streamflow computer model.
DEM	Digital Elevation Model, a computer file with regularly spaced x, y, and z coordinates where z represents elevation.
EWEB	Eugene Water and Electric Board, a city agency.
GIS	Geographic Information System.
HEC-5	Hydrologic Engineering Center—Fifth model, a one-dimensional unsteady-state streamflow computer model.
HRU	Hydrologic Response Unit, the basic area unit of the PRMS model.
NAWQA	National Water-Quality Assessment program of the Water Resources Division of the U.S. Geological Survey.
NMD	National Mapping Division, of the U.S. Geological Survey.
NRCS	Natural Resources Conservation Service of the Department of Agriculture.
NWS	National Weather Service of the National Oceanic and Atmospheric Administration.
ODEQ	Oregon Department of Environmental Quality.
PRMS	Precipitation-Runoff Modeling System, a physical-process watershed computer model.
RM	River Mile.
SSARR	Streamflow Simulation and Reservoir Regulation model, an empirically based watershed computer model.
SWSTAT	Surface-water statistical package in ANNIE.
USACE	U.S. Army Corps of Engineers.
USGS	The Water Resources Division of the U.S. Geological Survey.
WATSTORE	A public data base of water information supported by USGS.
WDM	Water Data Management file used in ANNIE.IOWDM is an input-output program used in conjunction with the WDM files.

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Precipitation-Runoff and Streamflow-Routing Models for the Willamette River Basin, Oregon

By Antonius Laenen *and* John C. Risley

Abstract

Precipitation-runoff and streamflow-routing models were constructed and assessed as part of a water-quality study of the Willamette River Basin. The study was a cooperative effort between the U.S. Geological Survey (USGS) and the Oregon Department of Environmental Quality (ODEQ) and was coordinated with the USGS National Water-Quality Assessment (NAWQA) study of the Willamette River. Routing models are needed to estimate streamflow so that water-quality constituent loads can be calculated from measured concentrations and so that sources, sinks, and downstream changes in those loads can be identified. Runoff models are needed to estimate ungaged-tributary inflows for routing models and to identify flow contributions from different parts of the basin. The runoff and routing models can be run either separately or together to simulate streamflow at various locations and to examine streamflow contributions from overland flow, shallow-subsurface flow, and ground-water flow.

The 11,500-square-mile Willamette River Basin was partitioned into 21 major basins and 253 subbasins. For each subbasin, digital data layers of land use, soils, geology, and topography were combined in a geographic information system (GIS) to define hydrologic response units (HRU's), the basic computational unit for the Precipitation-Runoff Modeling System (PRMS). Spatial data layers were also used to calculate noncalibrated PRMS parameter values. Other PRMS parameter values were obtained from 10 nearby calibrated subbasins of representative location and character.

About 760 miles of the Willamette River system were partitioned into 4 main-stem networks and 17 major tributary networks for streamflow routing. Data from time-of-travel studies, discharge measurements, and flood analyses were used to develop equations that related stream cross-sectional area to discharge and stream width to discharge. These relations were derived for all 21 stream networks at approximately 3-mile intervals and used in the Diffusion Analogy Flow model (DAFLOW) in streamflow routing.

Ten representative runoff models and 11 network-routing models were calibrated for water years 1972–75 and verified for water years 1976–78. These were the periods with the most complete and widespread streamflow record for the Willamette River Basin. Observed and estimated daily precipitation and daily minimum and maximum air temperature were used as input to the runoff models. The resulting coefficient of determination (R^2) for the representative runoff models ranged from 0.69 to 0.93 for the calibration period and from 0.63 to 0.92 for the verification period; absolute errors ranged from 18 to 39 percent and from 27 to 51 percent, respectively. Bias error for the runoff modeling ranged from +13 to -32 percent. Observed daily streamflow data were used as input to the

network-routing models where available, and simulated streamflows from runoff model results were used for ungaged areas. Absolute error for the network-routing models ranged from about 21 percent for the Molalla River model, for which 70 percent of the subbasin was ungaged, to about 4 percent for the Willamette main-stem model (Albany to Salem), for which only 9 percent of the subbasin was ungaged.

With an input of current streamflow, precipitation, and air temperature data the combined runoff and routing models can provide current estimates of streamflow at almost 500 locations on the main stem and major tributaries of the Willamette River with a high degree of accuracy. Relative contributions of surface runoff, subsurface flow, and ground-water flow can be assessed for 1 to 10 HRU classes in each of 253 subbasins identified for precipitation-runoff modeling. Model outputs were used with a water-quality model to simulate the movement of dye in the Pudding River as an example application in the Willamette River Basin.

INTRODUCTION

In 1991, the U.S. Geological Survey (USGS) began a cooperative program with the Oregon Department of Environmental Quality (ODEQ) to study water quality in the main stem and major tributaries of the Willamette River. The program was part of a larger study that included participation by ODEQ, USGS, a private consultant, and Oregon State University. The larger ODEQ study (Tetra Tech, Inc., 1993) is intended to provide information on dissolved oxygen, nutrients, algae, toxics, bacteria, point and nonpoint pollution sources, sediments, river ecology, and river flow. The information from the ODEQ study, in turn, will provide a foundation for future long-term work and management decisions on water-quality issues in the basin.

The USGS cooperative program with ODEQ consisted of three parts: (1) a streamflow simulation using precipitation-runoff and streamflow-routing models, (2) an analysis of sediment transport (Laenen, 1995), and (3) a reconnaissance-level determination of contaminants. This report describes the development of models for streamflow simulation. The existing models have not been fully calibrated for use in water-quality assessment; however, they can be used to supply the required hydrologic inputs for future water-quality modeling.

The USGS program was also designed to complement the USGS Willamette National Water-Quality Assessment (NAWQA) study that began in fiscal year 1993. The Willamette Basin is one of 60 basins in the Nation that will be studied by NAWQA. NAWQA is designed to describe the status of and trends in the Nation's ground- and surface-water resources and to provide a sound understanding of the natural and human factors that affect the quality of these resources. The NAWQA intends to integrate information at different spatial scales—local, study unit, regional, and national—and will focus on water-quality conditions that affect large areas or are recurrent on the local scale.

Background

A large quantity of streamflow data is available for the Willamette River Basin, and two previously developed streamflow-simulation models are regularly used to simulate flows in the basin. Most streamflow routing in the basin has been done by the National Weather Service (NWS) and the U.S. Army Corps of Engineers (USACE). The NWS uses the Streamflow Synthesis and Reservoir Regulation (SSARR) model (U.S. Army Corps of Engineers, 1975) for flood prediction purposes. The USACE primarily uses Hydrologic Engineering Center—Fifth Model (HEC–5) (U.S. Army Corps of Engineers, 1982) for through-reservoir streamflow routing and testing.

The existing models are intended for flood routing and are satisfactory for this purpose, but they are less satisfactory for water-quality applications. The existing models do not adequately define the complex hydrology of the basin or identify effects of human activities other than reservoir regulation, do not have hydraulic-flow equations, they do not link precipitation runoff to physical properties in the basin, and have not been calibrated to low-streamflow conditions because low-flow data are missing for critical locations.

Current SSARR and HEC models provide very usable high-flow simulations but cannot provide a conceptual understanding of the physical flow system. The precipitation-runoff component of the SSARR model simulates the streamflow response to precipitation by means of simple equations that represent surface flow by using hypothetical reservoirs that do not account for surface topology and represent subsurface and ground-water flow by using hypothetical reservoirs that do not account for soil infiltration. These equations are empirically fit to observed peak flows. Flow sources can be empirically simulated by the equations, but the equations do not adequately represent the physical environment. For example, soil characteristics change due to freezing or extreme drying conditions, and the hydrologic response varies markedly. Models based entirely on empirical fitting require different calibrations for different soil conditions. Thus, the precipitation-runoff component of the SSARR model cannot simulate variations of hydrologic response in a basin and, for most situations, cannot be used to predict changes in hydrology caused by either natural or anthropogenic changes. Stream and reservoir routing in the currently calibrated SSARR and HEC models is done by Muskingum (McCarthy, 1938) or other storage-routing techniques, which treat a river segment as a reservoir (using inflow and outflow relations); this technique limits the model's capability to relate streamflow to physical changes of the channel. Routing of sediment and contaminant fluxes cannot be accomplished by this simplified streamflow-routing scheme, because particle transport is not described by a physically based model component such as water velocity.

The Precipitation-Runoff Modeling System (PRMS) (Leavesley and others, 1983) was used in the study for simulation of runoff, and the Diffusion Analogy FLOW model (DAFLOW) (Jobson, 1980) was used for in-channel streamflow routing. In contrast to the precipitation-runoff component of SSARR, a physical-process model such as PRMS can be used to answer questions regarding the physical effects of human activities on basin hydrology. In contrast to the streamflow-routing component of SSARR and HEC–5, DAFLOW can be used to determine local velocity information and to simulate both the attenuation of a flood wave and the dispersion of a water-quality constituent needed to describe transport for water-quality models.

Purpose and Scope

The purpose of this study was to construct flow-routing (routing) models capable of driving a water-quality transport model for the Willamette River Basin and to construct precipitation-runoff (runoff) models based on physical properties of the basin that would simulate runoff from ungaged areas and would be capable of helping assess natural and anthropogenic processes that affect streamflow and stream water quality. As part of the overall purpose, this report (1) describes the construction and verification of the runoff and routing models specifically developed as a precursor for water-quality modeling, (2) presents an example of model use in a water-quality application, and (3) provides a guide to creating and using files for modeling.

This study was the beginning of a larger effort to build a comprehensive understanding of water quality in the Willamette River Basin. The study was designed to be open-ended, providing only the hydrology needed to drive a water-quality model. No work was done to collect data from or to model the 26.5-miles tidal reach of the Willamette River from Willamette Falls to the mouth, although tributary streams to this reach of the river were modeled.

Approach

Study elements were as follows: (1) collection of data to supplement existing low streamflow information, (2) assembly of spatial data defining hydrologic response units for runoff models, (3) assembly of time-series climate and streamflow data to calibrate and verify the model parameter values, (4) definition of uncalibrated runoff-model parameters from digital spatial data layers, (5) calibration of other parameter values using data from unregulated basins—the resulting values to be used for flow simulation in ungaged basins, (6) development of stream channel cross-sectional-area and width relations from time-of-travel measurements and other flow information, (7) division of the Willamette River Basin into 21 major basins and corresponding stream-routing networks, (8) construction and verification of selected routing-network models, and (9) application of a water-quality model using output from one of the networks.

The following low streamflow data were collected to determine spatial and temporal hydraulic properties and their relation to the stream system: (1) time-of-travel measurements, made by using dye-tracing techniques on seven tributary reaches of the Willamette River previously unmeasured by Harris (1968) and on the main stem of the Willamette River between Harrisburg and Peoria to verify the work of Harris, and (2) gain-loss (seepage) measurements, made on the main stem at base-flow periods in the spring and in late summer to better define ground-water flow contributions to streams of the Willamette River Basin.

Spatial data layers of land use, soils, geology, topography, and precipitation were used to define the basic computational unit for PRMS—the unique hydrologic response unit (HRU). The Willamette River Basin was partitioned into 21 major tributary basins, each defining a major tributary inflow to the main stem or an intervening segment between major tributary inflows. The major tributary basins were further divided into 253 subbasins. Each subbasin had from 2 to 12 individual HRU's, which collectively numbered approximately 1,000 basinwide.

To obtain the most complete data set for model calibration and verification, time-series climate and streamflow data were assembled for water years 1972–78. This period had the greatest number of operational stream-gaging stations in the Willamette River Basin. Daily precipitation and air temperature data were compiled for 52 weather stations, and daily streamflow data were compiled for 31 streamflow stations. Hourly hydrographs for 5 major storms for 22 of the stream-gaging-station locations were also compiled for subsequent use in storm modeling.

A computer program was written to convert spatial-data coverage information into specific PRMS model parameter values. Spatial data were input to a geographic information system (GIS) that was used to define average annual precipitation (and subsequently, to compute a precipitation weighting factor for each HRU for application to observed data from a specific rain gage location) and physiographic parameters such as elevation, slope, aspect, soil, vegetation, geology, and total drainage area for each HRU. Tables were used to cross reference specific physical model-parameter values related to interception, evapotranspiration, infiltration, and runoff to codes identified in the HRU data layer. For each subbasin or tributary basin, 43 parameter values for each HRU were written to a file used by the runoff model.

To determine PRMS parameter values for ungaged areas, runoff models for 10 unregulated basins that have historic streamflow records were calibrated. The PRMS user's manual (Leavesley and others, 1983) should be used with this report documentation to fully understand the precipitation-runoff models used in the study. Most model parameters had values that were assigned on the basis of geographic information and field and laboratory data; however, 11 model parameters were optimized during model calibration. Five of the optimized parameters were given regionally constant values, but values for five other parameters describing subsurface and ground-water flow were obtained by using values from the calibration basin having characteristics that best matched the characteristics of the ungaged basin. The remaining parameter value was an overall adjustment to rainfall to accommodate the water balance and was applied in addition to the individual HRU precipitation adjustment.

Equations that relate cross-sectional area and width to discharge were defined for stream-reach segments located at approximately 3-mile intervals on the main stem and all major tributaries of the Willamette River. The form of these equations is given in Appendix 1. Time-of-travel measurements define cross sections at low flow, when pools and riffles are the hydraulic controls. Cross sections measured at stream-gaging-station locations and for flood reports (U.S. Army Corps of Engineers, 1968–1972) define high flow conditions when channel roughness is the primary hydraulic control. Approximately 760 miles of main stem and tributary geometry was described at intervals of about 3 miles (Appendix 1).

Streamflow-routing models were constructed using the Diffusion Analogy Flow model (DAFLOW) (Jobson, 1989) to simulate the different stream networks in the Willamette River Basin. In running DAFLOW, it was necessary to define inflow hydrographs at the upstream boundary of the network and all tributary and diversion hydrographs at intermediate points. Upstream boundary hydrographs were from existing stream-gaging-station data, and tributary hydrographs were from runoff-model simulations of tributary basins. The user's manual for DAFLOW (Jobson, 1989) should be used in conjunction with this report to fully understand the flow-routing system. Eleven network models, each consisting of several precipitation-runoff models linked to a streamflow-routing model, were constructed and verified.

As an example application for water-quality simulation, the Branched Lagrangian Transport Model (BLTM) (Jobson and Schoellhamer, 1987) was calibrated and used to simulate dye concentrations. Dye concentration data were from time-of-travel studies. Flow hydrographs used in simulations were from streamflow-routing and precipitation-runoff models.

Study Area Description

The Willamette River Basin (fig. 1) has an area of approximately 11,500 mi^2 (square miles) and contains the State's four largest cities, Portland, Eugene, Salem, and Gresham. About 2 million people, representing 69 percent of the State's population (1990 census), live in the basin. The basin supports an economy based on agriculture, manufacturing, timber, and recreation and contains extensive fish and wildlife habitat.

The Willamette River Basin has a temperate marine climate characterized by dry summers and wet winters. About 80 percent of the normal precipitation falls between October and May. Mean annual precipitation ranges from about 40 inches in the Willamette Valley to 175 inches at crests in the Coast and Cascade Ranges (fig. 4). About 35 percent of the precipitation falls as snow at the 4,000 ft (foot) elevation, and more than 75 percent falls as snow at 7,000 ft. Because the basin is largely dominated by maritime air, both annual and diurnal temperature ranges are relatively small. In the Willamette River Basin, the average annual temperature ranges between 40^{o}F (degrees Fahrenheit) and 65^{o}F (primarily dependent on elevation), with an average daily minimum of 30^{o}F in January and an average daily maximum of 80^{o}F in July at lower elevations in the valley.

The basin is bounded on the west by the Coast Range, on the east by the Cascade Range, on the south by the Calapooya Mountains, and on the north by the Columbia River. Elevations range from less than 10 ft above sea level near the Columbia River to more than 10,000 ft in the Cascade Range. The slopes and foothills of the Cascade Range account for more than 50 percent of the basin area. The Willamette Valley, generally considered the part of the basin below 500 ft, is about 30 miles wide and 117 miles long and represents about 30 percent of the basin area. The mountains of the Coast Range, reaching elevations of about 4,000 ft, make up the remaining 20 percent of the basin area. About 20 percent of the basin is above 4,000 ft, which is considered the lower limit of the transient snow zone.

On the basis of physiography (Fenneman, 1931) and geology (Baldwin, 1981), the Willamette River Basin can be divided into three north-south-trending provinces: the Cascade Range, the Coast Range, and the Willamette Valley. The Cascade Range is composed of volcanic rocks, consisting of (1) Tertiary basaltic and andesitic rocks together with volcanic debris, primarily in the western part of the range, and (2) Quaternary basaltic and andesitic lava flows, primarily in the high Cascade Range. The Coast Range is composed of Tertiary marine sandstone, shale, and mudstone interbedded with volcanic basalt flows and volcanic debris. Much of the terrain in the Willamette Valley up to an elevation of about 400 ft is covered by sandy to silty terrace deposits that settled from water ponded in a great glaciofluvial lake (Glenn, 1965; Allison, 1978). Alluvial deposits that border existing rivers and form alluvial fans near river mouths were derived from the surrounding mountains, and they consist of intermingled layers of clay, silt, sand, and gravel.

The main stem of the Willamette River is formed by the confluence of the Coast and Middle Forks near Eugene and flows 187 miles to the Columbia River. The main stem can be divided into four distinct reaches whose physical characteristics govern the hydraulics of flow. The upper reach extends from Eugene to Albany, river mile (RM) 187 to 119, and is characterized by a meandering and braided channel with many islands and sloughs. The river is shallow and the bed is composed almost entirely of cobbles and gravel which, during the summer, are covered with biological growth. The middle reach extends from Albany to the mouth of the Yamhill River, RM 119 to 55, and is characterized by a meandering channel deeply incised into the valley. The river is deeper and has fewer gravel bars exposed in the summer compared to the upper reach. The Newberg Pool reach extends from RM 55 to Willamette Falls at RM 26.5. Hydraulically, the deep, slow-moving pool can be characterized as a reservoir. The pool is a depositional area for small gravel- to silt-sized material. Gravels are regularly mined from the streambed, and about 6.5 million cubic yards have been removed over the last 20 years (USACE, Portland District, Navigation Section, written commun., 1992). Willamette Falls is a 50-ft high natural falls; flashboards are used to control pool elevation during summer low flow. The tidal reach, from RM 26.5 to the mouth, is affected by tides and, during spring and early summer, by backwater from the Columbia River. The tidal reach was not modeled in this study.

The Willamette River Basin has 11 major reservoirs (fig. 1); their combined usable capacity is nearly 1.9 million acre-feet. The reservoirs are designed for multipurpose use, but their primary, legally designated function is the maintenance of a minimum navigable

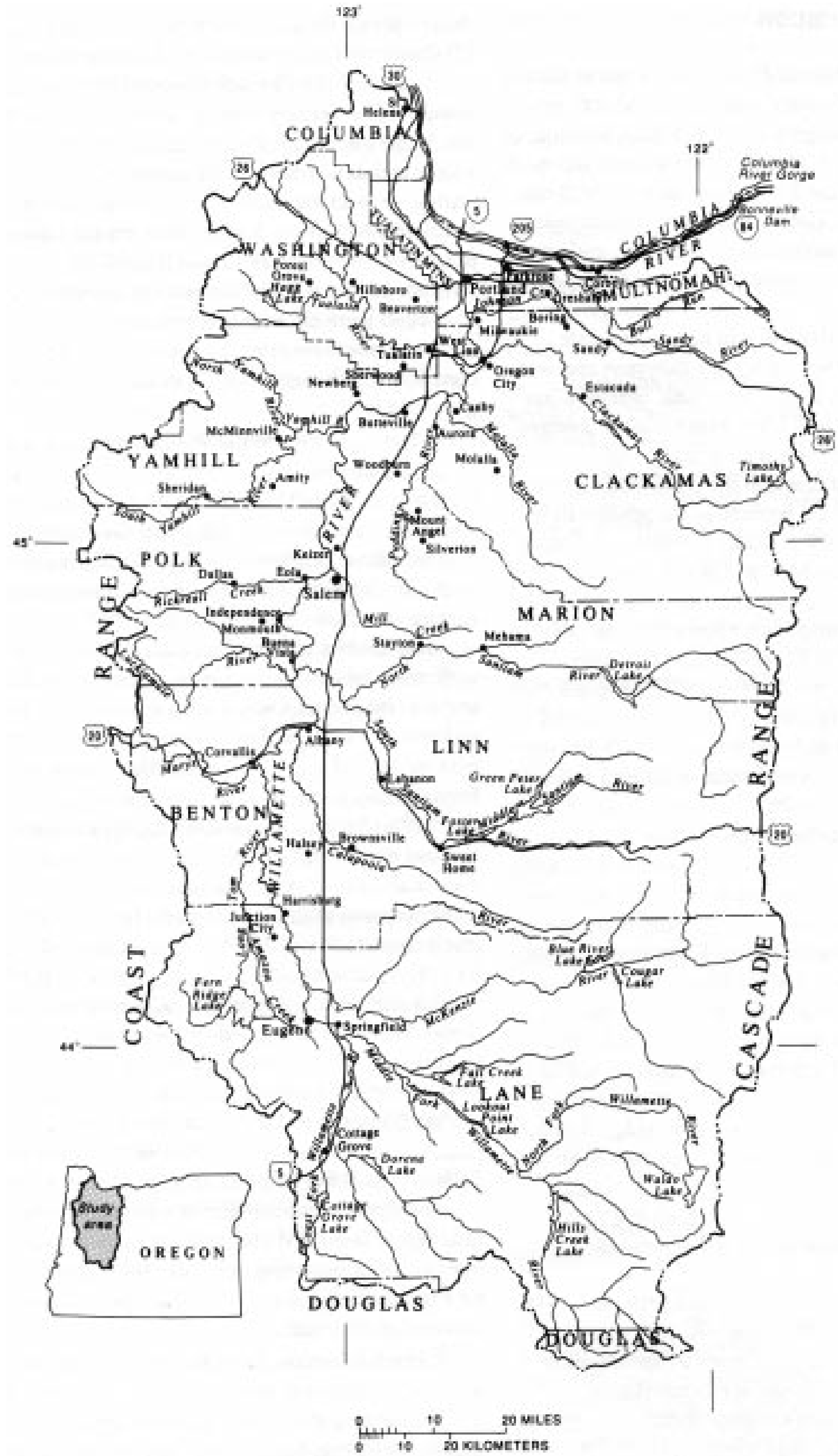


Figure 1. Willamette River Basin, Oregon.

depth during the summer (Willamette Basin Task Force, 1969). The required minimum flow for navigation is 6,000 ft^3/s (cubic feet per second) at Salem. Most of the flow in the Willamette River occurs from November to March as a result of persistent winter rainstorms and spring snowmelt. Snowmelt supplies about 35 percent of the annual runoff, either directly to the stream or indirectly through the ground-water system. Reservoir regulation affects the magnitude of low flows in the Willamette River and curtails the period of low flow, which typically occurred from mid-July through mid-October prior to regulation, but since regulation occurs from mid-July through mid-August. Increased flows in mid-August through mid-October are utilized to facilitate anadromous fish runs.

Acknowledgments

The authors wish to acknowledge the help of Jim Wilkinson of the U.S. Geological Survey in Portland, Oregon, for writing an Arc Macro Language (AML) program that converts spatial coverage information to PRMS parameter values. This program is included in Appendix 2 of this report. In acknowledgment, we wish to thank George Taylor, the State Climatologist at Oregon State University, for his prompt response to our requests for weather reports and climatological data. We also wish to thank Bob Baumgartner of ODEQ for his help in planning the study.

PRECIPITATION-RUNOFF MODELS

Precipitation-runoff modeling was used in the study to provide simulated inflows from ungaged basins to use in conjunction with gaged inflows to drive flow routing in stream-network simulations using the DAFLOW streamflow-routing model. PRMS runoff and DAFLOW simulated streamflow are the hydrologic drivers of the BLTM water-quality models.

Description of Precipitation-Runoff Modeling System

PRMS is a physical-process, deterministic, distributed-parameter modeling system designed to analyze the effects of precipitation, climate, and land use on streamflow and general basin hydrology (Leavesley and others, 1983). “Physical process” refers to the use of described mathematical equations to simulate processes such as precipitation, snowmelt, evaporation, evapotranspiration, interception, and infiltration. “Deterministic” refers to the process of calculation from a sequence of causes not characterized by a probability function by forcing the model to solve a given set of equations that have no random component. “Distributed parameter” refers to the capability to represent the watershed as a collection of hydrologically similar areas, each with a unique set of physical-parameter values. The model is not considered fully distributed because the similar areas are not contiguous and thus have a distribution not represented within the individual watershed.

Heterogeneity within the basin is accounted for by partitioning the basin into specific areas on the basis of elevation, slope, aspect, land use, soil type, geology, and precipitation distribution. Each specific area, assumed to be hydrologically homogeneous, is designated a HRU. A water-energy balance is computed during each time step for each HRU and for the entire basin. No channel routing is performed within the HRU’s in the mode of operation (daily time step) used with PRMS for this study.

In PRMS, the basin is conceptualized as a series of reservoirs, which are illustrated as boxes in figure 2. The model generates a water-energy balance for each component of the hydrologic cycle for each time step during the simulation. PRMS can be operated in two modes—daily and storm. For this study, only the daily mode of operation was used. For our application, the model input variables were daily precipitation and minimum and maximum daily air temperatures. For other applications, other measured parameters, such as pan evaporation or solar radiation, can be used to determine evapotranspiration in the model. Model output variables can be obtained for each reservoir component of each HRU, including streamflow at the basin outlet, and are simulated as daily mean and total values. Streamflow is the sum of the various reservoir contributions. System inputs of precipitation and temperature drive the processes of evaporation, transpiration, snowfall and snowmelt, and sublimation.

Gross precipitation is reduced by interception and becomes net precipitation, which falls on a basin surface that is defined as pervious or impervious. Water enters the soil zone in the pervious areas as a result of infiltration. The soil is represented as a two-layered system. Evaporation and transpiration deplete moisture from the upper or recharge zone, which is

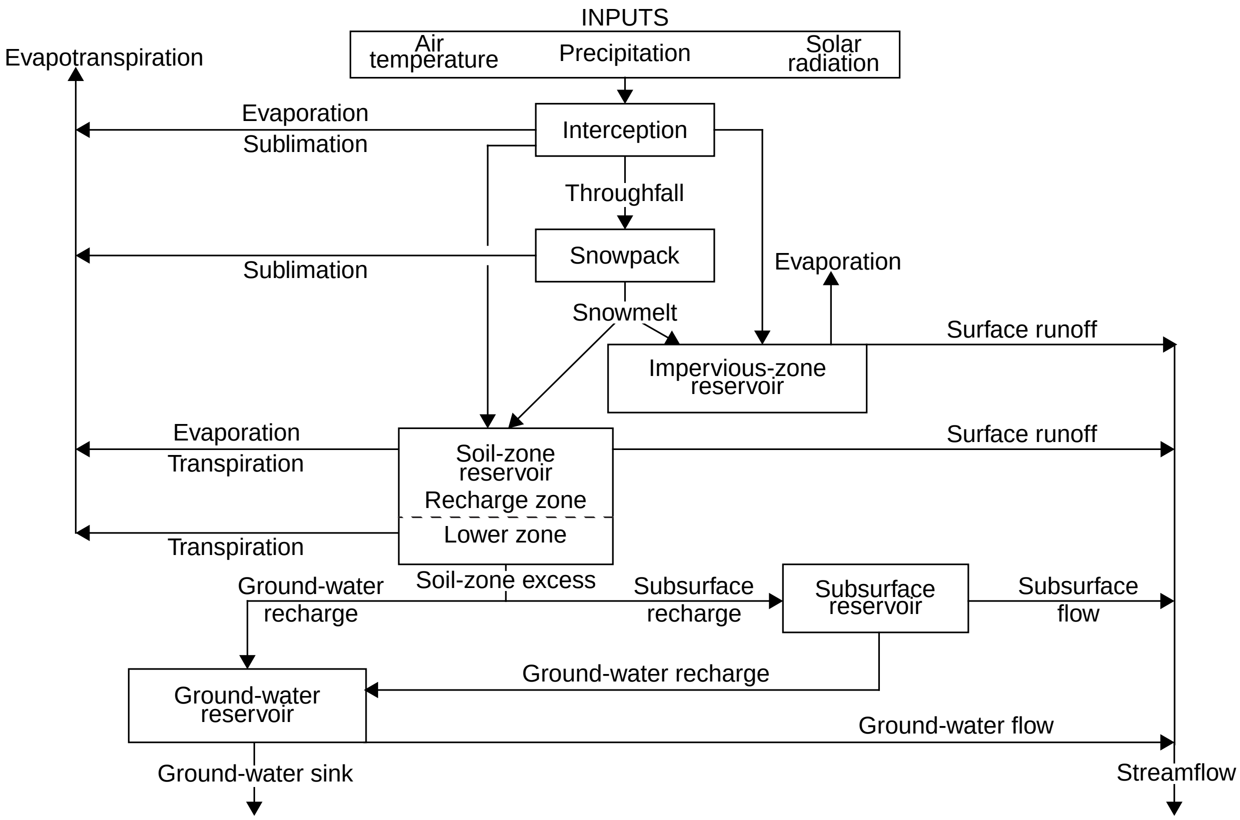


Figure 2. Flow diagram of the Precipitation-Runoff Modeling System conceptual model.

user defined by depth and water-storage characteristics. Transpiration depletes moisture only in the lower zone, the depth of which is based on the rooting depth of the predominant vegetation type. Surface retention of water on impervious zones is modeled as a reservoir. A maximum retention-storage capacity for this zone must be satisfied before surface discharge can occur. When free of snow, the reservoir is depleted by evaporation.

Computation of infiltration is dependent on whether the input source is rain or snowmelt. For rain falling on ground with no snow cover, the infiltration is computed as a function of soil characteristics, antecedent soil-moisture conditions, and storm size. Surface runoff is computed using the contributing- or variable-source area approach, where a dynamic source area expands and contracts according to rainfall characteristics and the capability (field capacity) of the soil mantle to store and transmit water (Troendle, 1985). As rainfall continues and the ground becomes wetter, the proportion of precipitation diverted to surface runoff increases, while the proportion that infiltrates to the soil zone and subsurface reservoir decreases. Daily infiltration (net precipitation less surface runoff) can be computed as either a linear or a nonlinear function of antecedent soil moisture and rainfall.

For snowmelt, and for rain falling on a snowpack, all water is assumed to infiltrate until field capacity of the soil is reached. At field capacity, any additional snowmelt is apportioned between infiltration and surface runoff. Snowmelt in excess of this capacity contributes to surface runoff. Infiltration in excess of field capacity is first used to satisfy recharge to the ground-water reservoir. Recharge to the ground-water reservoir is assumed to have a maximum daily limit. Excess infiltration, after ground-water recharge has been satisfied, will recharge the subsurface reservoir. Water available for infiltration as the result of rain-on-snow is treated as snowmelt if the snowpack is not depleted or as rain if the snowpack is depleted.

Input to the subsurface component is water from the soil zone in excess of field capacity. Subsurface moisture can percolate to the shallow ground-water component or move downslope to some point of discharge above the water table. In the model, the rate of subsurface flow from this reservoir is computed using the storage volume of the reservoir and two user-defined routing coefficients.

The ground-water reservoir is defined as a linear system and is the source of baseflow. Recharge can originate from the soil zone (in excess of field capacity) and from the subsurface reservoir. Contributions from the subsurface reservoir are computed daily as a function of a recharge-rate coefficient and the volume of water stored in that reservoir. Movement of ground water out of the system boundaries is accomplished by routing to a ground-water sink.

Many of the equations used in the model require coefficients that can be estimated directly from known or measurable basin characteristics. A few empirical parameter values, however, can be estimated only by calibration to observed data. These parameters are primarily associated with subsurface and ground-water reservoirs and snowpack-energy computations.

Time-Series Data

Daily total precipitation and maximum and minimum air temperature time-series data were used as PRMS model input data for 10 representative basin models and for 11 streamflow-routing-network simulations. Daily mean discharge data were used to calibrate and verify model simulations for the representative basins and was used as both input and verification for the streamflow-routing-network simulations. With the exception of three streamflow-routing-network simulations (Johnson Creek, McKenzie River, and Willamette River from Salem to Wilsonville), all model simulations in the study used data from water years 1972 through 1978. For the calibration basins, the first 4 years were used for model calibration, and the remaining 3 years were used for model verification.

Precipitation

Precipitation data were provided by the Office of the State Climatologist, located at Oregon State University in Corvallis, Oregon. The data are from a statewide climate data inventory compiled by the State Climatologist (Redmond, 1985). Most of the precipitation data were collected under the auspices of the National Weather Service Cooperative Program. Standardized NWS collection equipment was provided to the program participants. The location names, identification number, latitude and longitude, and elevations of the climate-data stations used in this study are shown in table 1; site locations are shown in figure 3. Nine of these 54 precipitation-data records contained missing values, which were estimated by using linear regression equations that incorporated records of neighboring stations.

Air Temperature

Daily maximum and minimum air temperature data were also provided by the State Climatologist and collected by the NWS. Most of the climate stations listed in table 1 had daily maximum and minimum air temperature records for the model simulation time periods. Twenty of both maximum and minimum air temperature data records out of 54 total records contained some missing values. As with precipitation data, the missing values were estimated using linear regression relations as correlated to records of neighboring stations.

Discharge

Daily mean discharge values for the 30 gaging stations listed in table 2 were used for both runoff and routing models. Station locations are shown in figure 3. All gaging stations were operated by the USGS for the data time periods used in the model simulations. The data were collected according to standard techniques of the USGS (Rantz, 1982). Complete records of daily streamflow are available in USGS annual water-data publications. The flow data used in the precipitation-runoff-model calibration reflect little or no flow regulation.

Delineation of Basin Physical Characteristics

PRMS allows the user to define hydrologic response variations over the basin surface (Leavesley and others, 1983). The entire Willamette River Basin was partitioned into “homogeneous” HRU’s using characteristics such as soil type, land use (vegetation type), slope, aspect, and geology. The five data layers of different land-surface data and precipitation distribution were assembled using ARC-INFO, a geographic information system (GIS) software package. The HRU’s were defined after merging these data layers into a composite data layer.

Data layers used for creating the HRU’s included average annual precipitation, basin and subbasin delineations, land use, slope, aspect, surficial geology, and soils. The data layer categories used in the study and

Table 1. Climate stations used to collect data for input to precipitation-runoff and streamflow-routing models of the Willamette River Basin, Oregon

[Map numbers refer to figure 3; ^{o}, degrees; ’, minutes; ”, seconds]

Map number	Station name	Station number[1]	Station location (Latitude	–	Longitude)	Elevation (feet)
1	Aurora	sod350343	45^{o}14’0”	–	122^{o}45’0”	720
2	Beaverton SSW	sod350595	45^{o}30’0”	–	122^{o}49’0”	150
3	Bellfountain	sod350673	44^{o}22’0”	–	123^{o}21’0”	320
4	Blackbutte	sod350781	43^{o}35’0”	–	123^{o}4’0”	970
5	Bonneville Dam	sod350897	45^{o}38’0”	–	121^{o}57’0”	60
6	Cascadia	sod351433	44^{o}24’0”	–	122^{o}29’0”	860
7	Clatskanie	sod351643	46^{o} 6’0”	–	123^{o}17’0”	22
8	Corvallis OSU	sod351862	44^{o}38’0”	–	123^{o}12’0”	225
9	Corvallis Water	sod351877	44^{o}31’0”	–	123^{o}27’0”	592
10	Cottage Grove 1S	sod351897	43^{o}47’0”	–	123^{o}4’0”	650
11	Cottage Grove Dam	sod351902	43^{o}43’0”	–	123^{o}3’0”	831
12	Dallas	sod352112	44^{o}56’0”	–	123^{o}19’0”	290
13	Dilley	sod352325	45^{o}29’0”	–	123^{o}7’0”	165
14	Dorena Dam	sod352374	43^{o}47’0”	–	122^{o}58’0”	820
15	Eagle Creek	sod352493	45^{o}17’0”	–	122^{o}12’0”	930
16	Estacada	sod352693	45^{o}16’0”	–	122^{o}19’0”	410
17	Eugene WSOAP	sod352709	44^{o}7’0”	–	123^{o}13’0”	364
18	Fern Ridge Dam	sod352867	44^{o}7’0”	–	123^{o}18’0”	485
19	Forest Grove	sod352997	45^{o}32’0”	–	123^{o}6’0”	180
20	Foster Dam	sod353047	44^{o}25’0”	–	122^{o}40’0”	550
21	Glenwood	sod353318	45^{o}39’0”	–	123^{o}16’0”	640
22	Gresham	sod353521	45^{o}30’0”	–	122^{o}26’0”	310
23	Haskins Dam	sod353705	45^{o}19’0”	–	123^{o}21’0”	756
24	Headworks	sod353770	45^{o}27’0”	–	122^{o}9’0”	748
25	Hillsboro	sod353908	45^{o}31’0”	–	122^{o}59’0”	160
26	Holley	sod353971	44^{o}21’0”	–	122^{o}47’0”	540
27	Lacomb	sod354606	44^{o}37’0”	–	122^{o}43’0”	520
28	Leaburg 1SW	sod354811	44^{o}6’0”	–	122^{o}41’0”	675
29	Lookout Point Dam	sod355050	43^{o}55’0”	–	122^{o}46’0”	712
30	McMinnville	sod355384	45^{o}14’0”	–	123^{o}11’0”	148
31	N. Willamette ES	sod356151	45^{o}17’0”	–	122^{o}45’0”	150
32	Noti	sod356173	44^{o}4’0”	–	123^{o}28’0”	450
33	Oregon City	sod356334	45^{o}21’0”	–	122^{o}36’0”	167
34	Portland KGW-TV	sod356749	45^{o}31’0”	–	122^{o}41’0”	160
35	Portland WSOAP	sod356751	45^{o}36’0”	–	122^{o} 36’0”	21
36	Rex	sod357127	44^{o}18’0”	–	122^{o}55’0”	520
38	Salem WSOAP	sod357500	44^{o}55’0”	–	123^{o}1’0”	195
39	Scotts Mills	sod357631	44^{o}57’0”	–	122^{o}32’0”	2,315
40	Silver Creek Falls	sod357809	44^{o}52’0”	–	122^{o}39’0”	1,350
41	Silverton	sod357823	45^{o}00’0”	–	122^{o}46’0”	408
42	Stayton	sod358095	44^{o}48’0”	–	122^{o}46’0”	470
43	Troutdale	sod358634	45^{o}34’0”	–	122^{o} 24’0”	29
44	Waterloo	sod359083	44^{o}30’0”	–	122^{o}49’0”	450
45	Belknap Springs	cnv0652	44^{o}18’0”	–	122^{o}2’0”	2,152
46	Detroit Dam	cnv2292	44^{o}43’0”	–	122^{o}15’0”	1,220
47	Government Camp	cnv3908	45^{o}18’0”	–	121^{o}45’0”	3,980
48	Marion Forks	cnv5221	44^{o}37’0”	–	121^{o}57’0”	2,480
49	McKenzie Bridge	cnv5362	44^{o}11’0”	–	122^{o}7’0”	1,478
50	Oakridge	cnv6213	43^{o}45’0”	–	122^{o}27’0”	1,275
51	Santiam Pass	cnv7559	44^{o}25’0”	–	121^{o}52’0”	4,748
52	Three Lynx	cnv8466	45^{o}7’0”	–	122^{o}4’0”	1,120
53	Valsetz	sod358833	44^{o}51’0”	–	123^{o}40’0”	1,150
54	Sisters	cnv7857	44^{o}17’0”	–	121^{o}33’0”	3,180

[1] State Climatologist station-identification number.

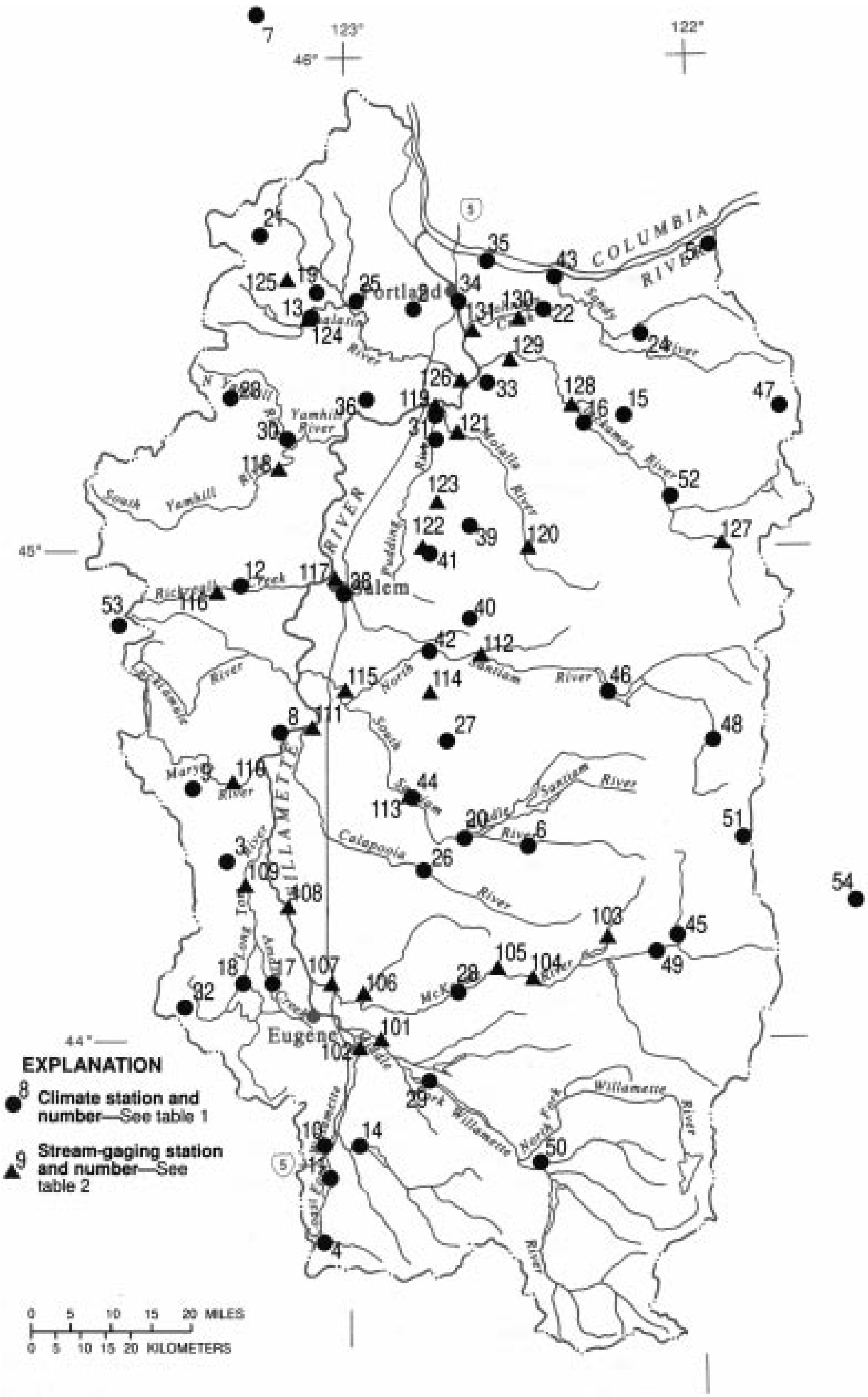


Figure 3. Location of climatological and hydrological stations in the Willamette River Basin, Oregon, used in this study. (Map numbers correspond to number in tables 1 and 2.)

Table 2. Stream-gaging stations used to collect data for input to precipitation-runoff and streamflow-routing models of the Willamette River Basin, Oregon
[Map numbers refer to figure 3; °, degrees;’, minutes; ”, seconds]

Map number	Station name	Station number [1]	Station location (Latitude – Longitude)
101	Middle Fork Willamette River at Jasper	14152000	43°59’55” – 122°54’20”
102	Coast Fork Willamette River near Goshen	14157500	43°58’50” – 122°57’55”
103	Lookout Creek near Blue River	14161500	44°12’35” – 122°15’20”
104	McKenzie River near Vida	14162500	44°07’30” – 122 28’10”
105	Gate Creek at Vida	14163000	44°08’45” – 122°34’15”
106	Mohawk River near Springfield	14165000	44°05’34” – 122° 57’20”
107	McKenzie River near Coburg	14165500	44°06’45” – 123°02’51”
108	Willamette River at Harrisburg	14166000	44°16’14” – 123°10’21”
109	Long Tom River at Monroe	14170000	44°18’50” – 123°17’45”
110	Marys River near Philomath	14171000	44°31’35” – 123°20’00”
111	Willamette River at Albany	14174000	44°38’20” – 123°06’20”
112	North Santiam River at Mehama	14183000	44°47’20” – 122°37’00”
113	South Santiam River at Waterloo	14187500	44°29’55” – 122°49’20”
114	Thomas Creek near Scio	14188800	44°42’42” – 122°45’55”
115	Santiam River at Jefferson	14189000	44°42’55” – 123°00’40”
116	Rickreall Creek near Dallas	14190700	44°54’55” – 123°23’02”
117	Willamette River at Salem	14191000	44°56’40” – 123°02’30”
118	South Yamhill River at Whiteson	14194000	45°10’08” – 123°12’25”
119	Willamette River at Wilsonville	14198000	45°17’57” – 122°45’ 00”
120	Molalla River above Pine Creek nr Wilhoit	14198500	45°00’35” – 122°28’45”
121	Molalla River near Canby	14200000	45°14’40” – 122°41’10”
122	Silver Creek at Silverton	14200300	45°00’34” – 122°47’15”
123	Butte Creek at Monitor	14201500	45°06’06” – 122°44’42”
124	Tualatin River near Dilley	14203500	45°28’30” – 123°07’23”
125	Gales Creek near Forest Grove	14204500	45°33’20” – 123°11’10”
126	Tualatin River at West Linn	14207500	45°21’03” – 122°40’30”
127	Clackamas River at Big Bottom	14208000	45°01’00” – 121°55’10”
128	Clackamas River at Estacada	14210000	45°18’00” – 122°21’10”
129	Clackamas River near Clackamas	14211000	45°23’36” – 122°31’54”
130	Johnson Creek at Sycamore	14211500	45°28’40” – 122°30’24”
131	Johnson Creek at Milwaukie	14211550	45°27’11” – 122°38’31”

[1] U.S. Geological Survey stream-gaging-station number.

their corresponding codes in the GIS are defined in table 3.

Precipitation—The precipitation data layer contained contour lines of annual precipitation. The map showing mean annual precipitation (fig. 4) was derived by Taylor (1993) from grid cell output of the Precipitation elevation Regressions on Independent Slopes Model (PRISM) (Daly and Neilson, 1994). PRISM is an analytical model that distributes point measurements of monthly or annual average precipitation to regularly spaced grid cells by using precipitation-elevation regression functions. The model is well suited for regions with mountainous terrain dominated by orographic precipitation patterns. PRISM operates by first estimating the orographic elevation of each precipitation station by using a Digital Elevation Model (DEM) (U.S. Geological Survey, 1990) at 5-minute latitude/longitude grid-cell spacing. The “orographic elevation” is an adjustment of the station’s actual elevation based on the weighted elevation of cells surrounding the cell containing the weather station. In addition, all cells are assigned a topographic facet based on their slope orientation (either north, south, east, or west). The annual average precipitation value is then computed for each cell by using a precipitation/DEM-elevation regression function that is constructed uniquely for that cell. The nearby rainfall stations used in the regression function are selected if they have the same slope orientation facet and fall within a user-defined, designated radius distance of the cell. A post-processor program was used to draw lines of equal annual average precipitation at 5-inch intervals from

Table 3. Basin spatial-coverage categories and corresponding data-layer codes used to create hydrologic response units in the Willamette River Basin, Oregon

[Each code represents a specific polygon type created by merging the four different categories. # denotes a code number from one of the other categories; >, greater than]

Category	Code	Description
Land use	1###	Forest
	2###	Agriculture
	3###	Urban
	4###	Wetlands
	41##	Lakes and reservoirs
	42##	Rivers and canals
	5###	Rangeland
Slope and aspect	#0##	0 to 5 percent, aspect assigned to basin
	#3##	5 to 30 percent, aspect assigned to basin
	#6##	> 30 percent, 0 degrees aspect
	#7##	> 30 percent, 90 degrees aspect
	#8##	> 30 percent, 180 degrees aspect
	#9##	> 30 percent, 270 degrees aspect
Geology[1]	##0#	Tertiary-Quaternary sedimentary deposits (I)
	##1#	Tertiary rocks of the Coast Range (V)
	##3#	Tertiary-Quaternary volcanic rocks of the High Cascade Range (II)
	##6#	Columbia River Basalt Group (IV)
	##9#	Tertiary volcanic rocks of the Western Cascade Range (III)
Soils[2]	###1	Group A
	###2	Group B
	###3	Groups B and C
	###4	Group C
	###5	Groups C and D
	###6	Group D

[1] Definitions of these geologic assemblages are provided in table 4.

[2] Definitions of these soils groups are provided in table 5.

the grid cell data. Annual average precipitation values were later determined for individual HRU's and were used in computing rainfall adjustment weights for the input precipitation record in the PRMS model.

Basin and subbasin—The Willamette River Basin data layer was partitioned into 21 major basins for this study (fig. 5). These include major tributary basins to the main stem and intervening main-stem drainages outside the major tributary boundaries. (The Sandy River Basin is included on the map even though it is not part of the Willamette River Basin, because it is part of the Willamette Basin NAWQA study.) Each major basin was further partitioned into subbasins, which are selected at points where tributary confluences occur or where stream-gaging stations exist or have previously existed. A total of 253 subbasins were delineated for the Willamette River Basin (excluding the Sandy River Basin). Ten subbasins were used for calibrating PRMS. Both major and subbasin data layers were created by digitizing watershed delineations drawn on USGS 1:24,000-scale quadrangle maps.

Land use—The land-use data layer (scale 1:250,000, level I and II) used in the study was acquired from the USGS National Mapping Division (NMD) (Fegeas and others, 1983) as part of a large national land-use data-base coverage; therefore, land-use classifications for the Willamette River Basin are not specific. For different categories of agricultural lands, for example, the distinctions between irrigated and nonirrigated croplands are not indicated; similarly, croplands are not classified separately from orchards. Land-use classes included in the basin data layer used in this study were Forest, Agriculture, Urban, Wetland, Lakes and Reservoirs, Canals and Streams, and Rangeland (table 3). Forest, Agriculture, and Urban areas were the dominant classes throughout the basin. All forest land was considered to be predominantly conifer, because there are no large stands of deciduous forest. Figure 6 shows land-use classifications for the Molalla River Basin.

Slope and aspect—A slope data layer for the entire river basin was created from elevation data contained in a 1:250,000 scale DEM (U.S. Geological Survey, 1990). The DEM data were used to create a polygon data layer of slope containing three slope classes: 0 to 5 percent, 5 to 30 percent, and greater than 30 percent. For slopes greater than 30 percent, polygons were created to represent the four aspects of north, east, south, and west. For slopes less than 30 percent, statistical programs within the GIS computed a dominant aspect for each HRU. Statistical programs within the GIS also computed average elevation for each HRU. Figure 6 shows the slope and aspect classifications for the Molalla River Basin.

Geology—The surficial geology data layer was digitized from a 1:500,000-scale USGS aquifer-units

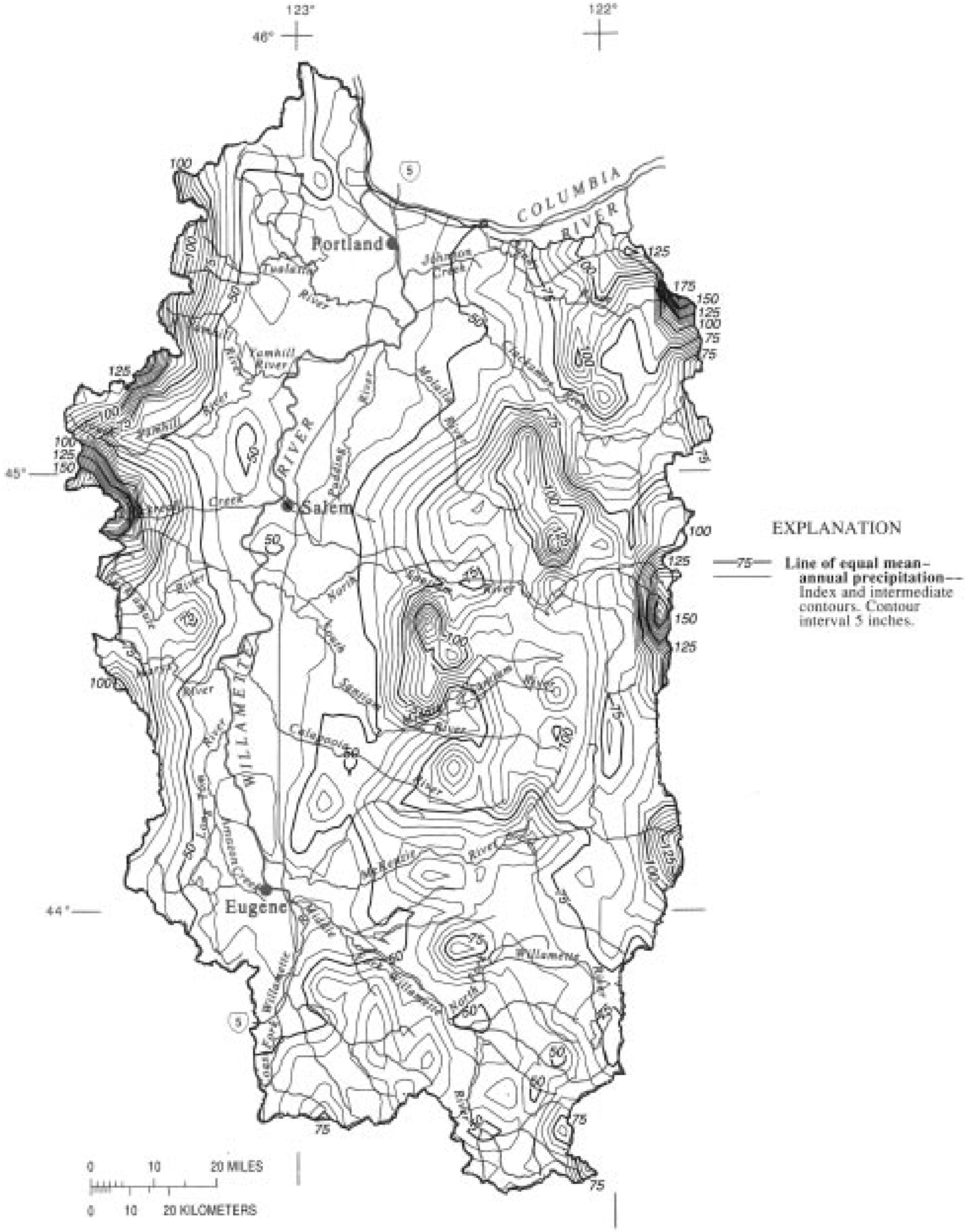


Figure 4. Mean annual precipitation in the Willamette River Basin, Oregon, 1961–90 (modified from Taylor, 1993).

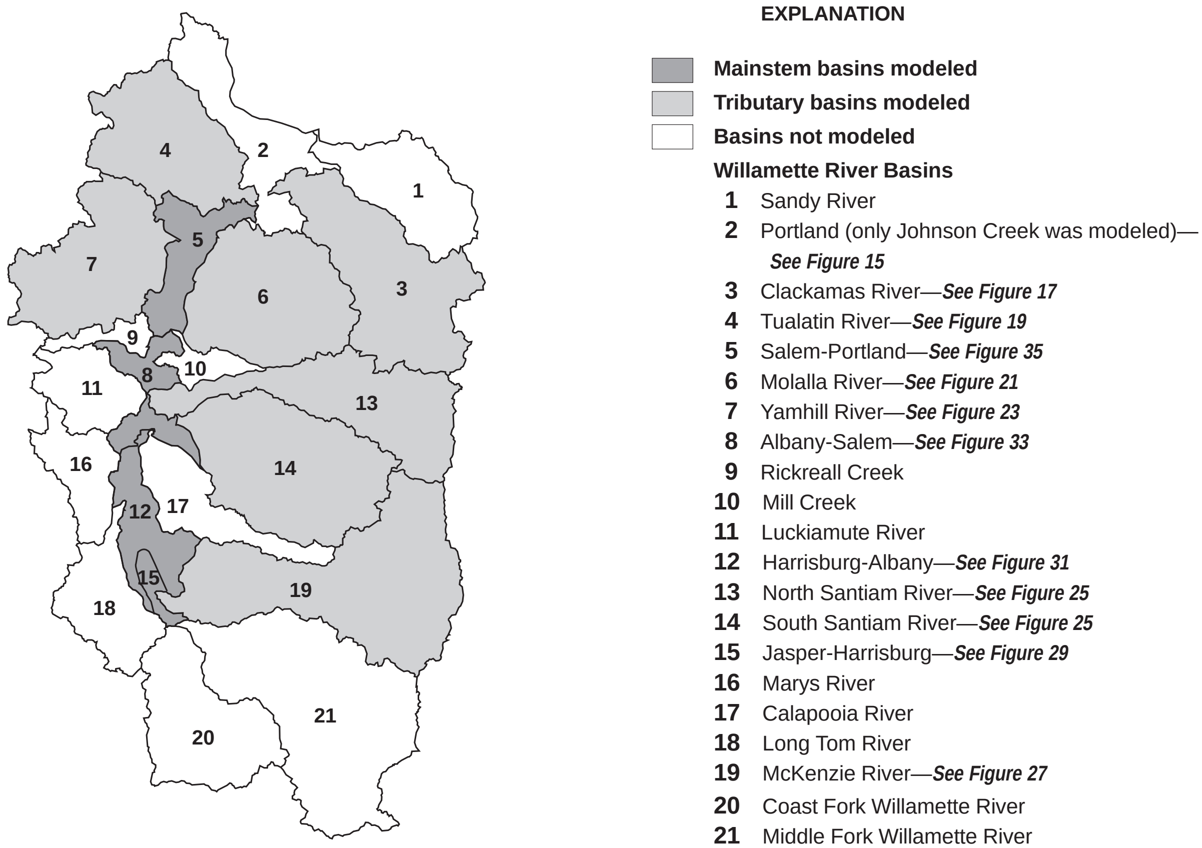


Figure 5. Major drainage basins of the Willamette River Basin, Oregon.

map (McFarland, 1983). The data layer included five classes of aquifer units found in the Willamette River Basin, each with varying permeability rates (table 4). Tertiary-Quaternary sedimentary deposits, located in the flatter regions of the basin near the river, have the highest permeability rates and yield as much as 2,000 gallons per minute to wells. Tertiary rocks of the Coast Range have the lowest permeability rates and yield less than 10 gallons per minute to wells. Figure 6 shows the geology classifications for the Molalla River Basin.

Soils—The soils data layer was digitized from a 1:500,000-scale Natural Resource Conservation Service (NRCS; formerly the Soil Conservation Service) general map of Oregon soil series (Soil Conservation Service, 1986). The data layer uses the NRCS four-group classification for infiltration properties, ranging from greater than 0.45 inch per hour (Group A) to less than 0.05 inch per hour (Group D). Soil series within the study area contain all four groups. Six classes in the soils data layer are listed (A, B, B+C, C, C+D, and D) in table 3 and defined in table 5. Figure 6 shows the soil classifications for the Molalla River Basin.

Hydrologic response units—The land-use, slope, aspect, geology, and soils data layers were merged (overlain) to create an HRU data layer for each major basin and each subbasin in the Willamette River Basin. Figure 7, the HRU data layer for the Molalla River Basin, is an example showing the many categories created by merging the data layers. New polygons created from the merged data layers contain a sum of attributes that already exist with the five contributing data layers. A four-digit code that identified the combination of land-use, slope and aspect, geology, and soils classes within the polygon was assigned to all polygons (table 3). Polygons that have a unique aspect of north, east, south, or west were created only for areas with slopes greater than 30 percent. For polygons where the slope was less than 30 percent, a basin-dominant value of aspect was assigned as an attribute. Aspect, as a parameter value used in PRMS, is less sensitive and less important in areas of lower relief than it is in steeper areas. More than 1,000 individual HRU's were created for the Willamette River Basin. Later, INFO tables were created that assigned PRMS parameter values to each individual HRU category as described by their codes. Small polygons of less than

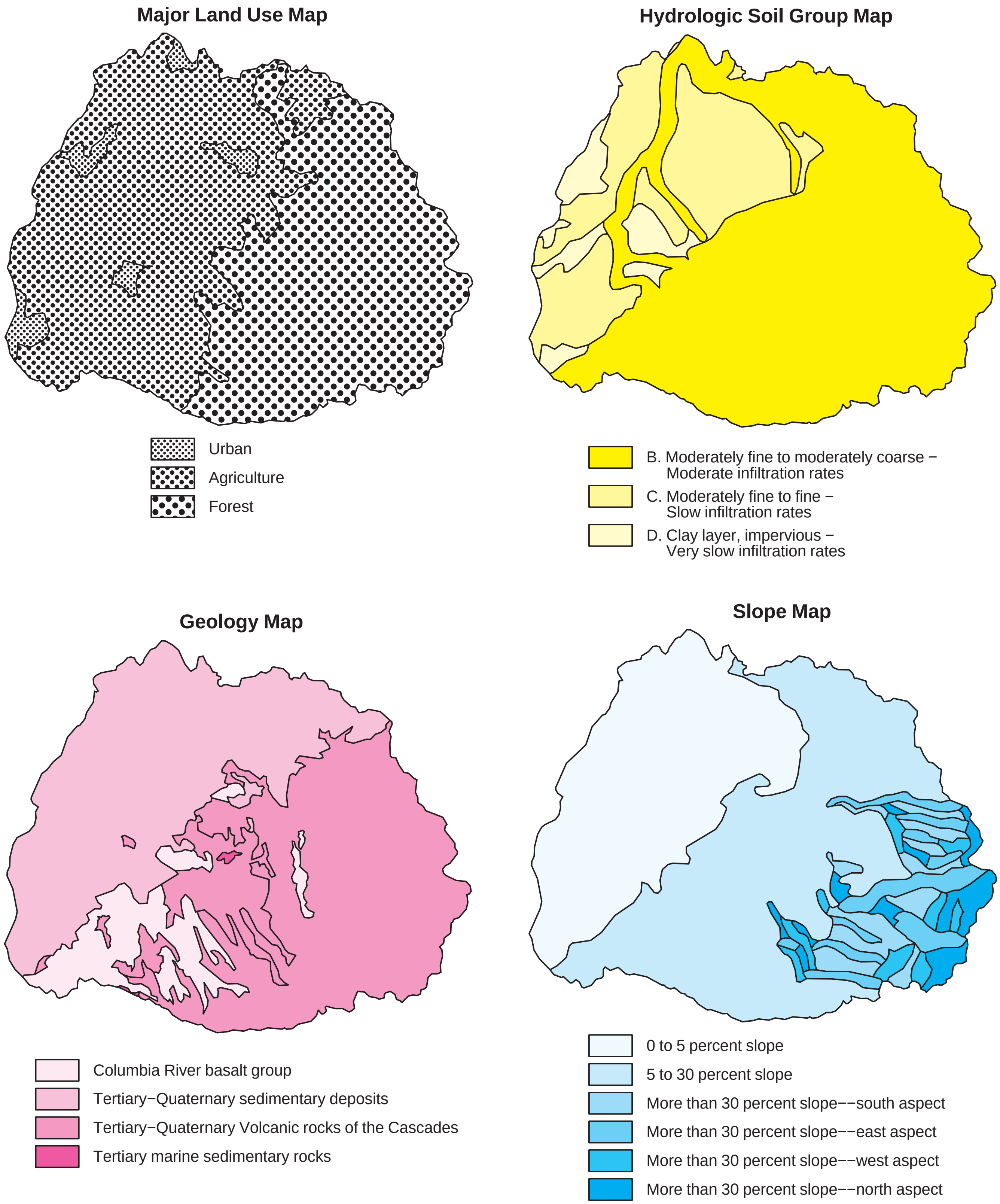


Figure 6. Major land use, slope and aspect, geology, and soils in the Molalla River Basin, Oregon.

Table 4. Definition of geologic assemblages in the Willamette River Basin, Oregon, grouped according to water-bearing characteristics

[#, a code number component from other categories of land use, slope, and soils; [gal/min, gallons per minute (table is excerpted from table 1, by McFarland [1983])]

Geologic assemblage and code	Lithologic description	Water-bearing characteristics
Tertiary-Quaternary sedimentary deposits ##0#	Sand, gravel, and silt, unconsolidated to consolidated; some weathered basalt and pyroclastic rocks are also included.	Permeability generally high; however, less permeable fine material is commonly interlayered with good aquifers. Wells yield more than 2,000 gal/min in some areas, but average less than 300 gal/min. Most productive aquifer unit in western Oregon.
Tertiary-Quaternary volcanic rocks of the High Cascade ##3#	Andesite and basalt, flow and pyroclastic rocks.	Largely unknown. Available data indicate variable permeability. Well yields range from a few gallons per minute to 300 gal/min. Springs issuing from the unit are commonly large.
Columbia River Basalt ##6#	Basalt; distinctive columnar jointing and fractured interflow zones.	Overall permeability low, but interflow zones and scoriaceous flow tops are relatively permeable. Dense, poorly permeable flow centers may limit recharge. Yields may exceed 1,000 gal/min, but are typically less than 100 gal/min.
Tertiary volcanic rocks of the Western Cascade Range ##9#	Andesite, basalt, and dacite; older rocks are dominantly volcaniclastic and younger rocks are almost entirely flow material.	Permeability is generally low; however, fracturing may form localized permeable zones. Well yields may reach 100 gal/min, but average less than 20 gal/min.
Tertiary rocks of the Coast Range ##1#	Sandstone, siltstone, and mudstone, commonly tuffaceous; intrusive rocks.	Permeability low. Well yields are generally less than 10 gal/min.

Table 5. Definitions of soil groups in the Willamette River Basin, Oregon

[Source: Hydrologic soil groups from U.S. Soil Conservation Service, 1975]

Hydrologic group	Infiltration rate [inches/hour]	Description
A	0.45–0.30	Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sand or gravelly sand. These soils have a high rate of water transmission.
B	.3–.15	Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
C	.15–.05	Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.
D	<.05	Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clay that has high shrink-swell potential, soils that have a permanent high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

0.5 mi^2, created in the merge of the data layers, were dissolved into the largest adjacent polygon.

Model Parameterization

(To fully comprehend the following discussion, it would be advisable to become familiar with the PRMS user's manual [Leavesley and others, 1983]). Before using PRMS for basin simulations, it was necessary to assign values to a wide range of parameters reflecting the various physical processes that are modeled. Definitions for PRMS parameter names are in Appendix 3. Many of the initial parameter values used in this study were determined from an earlier USGS study regarding the effects of timber harvesting in the Oregon Coast Range (Risley, 1994). One objective of that study was to regionalize PRMS parameter values for use in simulating flows in nearby ungaged basins. PRMS parameters are both distributed and nondistributed. Distributed parameters contain specific values for each HRU, subsurface reservoir, or ground-water reservoir, allowing representation of varying basin surface conditions. In contrast to distributed parameters, nondistributed, or lumped, parameters are applied over the entire basin.

Hydrologic Response Unit-Related Parameters

Many of the values assigned to HRU-related parameters were determined from various GIS data layers. Area mean elevation and aspect were directly computed from the GIS data layers. Parameter values for land-use type, cover density, and interception, for example, were assigned by using relational tables. Some additional analysis was required to determine appropriate precipitation and temperature adjustments required for each HRU.

Converting HRU data layer codes to parameter value—PRMS uses 43 parameters to reflect HRU surface-related physical characteristics in hydrologic processes. Because more than 1,000 individual HRU's were created for the Willamette River Basin, an Arc Macro Language (AML) program (a component of ARC/INFO GIS software) was written to automate transfer of information between the GIS data layers and attributes and the associated data tables into a format usable by PRMS. The AML program (Appendix 2) (1) assigned values of mean slope, mean elevation, and aspect for each HRU class within a specified basin, (2) related data-layer attribute information within each HRU class with tables of PRMS parameter values for different attribute combinations, and (3) created output files containing PRMS parameter values for each HRU class in the basin.

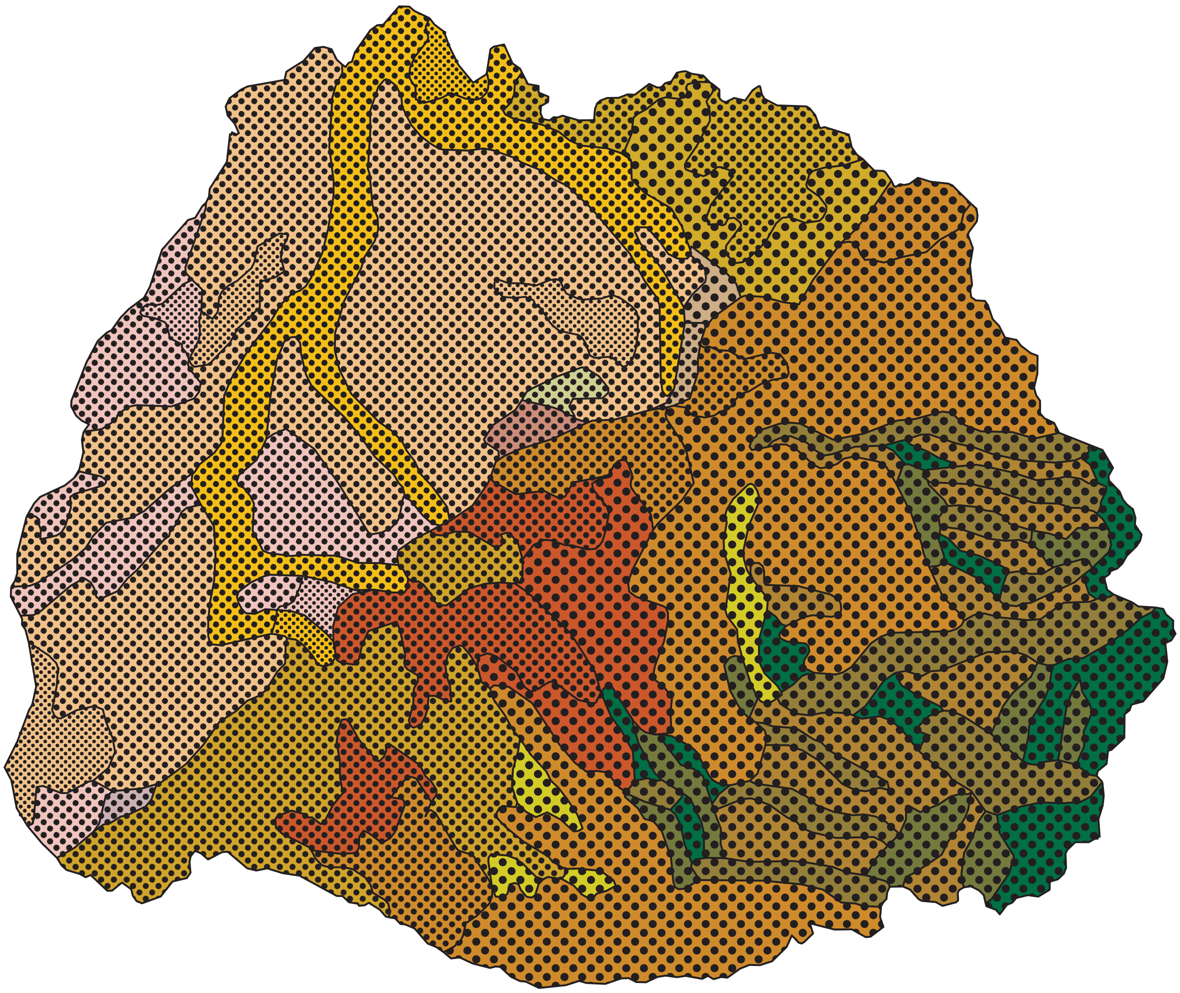
The AML program used a basin or subbasin outline from a data layer that contained all the major basins and subbasins for the Willamette River Basin as a template to define HRU's in each subbasin. All polygons within the subbasin were grouped together by their HRU class. The program also assigned an average aspect value for the HRU classes that had a slope of less than 30 percent. Assigned aspect values were defined by an analysis of dominant aspect for each of the 21 major tributary basins. For slopes greater than 30 percent, aspect was already given a separate aspect classification of north, south, east, or west to account for the differences in snow accumulation and melt that occur on those different aspects.

Matrix tables of basin data-layer codes and corresponding PRMS parameter values, such as those for geology and soils (table 6) and land use (table 7), were used by the AML program to assign appropriate parameter values for the subbasin HRU's. For example, in table 3, an HRU with a class code of "1304" represents forest land use, 5 to 30 percent slope, Tertiary-Quaternary sediments deposits, and group C soils. The HRU class was assigned an SMAX parameter value of 7.0 inches from table 6, and a COVDNS value of 0.9 (decimal percent) from table 7. Also, the AML program merged the HRU data layer with the PRISM precipitation coverage and computed a mean annual precipitation value for each HRU class in the subbasin.

The AML program creates three ASCII output files containing HRU parameter values for the groups 36, 37, 38 in the PRMS parameter file (Leavesley and others, 1983). A postprocessing program is used to reformat output from these files into a PRMS input file. This program also assigns radiation plane values (group 14) for each HRU based on the slope and aspect combination of the HRU.

Precipitation data adjustments—Mean annual precipitation values were derived from the annual precipitation data layer created by PRISM. The mean annual precipitation for each HRU, as determined by the AML program, was used to determine a precalibration precipitation adjustment to account for elevation and orographic differences between the input precipitation gage(s) and the HRU. Precipitation adjustments were computed by dividing the mean annual precipita-

Hydrologic Response Units



EXPLANATION

AGRICULTURE

PERCENT SLOPE	GEOLOGY TYPE	SOIL GROUP
0–5	Sedimentary	B
0–5	Sedimentary	C
0–5	Sedimentary	D
5–30	Sedimentary	D
5–30	Tertiary	B
5–30	Volcanic	B
5–30	Volcanic	C
5–30	Basalt	B
5–30	Basalt	C

FOREST

PERCENT SLOPE	GEOLOGY TYPE	SOIL GROUP
5–30	Tertiary	B
5–30	Volcanic	B
5–30	Basalt	B
More than 30 North aspect	Volcanic x	B x
More than 30 East aspect	Volcanic x	B x
More than 30 West aspect	Volcanic x	B x
More than 30 South aspect	Volcanic x	B x

URBAN

PERCENT SLOPE	GEOLOGY TYPE	SOIL GROUP
0–5	Sedimentary	B
0–5	Sedimentary	C
0–5	Sedimentary	D

Figure 7. Hydrologic response units in the Molalla River Basin, Oregon.

Table 6. Geology and soils matrix of basin data-layer codes and corresponding Precipitation-Runoff Modeling System parameter values

[#, denotes a code number from another category; SEP, soil to ground-water reservoir seepage; SMAV, initial available water in soil profile; SMAX, maximum available water holding capacity of soil profile; RECHR, storage in upper part of soil profile; REMX, maximum value of RECHR; ISOIL, soil type (1; sand; 2, loam; 3, clay); code, four-digit code use to describe basin surface conditions in the hydrologic response unit]

Code	SEP [inches/day]	SMAV [inches]	SMAX [inches]	RECHR [inches]	REMX [inches]	ISOIL
##01	0.15	1.0	4.0	1.0	1.0	1
##02	.15	1.0	8.0	1.0	1.0	1
##03	.15	1.0	7.0	1.0	1.0	2
##04	.15	1.0	7.0	1.0	1.0	2
##05	.15	1.0	6.0	1.0	1.0	2
##06	.15	1.0	5.0	1.0	1.0	3
##11	.15	1.0	7.0	1.0	1.0	1
##12	.15	1.0	10.0	1.0	1.0	1
##13	.15	1.0	9.0	1.0	1.0	2
##14	.15	1.0	8.0	1.0	1.0	2
##15	.15	1.0	7.0	1.0	1.0	2
##16	.15	1.0	6.0	1.0	1.0	3
##31	.15	1.0	4.0	1.0	1.0	1
##32	.15	1.0	8.0	1.0	1.0	1
##33	.15	1.0	7.0	1.0	1.0	2
##34	.15	1.0	7.0	1.0	1.0	2
##35	.15	1.0	5.0	1.0	1.0	3
##61	.15	1.0	7.0	1.0	1.0	1
##62	.15	1.0	10.0	1.0	1.0	1
##63	.15	1.0	9.0	1.0	1.0	2
##64	.15	1.0	8.0	1.0	1.0	2
##65	.15	1.0	7.0	1.0	1.0	2
##66	.15	1.0	6.0	1.0	1.0	3
##91	.15	1.0	7.0	1.0	1.0	1
##92	.15	1.0	10.0	1.0	1.0	1
##93	.15	1.0	9.0	1.0	1.0	2
##94	.15	1.0	8.0	1.0	1.0	2
##95	.15	1.0	7.0	1.0	1.0	2
##96	.15	1.0	6.0	1.0	1.0	3

Table 7. Land-use matrix of basin data-layer codes and corresponding Precipitation-Runoff Modeling System parameter values

[#, a code number from another category; HRU, hydrologic response unit; IMPERV, percent impervious area for each HRU; ICOV, vegetation cover type for each HRU (0 = bare, 1 = grasses, 2 = shrubs, 3 = trees); COVDNS, summer cover density for major vegetation for each HRU; COVDNW, winter cover density; SNST, interception storage capacity of unit area of vegetation for snow for each HRU; RNSTS, interception storage capacity of unit area of vegetation for rain during summer period, for each HRU; RNSTW, interception storage capacity of unit area of vegetation for rain during winter period, for each HRU; ITST, month to begin checking for start of transpiration for each hydrologic-response unit; ITND, month that transpiration ends for each hydrologic-response unit; TST, accumulated daily maximum temperature value for month ITST at which transpiration begins for each HRU; ^{o}C, degrees Celsius; ITST, month to begin checking for start of transpiration for each HRU; SCX, maximum possible contributing area for surface runoff as proportion of each HRU; RETIP, maximum retention storage on impervious area for each HRU; SCN, minimum contributing area for surface runoff when ISSR1 = 0, coefficient in contributing area—soil moisture index relation when SSR1 = 1; SC1, coefficient in surface runoff contributing area-soil moisture index relation; KDS, index of rain gage associated with each HRU; KGW, index of ground-water reservoir receiving seepage from each HRU; KDC, index of snow covered area depletion curve for each HRU; TRNCF, transmission coefficient for shortwave radiation through vegetation canopy for each HRU; AJMX, adjustment proportion of rain in a rain-snow mix, for months I = 1 through 12; SRX, maximum daily snowmelt infiltration capacity of soil profile at field capacity for each HRU; KRES, index of subsurface reservoir receiving seepage from each HRU; KTS, index of temperature gage associated with each HRU; TXAJ, adjustment for maximum air temperature for slope and aspect for each HRU; TNAJ, adjustment for minimum air temperature for slope and aspect for each HRU]

Code	Precipitation-Runoff Modeling System parameters								
	IMPERV (percent)	**ICOV**	**COVDNS (percent)**	**COVDNW (percent)**	**SNST (inches)**	**RNSTS ([inches)**	**RNSTW (inches)**	**ITST (month)**	**ITND (month)**
1###	0.01	3	0.9	0.8	0.10	0.10	0.10	1	12
2###	.05	1	4	.3	.05	.05	.05	3	11
3###	.25	1	.5	.4	.05	.05	.05	3	11
4###	.90	1	.1	.1	.05	.05	.05	3	11
41##	1.0	0	.0	.0	.00	.00	.00	0	0
5###	.01	1	.2	.1	.05	.05	.05	3	11
	TST (^{o}C)	**SCX (percent)**	**RETIP (inches)**	**SCN (inches)**	**SC1**	**KGW**	**KDS**	**KDC**	
1###	0	0.01	0.0	0.001	0.2	1	1	1	
2###	0	.1	.05	.001	.2	1	1	1	
3###	0	.2	.1	.001	.2	1	1	1	
4###	0	.9	.0	.001	.2	1	1	1	
41##	0	1.0	.0	.001	.2	1	1	1	
5###	0	.05	.05	.001	.2	1	1	1	
	TRNCF	**AJMX (percent)**	**SRX (inches)**	**KRES**	**KTS**	**TXAJ (^{o}C])**	**TNAJ (^{o}C)**		
1###	0.5	50	2	1	1	0	0		
2###	.5	50	2	1	1	0	0		
3###	.5	50	2	1	1	0	0		
4###	.5	50	2	1	1	0	0		
41##	.5	50	2	1	1	0	0		
5###	.5	50	2	1	1	0	0		

tion value of the HRU class by the observed mean annual precipitation of the precipitation gage, and this adjustment was used as model input. Generally, the precipitation gage nearest an HRU was used as the precipitation station for that HRU. It should be noted that precipitation gages are often subject to an under catch of precipitation (especially snow), particularly if they are not protected by wind shields. In final calibration, a more general basinwide adjustment also was applied to each subbasin by adjusting the precipitation input of all HRU's within a subbasin equally to accommodate the water balance. Generally, precipitation input was adjusted upward.

Temperature data adjustments (lapse rates)—Minimum and maximum air temperature data were used by PRMS to compute potential evapotranspiration at each HRU. To account for the air temperature difference between the elevation of the temperature station and the mean elevation of the HRU, minimum and maximum air temperature lapse rates (change in degrees per 1,000 ft change in elevation) were included as PRMS parameter input. Using the 30-year (1961–90) mean monthly minimum and maximum air temperature data, 18 monthly lapse rates were computed for various locations throughout the Willamette River Basin (fig. 8). These tables can be found in individual PRMS *basin.g1* files used in modeling. An example can be found in Appendix 5 in groups 22 (maximum rate) and 23 (minimum rate). The lapse rate table found in Appendix 5 was developed from temperatures collected at stations 33 and 16 (fig. 8).

Basinwide Parameters

Most basinwide parameters in PRMS are related to potential evapotranspiration, subsurface flow, ground-water flow, snow, and snowmelt processes.

Potential Evapotranspiration—The Hamon (1961) method was used in this study to estimate potential evapotranspiration. The method incorporates 12 monthly coefficients (CTS) that are used to adjust minimum and maximum air temperatures. The coefficients, shown in table 8, were adjusted during the calibration process to help replicate an appropriate estimate of actual evapotranspiration losses from the basin and define the water balance. Regional pan evaporation data were used to identify extremes.

Subsurface flow—Subsurface flow, as defined by PRMS, is the relatively rapid movement of water from the unsaturated zone to a stream channel. Subsurface flow is computed by using a conceptual reservoir-routing system. Two parameters, RCF and RCP, control the rate of subsurface flow as a function of storage volume in the subsurface reservoir. If both parameters are used, the routing relation becomes nonlinear. Otherwise, if RCP is set to zero, the relation becomes linear. Although values for these parameters cannot be determined through field measurement, initial values for RCP and RCF can be determined using graphical flow-separation techniques. The PRMS manual (Leavesley and others, 1983) provides some guidance for using these techniques. The RCF and RCP values were later adjusted during the calibration process using the Rosenbrock optimization routine in PRMS (table 9).

Ground-water flow—The ground-water system in PRMS is conceptualized as a linear reservoir. Baseflow leaving the ground-water reservoir is controlled by a single parameter, RCB. RSEP determines flow entering the ground-water reservoir. As with subsurface parameters, these parameters could not be determined through field measurement, so the value was initially estimated using graphical flow-separation techniques and adjusted during the calibration process (table 9).

Snow and snowmelt—The snow component of PRMS was used to simulate the initiation, accumulation, and depletion of a snowpack on each HRU. Critical snow parameters used in PRMS include TRNCF, a transmission coefficient for the vegetation canopy over the snowpack; PAT, the maximum air temperature that causes all precipitation to become rain; CECN, a convection-condensation energy coefficient; BST, the temperature below which precipitation is snow and above which it is rain; and EAIR, the emissivity of air on days without precipitation. Precalibration values used for these parameters were PRMS model default values. The values were later adjusted using optimization techniques during the calibration process. Most of the 10 calibration basins used in the study were in lower elevations where snowmelt was not a significant component of the hydrologic cycle. Snow accumulation and melt, however, was significant for the Lookout Creek Basin located in the head waters of the McKenzie River, so calibration of the snow-related parameters was based on data from this basin only.

Model Calibration and Verification

Precipitation-runoff modeling was used in the study to estimate inflows from ungaged basins for use

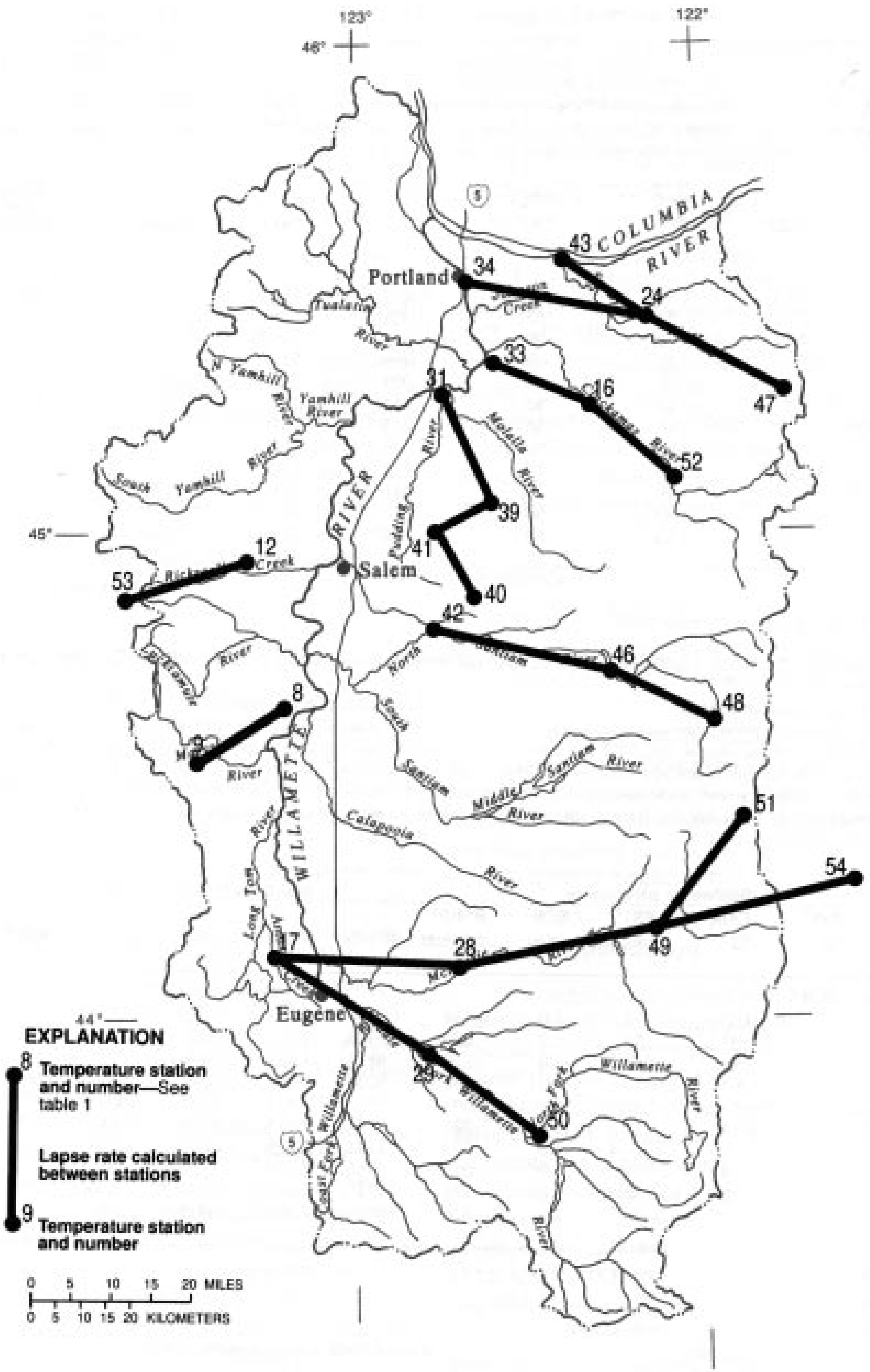


Figure 8. Temperature stations used to define monthly lapse rates as an increment of elevation, Willamette River Basin, Oregon.

Table 8. Selected monthly basinwide (nondistributed) calibration-parameter values for Precipitation-Runoff Modeling System (PRMS) in the Willamette River Basin, Oregon

[RDM, slope for relation between temperature (X) and (1) degree day (Y) or (2) sky cover (Y) when MRDC = 1 or 2; °F, degrees Fahrenheit; cal./°C, calories per degree Celsius; RDC, Y minus intercept for relation between temperature (X) and (1) degree day (Y) or (2) sky cover (Y) when MRDC = 1 or 2; TSOLX, maximum daily air temperature below which solar radiation adjustment factor (PA) equals RTB, for months I = 1 through 12; RTB is Y minus intercept of temperature range (TMAX(HRU) minus TSOLX(MO)) minus estimated solar radiation adjusted factor (PA) relation; CTS, monthly evapotranspiration coefficients; PAT, maximum air temperature, which when exceeded forces precipitation to be rain regardless of minimum air temperature, for months I = 1 through 12; AJMX, adjustment proportion of rain in a rain-snow mix, for months I = 1 through 12; CECN, convection-condensation energy coefficient for months I = 1 through 12]

Month	RDM	RDC (°F)	TSOLX (°F)	CTS	PAT	AJMX	CECN (cal./°C)
January	-0.13	1.83	50	0.007	32.0	1.0	5.0
February	-.13	1.83	50	.008	32.0	1.0	5.0
March	-.10	1.60	50	.008	32.0	1.0	5.0
April	-.08	1.46	50	.009	32.0	1.0	5.0
May	-.08	1.46	50	.009	32.0	1.0	5.0
June	-.07	1.42	50	.012	32.0	1.0	5.0
July	-.07	1.42	50	.013	32.0	1.0	5.0
August	-.07	1.42	50	.013	32.0	1.0	5.0
September	-.08	1.46	50	.012	32.0	1.0	5.0
October	-.08	1.46	50	.011	32.0	1.0	5.0
November	-.13	1.83	50	.01	32.0	1.0	5.0
December	-.13	1.83	50	.006	32.0	1.0	5.0

Table 9. Optimized Precipitation-Runoff Modeling System parameter values for 10 individual calibration basins in the Willamette River Basin, Oregon

[PAT, maximum air temperature, which when exceeded, forces precipitation to be rain for months I = 1, through 12; EAIR, emissivity of air on days without precipitation; BST, temperature below which precipitation is snow and above which it is rain; CECN, convection-condensation energy coefficient for months I = 1 through 12; HRU, hydrologic response unit; RSEP, seepage rate from each subsurface reservoir to ground-water reservoir; RESMX, coefficient for routing water from each subsurface reservoir to ground-water reservoir; REXP, coefficient for routing water from each subsurface reservoir to ground-water reservoir; RCB, routing coefficient for each ground-water reservoir, RCF, linear routing coefficient for each subsurface reservoir; RCP, nonlinear routing coefficient for each subsurface reservoir; DRCOR is daily precipitation correction factor for rain for each hydrologic-response unit; °C, degrees Celsius; in./day, inches per day; cal/°C, calories per degree Celsius]

Basin	Basinwide parameters				Distributed (HRU) parameters						
	PAT[1] °C	EAIR[1] °C	BST[1] cal/°C	CECN[1] in./day	RSEP[2] decimal	RESMX[2]	REXP[2]	RCB[2]	RCP[3]	RCF[3]	DRCOR
Molalla River	40	0.95	32	5.0	0.154	1.230	0.994	0.0200	0.1604	0.0001	1.30–1.09
Butte Creek	40	.95	32	5.0	.029	.7500	1.390	.0220	.1450	.0001	1.18–0.80
Silver Creek	40	.95	32	5.0	.220	.9817	1.535	.0248	.0577	.0001	1.35–1.11
Johnson Creek	40	.95	32	5.0	.245	.9242	2.997	.0368	.9044	.0001	1.08–1.00
Gales Creek	40	.95	32	5.0	.039	.896	1.857	.0295	.0911	.0001	1.65–1.08
Rickreall Creek	40	.95	32	5.0	.021	.8009	1.715	.0320	.0792	.0001	1.96–1.33
Thomas Creek	40	.95	29.4	5.0	.023	.8141	2.825	.0217	.2321	.0001	2.07–1.60
Marys River	40	.95	32	5.0	.022	.9956	2.299	.0264	.1022	.0001	1.16–0.50
Mohawk River	40	.95	32	5.0	.034	1.212	2.663	.0263	.1665	.0001	1.06–0.86
Lookout Creek	40	.95	32	5.0	.020	1.072	2.361	.0435	.0766	.0001	1.52–1.00

[1] Snow-related parameters.

[2] Ground-water-related parameters.

[3] Subsurface-flow-related parameters.

[4] Range shows the variation of the parameter value among the HRU's found in the subbasins. This parameter was manually adjusted.

as input to streamflow-routing models and ultimately to estimate surface, subsurface, and ground-water flows needed in water-quality models. By calibrating PRMS with observed discharge time-series data, it was possible to transfer PRMS parameter values to nearby ungaged basins for use in simulating runoff. Simulation by precipitation-runoff modeling, however, is generally still subject to a large uncertainty because of the point representation of rainfall and temperature in the basin.

Ten subbasins located throughout the Willamette River Basin were used for calibration and verification of the PRMS model (fig. 9). The calibration basins were selected to provide an adequate representation of Willamette River Basin headwater streams that do not have significant regulation. Gales Creek, Rickreall Creek, and Marys River represented Coast Range streams; Butte Creek and Mohawk River represented Willamette Valley streams; Molalla River, Silver Creek, and Thomas Creek represented Cascade Range foothill streams; and Lookout Creek represented a Cascade Range stream.

Water-Budget Adjustments

Initial simulations were made for each of the 10 calibration basins for the calibration period (water years 1972–75) to determine PRMS parameter values related to the monthly water budget. Many of the PRMS parameters could be set from values found in the literature (table 10). (For example, evapotranspiration values can be found in general texts, such as Chow [1964].) A monthly water balance output from each basin was examined and compared to expected regional water volumes for subbasins in the Willamette River Basin. Simulated evapotranspiration, precipitation, and snowmelt were balanced with observed runoff volume. Initially, both evapotranspiration and precipitation were adjusted to match observed runoff.

Next, evapotranspiration volumes were assessed for reasonableness. There is limited information pertaining to evapotranspiration losses from coniferous forests in the Willamette Valley; therefore, estimates of evapotranspiration were made by using a best-fit method. Simulated evapotranspiration losses were compared to long-term pan evaporation data for the Willamette Valley. Monthly Hamon coefficients (CTS) were adjusted to provide the best balance for all 10 calibration basins (table 8). Annual simulated potential evapotranspiration ranged from 33 to 50 inches. Annual simulated actual evapotranspiration ranged from 12 to 24 inches.

Next, rainfall was adjusted for each individual basin for each precipitation-gage record input. Repeated calibration period simulations were made, in which the precipitation was evenly adjusted (adjustments were made to each HRU by multiplying the precipitation-gage record by a factor) upward or downward, until the bias error of observed minus simulated flow was within $\pm$5 percent for each basin.

Finally, adjustments were made to some of the critical snowmelt parameters (TRNCF, PAT, CECN, BST, and EAIR) to obtain a balance between annual simulated and observed runoff in the Lookout Creek Basin. Snowmelt was a significant component of the hydrologic budget in that basin only. Observed snow water equivalent data (from Natural Resource Conversation Service snow telemetry system [SNOTEL]) were used as a comparison with simulations.

Sensitivity Analysis

There are 260 basinwide and 43 distributed (related to HRU's) parameters used in modeling in the daily mode of PRMS. A sensitivity analysis routine in PRMS was used to determine which of the many PRMS parameters had the greatest influence on flow simulation. Ten of these parameters and the precipitation-correction parameter were found to be consistently sensitive in all calibration basins (table 9). After the most sensitive parameters were determined, they were optimized by using other PRMS routines.

Parameter Optimization

For automated optimization, PRMS uses a technique described by Rosenbrock (1960). A brief description of the technique is contained in the PRMS manual (Leavesley, 1983). Systematic optimization was performed on all 10 basins for the parameters listed in table 9 (except for DRCOR). To keep cross influences to a minimum, no more than four parameters were optimized at a time. Parameters related to volume were optimized first, and parameters related to timing were optimized later. Snow-related parameters (PAT, EAIR, BST, and CECN) were optimized together; however, no changes had to be made in these values from those determined in the optimization of the Lookout Creek Basin, except for BST in the Thomas Creek Basin. Parameters related to subsurface and ground-water flows (RCF, RCP, and RCB) were also

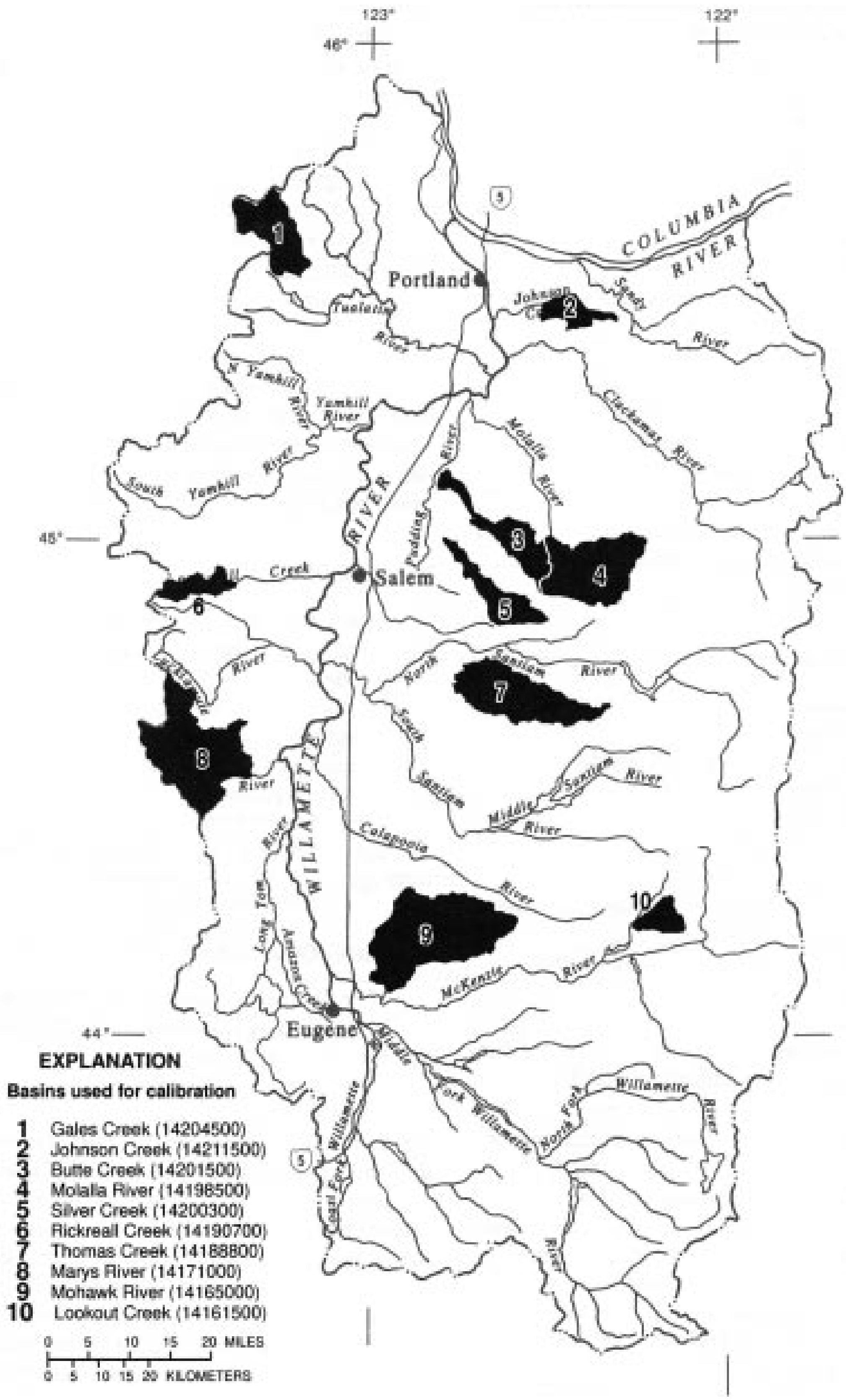


Figure 9. Location of Precipitation-Runoff Modeling System calibration basins, Willamette River Basin, Oregon.

Table 10. Additional distributed and nondistributed Precipitation-Runoff Modeling System calibration parameter values
[°F, degrees Fahrenheit; °C, degrees Celsius; HRU, hydrologic response unit]

Parameter	Units	Description	Value
ARSA	Inches	Minimum snowfall, in water equivalent, needed to reset snow albedo during the snowpack accumulation stage	0.05
ARSM	Inches	Minimum snowfall, in water equivalent, needed to reset snow albedo during the snowpack melt stage	.20
BST	°F or °C	Temperature below which precipitation is snow and above which it is rain	32
CTW		Coefficient for computing snowpack sublimation from PET	.50
DENI	Decimal	Initial density of new-fallen snow (decimal fraction)	.10
DENMX	Decimal	Average maximum density of snowpack (decimal fraction)	.60
EAIR		Emissivity of air on days without precipitation	.85
FWCAP	Decimal	Free water holding capacity of snowpack (fraction of snowpack water equivalent)	.05
GW	Acre-inches	Storage in each ground-water reservoir	1.13
PARS	Decimal	Correction factor for computed solar radiation on summer day with precipitation (decimal fraction)	.44
PARW	Decimal	Correction factor for computed solar radiation on winter day with precipitation (decimal fraction)	.50
RDB		Coefficient used in sky cover—solar radiation relation	.40
RDMX	Percent	Maximum percent of potential solar radiation (decimal fraction)	.80
RDP		Coefficient used in sky cover—solar radiation relation	.61
RES	Acre-inches	Storage in each subsurface reservoir	.50
RESMX		Coefficient for routing water from each subsurface reservoir to ground-water reservoir	1.00
REXP		Coefficient for routing water from each subsurface reservoir to ground-water reservoir	1.00
RMXA	Decimal	Proportion of rain in precipitation above which snow albedo is not reset for snowpack accumulation stage	.80
RMXM	Decimal	Proportion of rain in precipitation above which snow albedo is not reset for snowpack melt stage	.60
SCN	Acres	Minimum contributing area for surface runoff when ISSR1 = 0; coefficient in contributing area—soil moisture index relation when SSR1 = 1	.001
SCX	Decimal	Maximum possible contributing area for surface runoff as proportion of each hydrologic-response unit	.01
SC1		Coefficient in surface runoff contributing area—soil moisture index relation	.20
SETCON		Snowpack settlement time constant	.10
SRX	Inches	Maximum daily snowmelt infiltration capacity of soil profile at field capacity for each HRU	2.00
TRNCF		Transmission coefficient for shortwave radiation through vegetation canopy for each HRU	.50

optimized together. For most basins, the coefficient of determination increased by about 10 percent, and error decreased as a result of optimization. The absolute difference between the observed and simulated discharge was used as the optimization objective function.

Simulation Results

The final statistical results of both calibration and verification for the 10 basins are shown in table 11. Simulation results from the Butte Creek Basin (located in the Molalla River Basin) showed the highest calibration coefficient of determination for the calibration period (0.93) and also the lowest absolute error (18.22 percent). As an example of simulation results compared to observations, figure 10 shows the observed and simulated discharge for Butte Creek. Lookout Creek and Thomas Creek Basins were the most difficult basins to calibrate, which is shown by their respective coefficients of determination: 0.69 and 0.73. The lower correlation between simulated and observed values for Lookout Creek can be attributed to inadequate precipitation data coverage for the basin and its location in the snow zone of the McKenzie River Basin. This lower correlation of high flows probably can be expected for high-elevation locations, where data typically are lacking on precipitation type,

Table 11. Statistical analyses of Precipitation-Runoff Modeling System calibration and verification for 10 calibration basins in the Willamette River Basin, Oregon

[All basins used the same calibration and verification periods, water years 1972–75 and 1975–78, respectively—Precipitation-Runoff Modeling System was used in the daily time-step mode]

Basin name	Coefficient of determination[1]		Bias (in percent)[2]		Absolute error (in percent)[3]	
	Calibration	Verification	Calibration	Verification	Calibration	Verification
Molalla River	0.83	0.79	0.35	-7.96	26.34	35.45
Butte Creek	.93	.92	-1.63	-.65	18.22	26.51
Silver Creek	.92	.71	.26	-10.92	20.81	30.80
Johnson Creek	.82	.76	-1.86	13.33	36.52	50.86
Gales Creek	.86	.75	-2.95	-6.55	25.76	31.80
Rickreall Creek	.84	.80	.63	1.84	27.42	30.37
Thomas Creek	.73	.73	-1.64	-31.88	38.08	42.33
Marys River	.90	.88	2.16	1.29	20.75	26.55
Mohawk River	.88	.87	-2.09	-7.65	23.88	27.86
Lookout Creek	.69	.63	.09	-2.81	38.58	40.15

[1] coefficient of determination = $1 - \Sigma e^2 / \Sigma {e_M}^2$

$e = S - O$, where S is simulated runoff; and O is observed runoff.

$e_M = O - \overline{O}$, where $\overline{O}$ is mean observed runoff for full period of simulation.

[2] Bias, as a percent of mean observed runoff, $= 100 \times \Sigma e / \Sigma O$

[3] Absolute error, $= 100 \times \Sigma |S - O| / \Sigma O$

amount, and distribution. The lower correlation for Thomas Creek can be attributed to poor observed discharge data. The record of discharge at the streamgaging station was affected by variable backwater from debris that continually piled up on a bridge just downstream of the gage for most of the data collection period. Despite these limitations, Lookout and Thomas Creeks were important in the overall calibration by virtue of the type of situation that they represent: Very few data are gathered on a long-term basis for unregulated streams.

Simulated flow shown on figure 10 for Butte Creek is typical for all basin simulations for the periods of calibration and verification. A semilogarithmic plot is shown to illustrate the model’s capability to simulate peak flow and limited capability to simulate the complex base-flow recession. Simulated base flow is represented as a straight line on the logarithmic plot because the model algorithm for base flow is an exponential function. Flows in July and August were not well simulated, because irrigation withdrawals were not accounted for in the model. Flows in September and October were not well simulated because the model could not account for an increase from the ground-water reservoir caused by reduced evapotranspiration from plants that had become dormant.

Figure 11 shows the relative magnitude of flow separation for Butte Creek. The flow separation shown in the figure is typical for streams throughout the basin. Precipitation in the Willamette River Basin rarely exceeds 3 inches per day, even at the higher elevations. This relatively low precipitation intensity, coupled with predominantly forested areas that have loosely compacted soils and forest litter, results in a flow component derived mainly from the subsurface zone. In upland drainages, overland flow is a small component of the total flow and occurs only as a consequence of high-intensity storms. Some basins, especially in the high Cascade Range, have almost no overland flow component; whereas in Willamette Valley lowlands, when sustained precipitation causes ground-water tables to reach land surface, overland

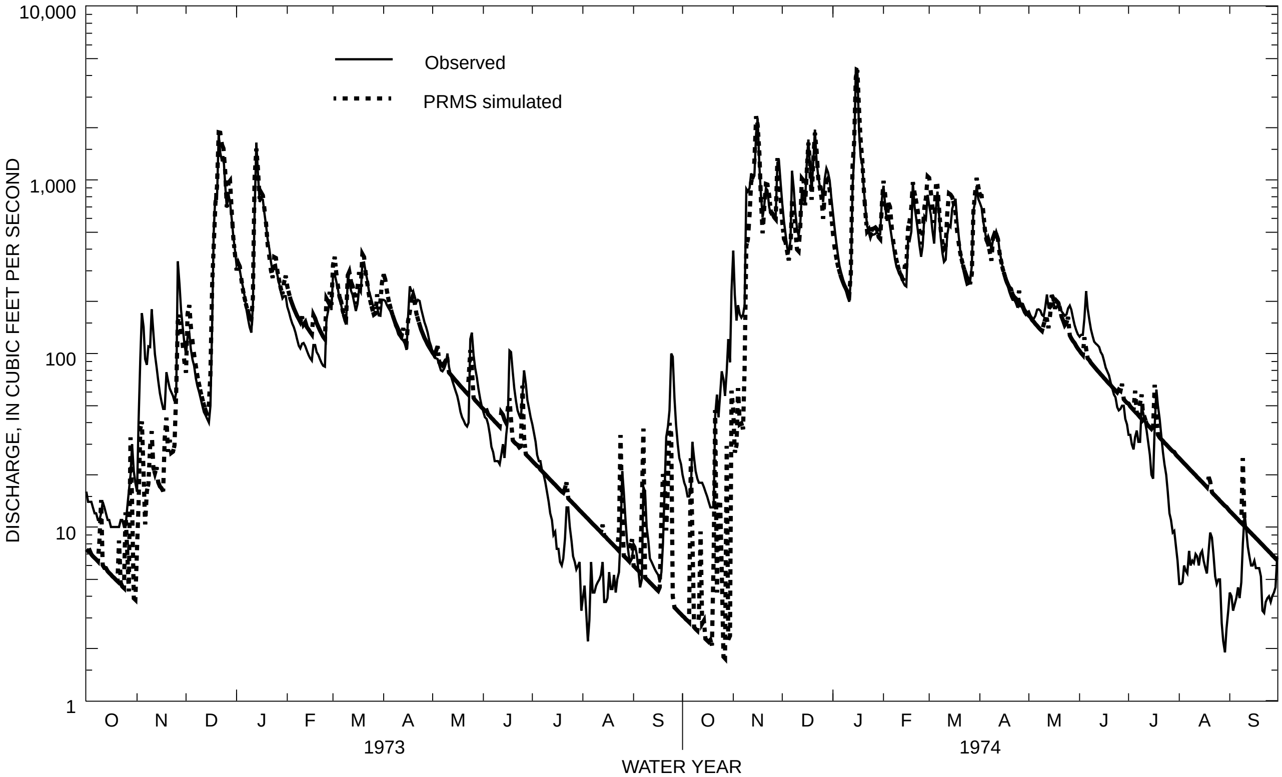


Figure 10. Observed and Precipitation-Runoff Modeling System (PRMS) simulated discharge for the Butte Creek, Oregon, calibration basin, 1973–74 water years.

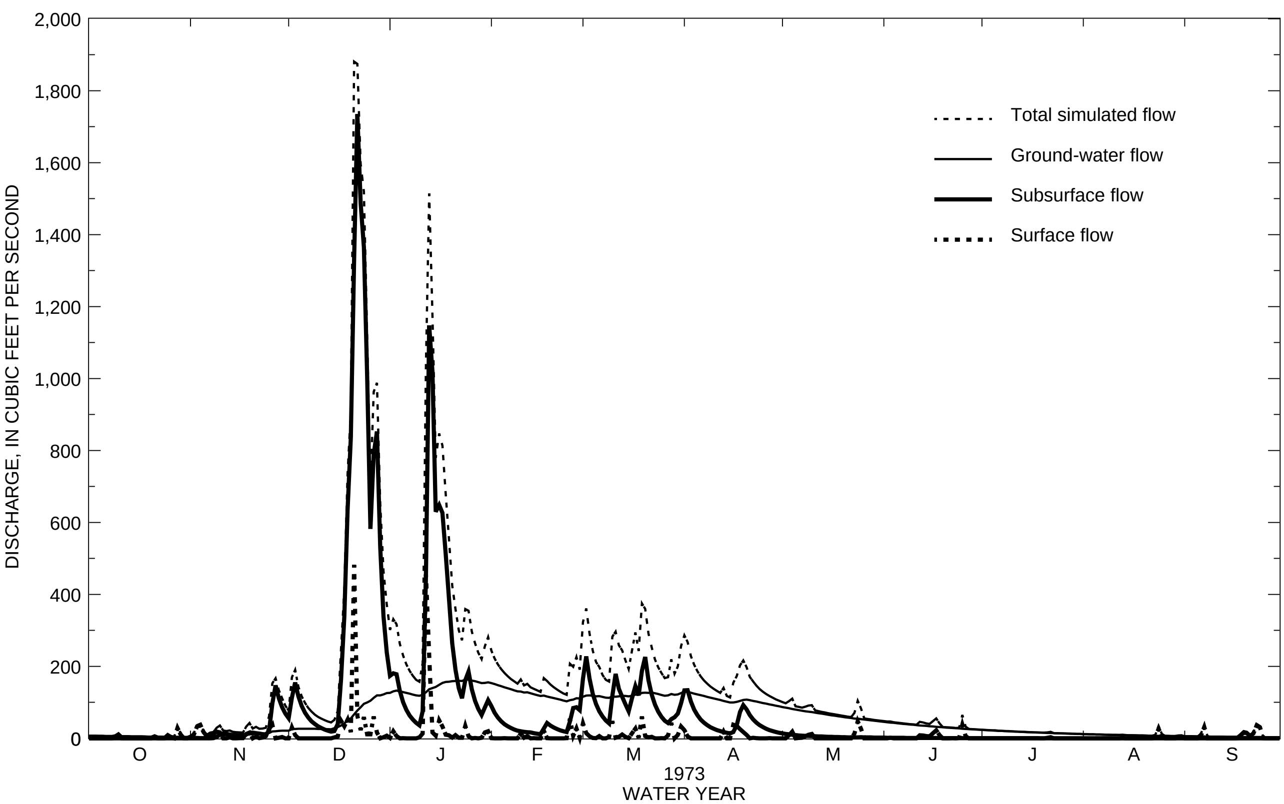


Figure 11. Typical simulated flow-separation output from the Precipitation-Runoff Modeling System. (This hydrograph is for Butte Creek at monitor, Oregon [Stream-gaging station 14201500], 1973 water year. See Glossary for program description.)

flow can become a significant component of the total flow.

Estimation of Parameters in Ungaged Basins

Of the many PRMS parameter values required for modeling, only 4 snow-related values, 6 subsurface- and ground-water-reservoir-related values, and 1 rainfall-related parameter value had to be specified for ungaged basins (table 9). Most of the PRMS parameters were assigned values in tables related to the HRU data layer because field and laboratory values could be related to mapped basin features. Of the 11 parameters that were optimized, 5 of those could be given a constant regional value for use in modeling in the Willamette River Basin. In modeling ungaged basins, five of the remaining parameters, RSEP, RESMX, REXP, RCP, and RCB, can be assigned values from those obtained in basin calibration based on their proximity to the calibration basin and (or) their similarity in watershed characteristics. For example, runoff models for ungaged basin tributary inflow in the McKenzie River network simulation used the five parameter values calibrated in the Mohawk River Basin in the lower part of the network and the parameter values from Lookout Creek Basin in the upper part of the network. Parameter values from Lookout Creek could be used for parameter estimates for all high elevation HRU's. Parameter values from Johnson Creek were used for urban HRU's. Parameter values from the Mohawk River, and Butte, Rickreall, and Thomas Creeks were used to represent varying states of agricultural development.

The most important correction factor applied, however, was to the daily precipitation correction factor for rain (DRCOR), which ranged from 0.50 to 2.07 and was applied to ensure that total water volumes between simulations and observations matched within $\pm$5 percent. The DRCOR values were initially set using the ratio of the historical mean annual precipitation for the precipitation record used as model input to the mean annual precipitation value for the HRU class. DRCOR provides adjustment weights to account for elevation and orographic differences between the input precipitation record(s) and the HRU. In calibration, the DRCOR values are adjusted upward or downward (as a unit, to preserve the original distribution) to optimize the match between the simulated and observed streamflows (bias in percent, tables 11 and 12). The application of this factor yields the greatest uncertainty in streamflow prediction in ungaged basins. For the network-routing models, an adjustment to DRCOR was uniformly applied in all precipitation-runoff models of ungaged basins in order to match total volume at the observed calibration location.

STREAMFLOW-ROUTING MODELS

The DAFLOW model was selected for use in this study because it allows for the routing of flows over hundreds of river miles with an adequate amount of spatial discretization and a fast computing time.

Description of Diffusion Analogy Flow Model

The DAFLOW model (Jobson, 1989) is a one-dimensional, unsteady-state (dynamic) streamflow-routing model that solves the energy equation and a simplified version of the momentum equation (acceleration terms of the momentum equation are neglected). The model is designed to be used in conjunction with the flow-transport model, BLTM. The model can be easily calibrated with time-of-travel data and requires minimal cross-section data.

"One dimensional" refers to flow that is modeled in one plane. In the case of DAFLOW, flow direction is limited to downstream only, because acceleration terms are neglected. Other one-dimensional models that use the complete momentum equation are able to model flows in both upstream and downstream directions. One-dimensional models based on the Lagrangian reference frame have been found to be very accurate and stable. Lagrangian refers to a computational x-coordinate reference frame, where computations are performed for a parcel of water as it moves downstream, rather than at a fixed grid location. The simplicity of solving the diffusion analogy in a Lagrangian reference frame greatly reduces computation time.

"Unsteady state" or "dynamic" refers to flow computations that are made at prescribed time intervals; time-varying input is allowed, and time-varying output is produced. Flood waves (which include even small perturbations) are routed downstream by using inputs of channel geometry and conveyance (ability of the stream channel to convey flow) to control attenuation.

For many situations, the DAFLOW model requires only a starting and ending cross section in a river reach of 10 to 20 miles to obtain acceptable cali-

Table 12. Statistical analyses of combined Precipitation-Runoff Modeling System and Diffusion Analogy Flow model calibration and verification for 11 Willamette River Basin, Oregon, stream-network applications (modeling was done for a daily time step)
[--, data not available]

Network	Data-set number[1]		Period of record[2]		Percent of basin simulated[3]	Bias (in percent)[4]		Absolute error (in percent)[5]	
	Observed	Simulated	Calibration	Verification		Calibration	Verification	Calibration	Verification
Clackamas River	1715	1120	1972–75	1976–78	28	2.53	0.26	7.13	7.09
Molalla River to Canby	8706	8210	1972–75	1976–78	70	-1.28	7.46	16.34	20.69
Tualatin River	13720	13050	1972–75	1976–78	82	-.14	.21	16.65	18.73
Johnson Creek[6]	15720	15050	1989–92	--	49	.04	--	9.43	--
McKenzie River	2720	2050	1972	--	17	4.68	--	8.31	--
Yamhill River	--	--	--	--	35	--	--	--	--
Santiam River	3710	3200	1972–75	1976–78	27	3.62	3.17	7.43	6.51
Willamette River—Jasper to Harrisburg	18710	20800	1972–75	1976–78	3	4.57	4.64	7.99	7.43
Willamette River—Harrisburg to Albany	710	20400	1972–75	1976–78	21	-1.38	-1.89	5.38	5.30
Willamette River—Albany to Salem	17710	20200	1972–75	1976–78	9	-.26	1.50	3.20	3.90
Willamette River—Salem to Willamette Falls[7]	16710	20600	1972	--	4	-1.51	--	3.32	--

[1] Data set number corresponds to the location of the observed and simulated flow time series in the Water Data Management file.
[2] All period of records are water years, except for Johnson Creek, which was from May 1, 1989 to August 31, 1992.
[3] Percent of basin simulated with precipitation-runoff modeling, other part of basin uses observed inflow hydrograph that is routed.
[4] Bias, as a percent of mean observed runoff, = $100 \times \Sigma e / \Sigma O$
[5]Absolute error, = $100 \times \Sigma |S - O| / \Sigma O$
[6] Johnson Creek is part of the Portland Basin.
[7] Simulations and observations are made at Wilsonville at river mile 38.5.

bration results. Geometry requirements of the model include a cross-sectional area relative to discharge relation, and a width relative to discharge relation. Channel roughness is therefore not a required input for the model. Instead, velocity information from dye-tracer studies made at various discharges are used to define cross-sectional area relative to discharge relations. These data yield true velocity information for low-flow situations, so channels that have pool-and-riffle morphology can be adequately quantified.

Channel Reach Delineation

Approximately 760 miles of stream channel were defined for the DAFLOW model for this study. At intervals of about every 1 to 3 miles, channel geometry was described by width and cross-sectional-area equations. The resulting channel-network description corresponded to changes in channel geomorphology, stream-gaging-station locations, tributary inflows, and canal outflows. This stream information can be found in Appendix 1. Stream geometry was defined in general for (1) the Willamette River main stem from RM 187.0 to the mouth (fig. 1); (2) major tributaries with reservoirs, from the most downstream reservoir to the mouth; (3) major tributaries without reservoirs, from an existing or discontinued USGS stream-gaging station to the mouth, and (4) a few important urban streams, through the urban areas.

Model Parameterization

The DAFLOW model requires channel input values for effective area, average width, and average wave diffusion at selected grid intervals (Jobson, 1989). Low-end values of area were primarily defined from time-of-travel studies, and high-end values were determined from flood-study cross sections. Widths were determined from streamflow measurements, 1:24,000-scale topographic maps, and flood-study cross sections. Diffusion coefficients were computed from associated width and discharge data.

Area Parameter

Average area (A) of a natural channel was approximated by an equation of the form (Jobson, 1989):

$$A = A_1 Q^{A_2} + A_0 \qquad (1)$$

where,
A_1 is the hydraulic area geometry coefficient,
Q is the stream discharge of interest,
A_2 is the hydraulic area geometry exponent, and
A_0 is the area at zero flow (intercept or offset).

The equation constant, exponent, and offset describe the relation of area to discharge for a given stream reach in the DAFLOW model and are listed in Appendix 1 for approximately 760 miles of streams. Figure 12 shows a typical area relation at a USGS stream-gaging-station location where area data were also available from discharge measurements. The low end of the relation was defined by time-of-travel measurements between the stream-gaging station and some distance downstream. Data points in the middle of the relation were from discharge measurements made at the stream-gaging station. The highest point on the rating was defined by a measured cross section from a flood-frequency report for a 100-year frequency flood of estimated discharge (U.S. Army Corps of Engineers, 1968–72).

Only a few channels did not have time-of-travel information available for use in determining area relations. The time-of-travel data reflect the geometry and water-storage characteristics of a reach and are a reliable means of estimating average low-flow geometry. For the few channels without time-of-travel measurements, streamflow measurements made at stream-gaging stations and miscellaneous locations were used to estimate the geometry. High-flow-area values came from flood-study cross sections, which were available for most channels at approximately 10-mile intervals. Intermediate values were usually interpolated on a straight-line basis. Area relation coefficients, exponents, and intercept values for all channels are listed in Appendix 1.

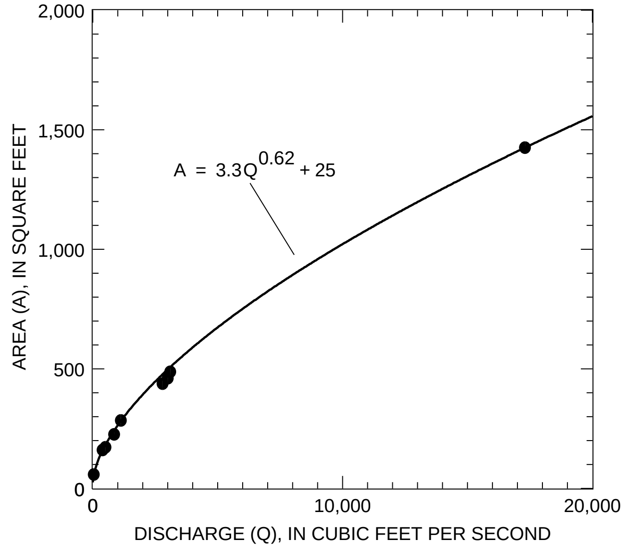


Figure 12. Typical area-discharge relation developed from time-of-travel data, stream-gaging-station measurements, and flood-study cross-section data. (This relation is for the reach of the Calapooia River between river miles 40.4 and 45.5 near the U.S. Geological Survey stream-gaging station at Holley [14172000].)

Because equation 1 represents an average cross-sectional area for a specific stream reach that is long compared to its width, changes in stream geometry caused by floods or other events are moderated. For example, during a flood, one part of the reach may be scoured while another part is subjected to sedimentation. The net result is little change to the average geometry. Dye-tracer studies to define travel times were made on sections of the Willamette and Santiam Rivers in 1968 and in 1992. Travel times determined for the same magnitude of stream discharge were not significantly different when computed with either the 1968 or 1992 data.

Width Parameter

Average stream width (Wfs) of a natural channel was also approximated by an equation (Jobson, 1989) that has the form:

$$Wfs = W_1 Q^{W_2} \qquad (2)$$

where,
W_1 is the hydraulic width geometry coefficient,
Q is stream discharge, and
W_2 is the hydraulic width geometry exponent.

Low-flow width was primarily scaled from 1:24,000 topographic maps or higher resolution areal photography. Both map and photographic information were tagged with a date of flight, and the corresponding stream discharge was obtained from USGS streamflow records. All high-flow widths came from flood-study cross sections. Missing data were approximated by interpolation and extrapolation. Width-relation coefficients and exponents for all channels are in Appendix 1.

Diffusion Coefficients

Values for the diffusion coefficient (D_f) were obtained from the channel slope (S_0), discharge (Q) of interest, and average width (equation 2) by using the following equation by Doyle and others (1983):

$$D_f = Q/2S_0W \quad (3)$$

Diffusion coefficients for specified high and low flows are in Appendix 1. Slope as shown in Appendix 1 was determined from either topographic maps or from U.S. Army Corps of Engineers (1968–72) floodplain information.

Special Studies to Document Low Flow

Low-streamflow data were needed at critical locations to calibrate low-flow model parameters and to relate streamflow to physical properties of the basin. Time-of-travel studies using dye tracers and low-flow measurements to define ground-water gains and losses were made during the study to identify model low-flow parameters and to better understand the low-flow system (fig. 13).

Time-of-Travel Studies

In the time-of-travel studies, rhodamine WT dye was injected at a selected location in a stream, and

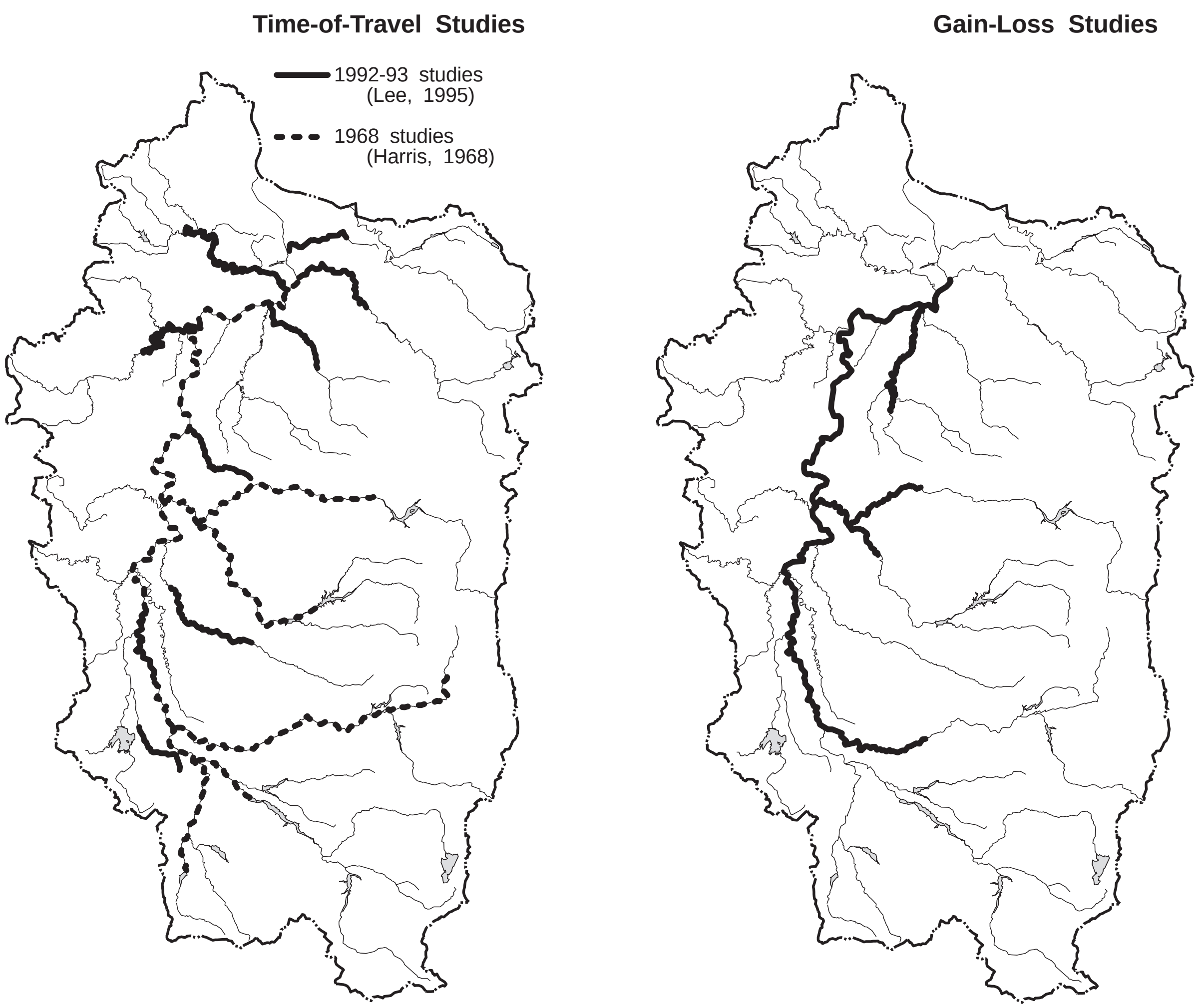


Figure 13. Location of time-of-travel and gain-loss studies, Willamette River Basin, Oregon.

samples were collected at various downstream locations over a time interval (Hubbard and others, 1982). Dye concentration was determined by measuring the fluorescence of the water samples. At each sampling location, a series of samples sufficient to define the passage of the dye cloud was collected. Stream discharge was measured at the beginning and end of each study reach and at all tributary inflows in order to define total stream volume. Travel time of the dye cloud was determined by plotting the time-concentration curves and defining times for the leading edge, peak, trailing edge, and centroid of the individual curves.

Dye-tracer studies to determine stream time-of-travel were conducted in the Willamette River and nine tributaries of the Willamette River from April 1992 through July 1993 during low- to medium-streamflow conditions. Results of these studies are presented in detail in a report by Lee (1995) for the main-stem Willamette River, Calapooia, South Yamhill, Yamhill, Molalla, Pudding, Tualatin, and Clackamas Rivers, and Amazon, Mill, and Johnson Creeks. Locations of the various time-of-travel studies are shown in figure 13. An earlier report by Harris (1968) gives time-of-travel study results on the Middle, Coast Fork, and main-stem Willamette Rivers, the Middle, South, North, and main-stem Santiam River, and the McKenzie River.

Time-of-travel data were used to define the low- and medium-flow range of area-discharge relations required in the DAFLOW model. Results of these studies can also be used to define dispersion rates in solute-transport models. Time-of-travel studies are important in understanding low flows where pools and riffles control stream velocities. Channel conveyance can be determined by a more conventional method—surveying stream cross-sections at selected intervals and estimating channel roughness (Manning's "n" value). However, the process of model calibration at low flows is tedious and inconclusive with this technique. The most accurate and cost-effective method to calibrate the low-flow component of a routing model within a given reach of channel is to measure the travel time of a dye tracer.

Gain-Loss Investigations

Gain-loss investigations are made to define the lateral inflow component used in streamflow-routing models; however, this information has not yet been fully utilized in the models presented in this report. Model algorithms that simulate the implied water exchanges between the river and river gravels are not yet available. For water-quantity distribution, these fluxes are not particularly important; however, when water-quality components are linked to the model, their importance will likely increase.

Stream-discharge measurements to determine gains from and losses to ground water were made on the Willamette River and the Santiam River at low flow during August 17–28, 1992, and at a snowmelt base flow during June 21–30, 1993 (fig. 14). The August measurements on the Willamette River were made from RM 195.0 at the USGS stream-gaging station at Jasper (14152000) to RM 55.0, just above the confluence of the Yamhill River and above Newberg Pool. The August measurements on the Santiam River were made from RM 28.5 at Stayton on the North Santiam River, and from RM 7.7 on the South Santiam River to RM 0.1 at the mouth of the Santiam River. The June measurements on the Willamette River were made in the reach from RM 195.0 to RM 84.0 at the stream-gaging station at Salem, where they were discontinued due to equipment failure. The June measurements on the Santiam River were made from RM 9.6 at the stream-gaging station at Jefferson (14189000) to RM 0.1 at the mouth. The Willamette River from RM 84.0 to RM 26.5 below the Tualatin River was measured September 21–22, 1993, to complete the reach of river that could not be measured in June because of equipment failure.

August measurements were made during a period of drought, when small tributary inflows to the main stem of the Willamette and Santiam Rivers were almost nonexistent and water use was high. Measurements were made with Price AA and pygmy mechanical current meters using techniques as described by Rantz (1982). To obtain accuracies within $\pm$3 percent, more measurements of point velocities (30–60 point velocities were measured rather than the 20–30 points normally measured when making conventional discharge computations) and more measurements of water depth were made for each separate computation of discharge. As part of the August measurements, a water-use inventory was conducted on the main stem of the Willamette and Santiam Rivers on the same reaches of river. The water-use inventory was intended as a synoptic measurement that would identify relative contributions. No attempt was made to account for evaporation from the river surface or for ground-water withdrawals for agricultural and domestic use.

June measurements were made after a dry winter followed by an unusually wet spring and probably reflect slightly higher than normal base flows for early summer. An Acoustic Doppler Current Profiler (ADCP) was used to measure discharge in the main-stem Willamette River and major tributary inflows. The ADCP provided better accuracy ($\pm$1.8 percent) than a mechanical current meter and the capability to make more measurements in a given time. Doppler theory and accuracy is described in a report by Simpson and Oltmann (1993). A water-use inventory was not made during the June measurements because there was little irrigation during this period. Major municipal and industrial users were accounted for in all estimates of gains and losses. No attempt was made to account for evaporation from the river surface or for ground-water withdrawals for agricultural and domestic use.

Measurements to determine gains and losses should be made when the flow is steady or nearly so, but this is rarely possible. Arrangements were made in August 1992 with the USACE for steady releases from reservoirs under their control; however, no such arrangements were made with the Eugene Water and Electric Board (EWEB). In August, the EWEB filled their reservoirs on the McKenzie River daily from 2200 to 0600, diverting about 300 ft^3/s. In June, flow was receding from recent rains and continuing snowmelt. In order to compare measured flows made at different locations and times with a flow that was changing with time, the changing flow, as recorded at a stream-gaging station, was routed to the measurement location. DAFLOW was used to route a flow hydrograph down the main stem. Tributary inflows and water-use withdrawals were added or subtracted from the routed flow, and the routed discharge was then compared to the measured discharge in estimating a gain or a loss (fig. 14). Differences greater than the error of the individual measurement and any routing error were considered to be significant. For example, measurements made in August from RM 72.0 to RM 60.0 indicated a loss, but the loss was smaller than the estimated accuracy; therefore, the loss may not have been real. In contrast, the loss at RM 55.0 in August of about 300 ft^3/s *was* real to within $\pm$ 120 ft^3/s, the measurement accuracy.

Gain-loss estimates identified (1) the seasonality of ground-water inflow to the main stem and (2) the magnitude and general location of the ground- and surface-water interactions. Tables in Appendix 4 list the locations, measured discharges, and gain-loss results of these measurements. Figure 14 shows the measured gains and losses for two representative, but different flow regimes (summer low flow, and spring/early summer base flow) on the main stem of the Willamette River.

Measurements made during the drought in August indicated very little water contribution from the ground-water system between RM 195.0 and RM 60.0 on the Willamette River main stem—an indication that the river was contributing to the ground-water system in the lower reach between RM 60.0 and RM 55.0 (fig. 14). All municipal, industrial, and agricultural surface-water withdrawals from the river were accounted for in the analysis; however, no attempt was made to account for ground-water withdrawals that would intercept water naturally flowing to the river. It was estimated that an average of 100 ft^3/s was being withdrawn from the ground-water system in the Willamette Valley during the time of the measurements (Broad and Collins, 1996).

Measurements made in June, after an exceptionally wet spring, indicated an approximate 2,000 ft^3/s ground-water contribution from about RM 140.0 near Peoria to RM 84.0 at Salem (fig. 13). Measurements in September of the same year indicated that the ground-water contribution continued from RM 84.0 to RM 40.0 (fig. 14). Large increases were noted adjacent to the alluvial fans of the Santiam and Molalla Rivers.

The upper main-stem Willamette River is a system of braided streams with many islands, sloughs, and gravel bars. Gain-loss measurements indicate that substantial hyporheic flow probably occurs between RM 195.0 and 140.0. The word “hyporheic” means “under river,” and the hyporheic zone is defined as the subsurface area where stream water and ground water mix. From a water-quality standpoint, important chemical and biological processes can occur in the hyporheic zone. Even though flows were higher during the June measurements than during the August measurements, a better flow picture emerges because more measurements and more accurate measurements were made in June (fig. 14). As much as 1,000 ft^3/s or 15 percent of the total river flow can be in the hyporheic flow zone.

NETWORK-ROUTING APPLICATIONS

In order to model a stream network, an inflow hydrograph at the upstream boundary of the network

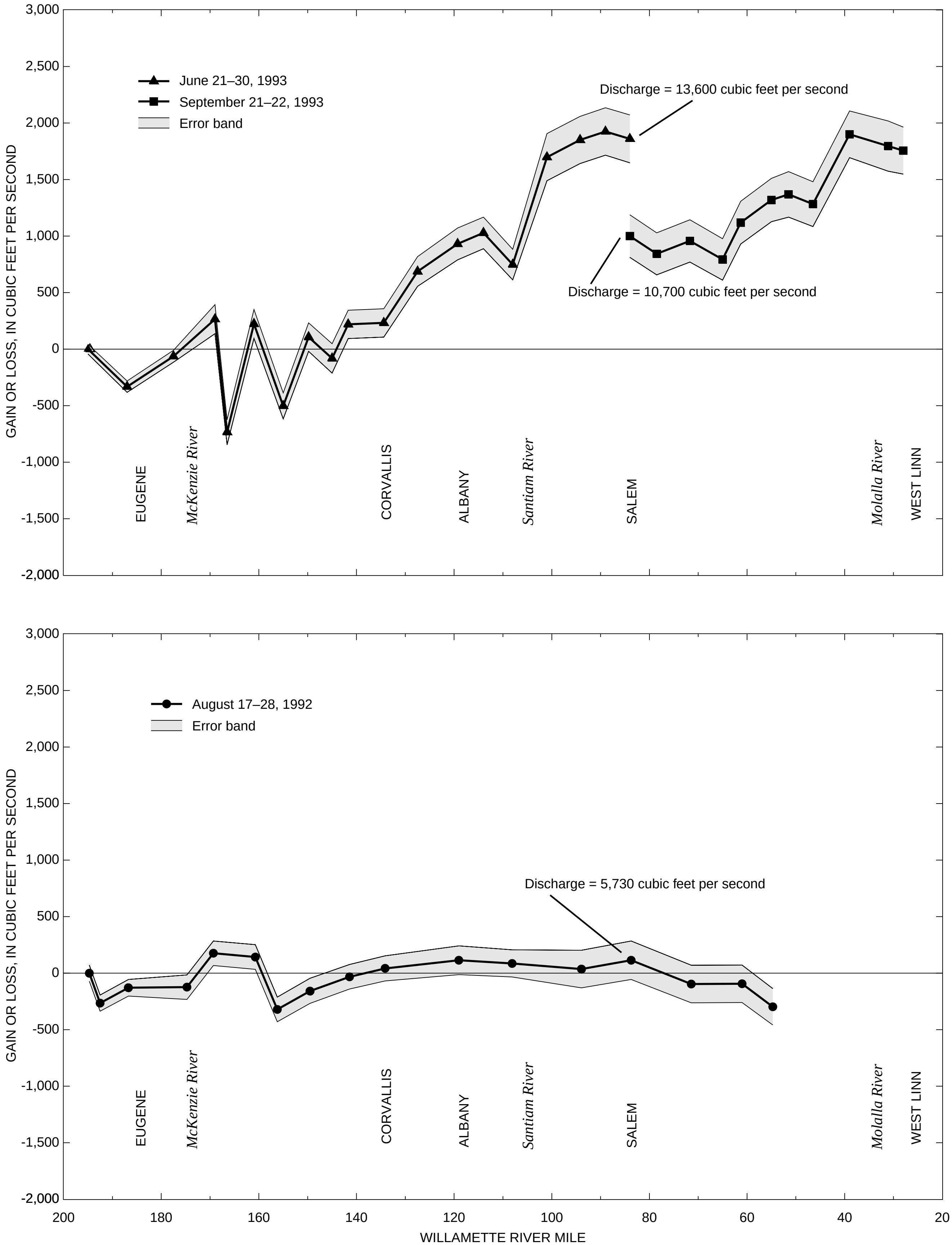


Figure 14. Ground-water gains from and losses to the Willamette River from Eugene to Willamette Falls, Oregon.

and all of the tributary and diversion hydrographs at intermediate points in the network are required. In application, upstream boundary hydrographs also usually were obtained from existing stream-gaging-station data, but occasionally the hydrograph was simulated with PRMS. Major tributary hydrographs were also usually obtained from stream-gaging-station data, but minor tributary hydrographs were typically PRMS simulations of those basins. Diversion hydrographs were estimated from available water-use records.

For this study, 11 of the 21 major streamflow-routing networks in the Willamette River Basin were modeled with DAFLOW and the results evaluated. This section explains network construction, identifies sources for input hydrographs, and describes individual network results. Statistical analyses of the results were used to verify the adequacy of the streamflow-routing models and to identify the improvement in the accuracy of streamflow prediction when flow routing of observed streamflow data is used in concert with precipitation-runoff simulation (table 12). A calibration phase was necessary in modeling to adjust only the overall rainfall in each network to match the observed downstream flow volume.

The coefficients of determination were greater and absolute errors smaller with a decrease in the total basin area simulated by precipitation-runoff modeling (table 12). When all basin runoff can be accounted for in the network-routing model by measured flow inputs, then the overall accuracy of the simulated flow is a function of the measured flow accuracy and the routing calibration (about $\pm$ 5 percent). When all basin runoff is simulated by using precipitation and temperature data, then the overall accuracy of the network-routing model is a function of the accuracy of the precipitation gages, their relation to basin precipitation, and the calibration of the other components of the precipitation-runoff models (about $\pm$ 40 percent).

Computer modeling details can be found in the appendixes and the following sections. Appendix 5 lists input data for the PRMS model used to simulate hydrographs for subbasins (tributary inflows) of the Molalla River Basin. Appendix 6 lists the DAFLOW input files for all 11 networks that were modeled. Appendix 8 lists the steps required to set up the HRU's required for PRMS modeling in a basin. Appendix 9 lists the steps required to set up the DAFLOW model. Appendix 11 contains a listing of all PRMS and DAFLOW files and a data directory, which includes input data files for other calibration basins. The calibration basins are shown in table 11.

For the 11 networks modeled, simulated-discharge hydrographs can be obtained at any DAFLOW model grid point for the time period 1972–78 by running DAFLOW with input files that have been created (Appendix 1 or Appendix 6). For other periods of interest, input data would first have to be imported to the Willamette water-data management (WDM) file, simulated hydrographs would be created with the PRMS model, and DAFLOW would be run by using the newly created hydrographs. If the steps in Appendixes 7, 8, and 9 are followed, the process is relatively simple. Ten networks on Willamette River tributaries remain to be constructed if the entire Willamette River Basin is to be modeled (fig. 5). All pertinent data exist for the construction of these networks, such as the parameters needed in tributary runoff modeling, but PRMS connections and DAFLOW input files still must be created. The models currently have the capability to estimate daily discharges at approximately 500 locations in the Willamette River Basin. In addition, simulated hydrographs of the separate flows from surface runoff (snowmelt and rain), subsurface flow, and ground water can be obtained for each HRU class within the subbasin. Because HRU's are not necessarily contiguous polygons, flow separation for an HRU does not necessarily pertain to a specific geographic location within the subbasin but rather for a specific HRU class. Subbasins can have from 1 to 10 HRU classes.

Tributary Networks

Seven tributary networks were modeled (fig. 5). For DAFLOW modeling, river segments were divided into several branches and connected to one another. Each branch had several grid points that permitted hydrographic input or output. A starting hydrograph from observed streamflow data was usually the input at grid 1 of branch 1. By merging PRMS outputs for subbasins that contained one or more HRU's, tributary inflow hydrographs were simulated at downstream grid and branch locations. Additional hydrographs from observed streamflow data and observed diversions were input to corresponding downstream grid and branch locations where available. The input files for the following networks can be found in Appendix 7.

Johnson Creek

Johnson Creek is located in the Portland Basin (fig. 5). The mapped and schematized Johnson Creek stream network is shown on figure 15. Johnson Creek is schematized as a one-branch network with three tributary inflows. A discharge hydrograph from observed data at the USGS stream-gaging station on Johnson Creek at Sycamore (14211500) at RM 10.2 was used as the upstream boundary input. Subbasin hydrographs for Deerdorf Creek, Begger's Tick Marsh, and Crystal Springs drainage were simulated by PRMS modeling and input to the Willamette WDM file. Crystal Springs inflow also was estimated, merged with the Crystal Springs drainage hydrograph, and input to the WDM file.

Figure 16 shows results of routing the input flow 9.5 miles downstream, where it can be compared to observed flow at the Johnson Creek at Milwaukie stream-gaging station (14211550). PRMS was used to simulate 25.3 mi^2 (square miles) of intervening drainage area (49 percent of the basin). The period of record used for calibration was 1989–90, because the lower Johnson Creek stream-gaging station was not installed until 1989. Statistical results for the calibration period (table 12) show an absolute error of 9.4 percent between simulated and observed data, with virtually no bias.

Clackamas River

The mapped and schematized Clackamas River stream network is shown on figure 17. The Clackamas River is schematized as a one-branch network with four tributary inflows. A discharge hydrograph from observed data at the USGS stream-gaging station on the Clackamas River at Estacada (14210000) at RM 23.1 was used as the upstream boundary

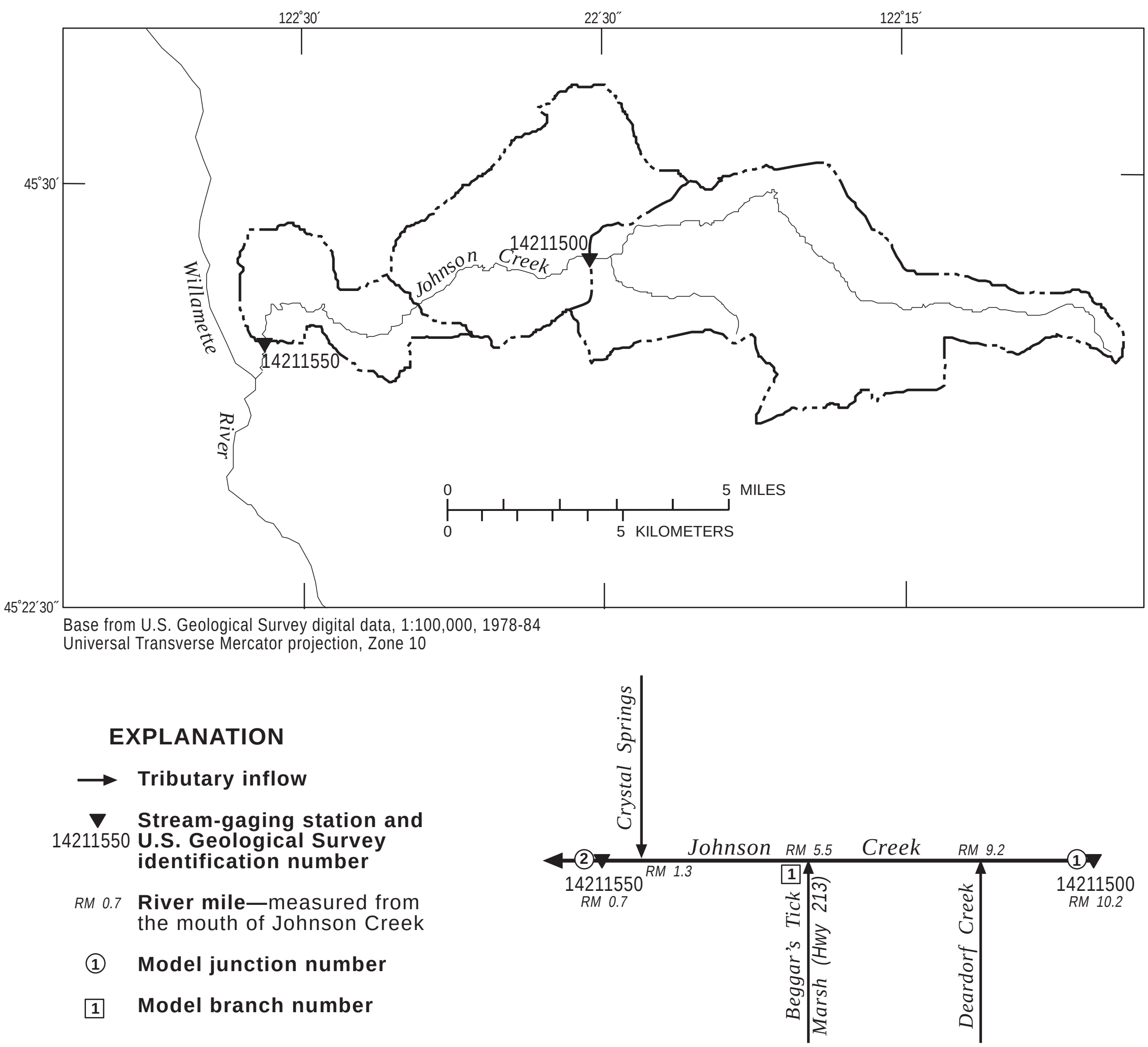


Figure 15. Johnson Creek Basin, Oregon, and schematic diagram of the stream network.

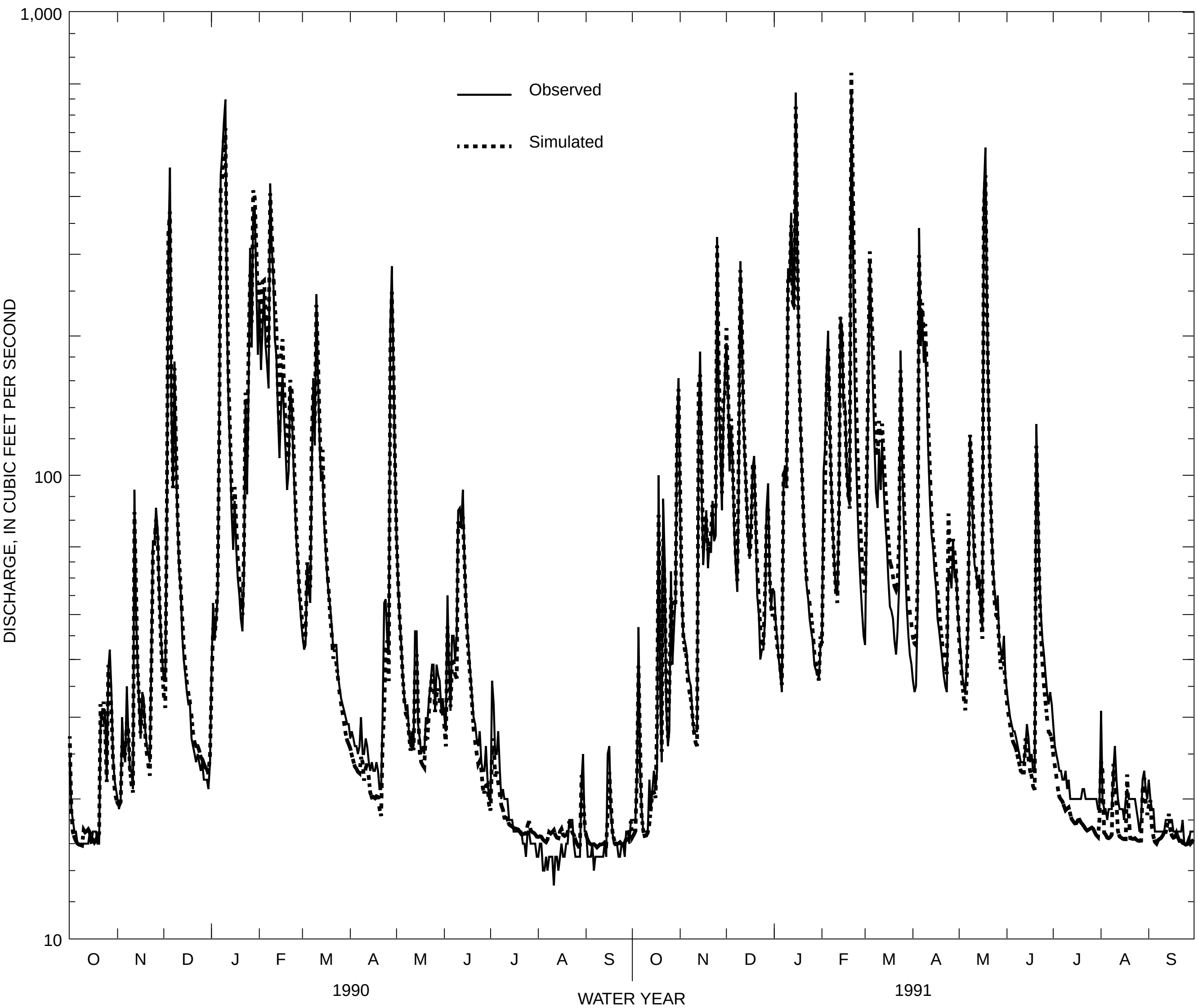


Figure 16. Observed and simulated discharge from combined Precipitation-Runoff Modeling System and Diffusion Analogy Flow modeling for Johnson Creek at Milwaukie, Oregon (stream-gaging station 14211550), 1990–91 water years. (See Glossary for program descriptions.)

input. Subbasin hydrographs for Eagle, Deep, Clear, and Rock Creeks were simulated by PRMS modeling and input to the Willamette WDM file.

Figure 18 shows the results of routing the input flow 18.3 miles downstream, where it can be compared to observed flow at the Clackamas River at Clackamas stream-gaging station (14211000). PRMS was used to simulate 265 mi^2 of intervening drainage area (28 percent of the basin). Statistical results indicate an absolute error of 7.2 percent for the calibration period and an absolute error of 7.1 percent for the verification period, with a bias error of +2.5 percent for both periods (table 12). Water-use information from Broad and Collins (1996) indicate that the annual consumption in the basin for 1990 was about 60 ft^3/s for all water uses, which is about 6 percent of the summertime flow of the Clackamas River at its mouth. Although water consumption is small for this basin compared to other Willamette River basins, it still may account for the positive bias of the simulation.

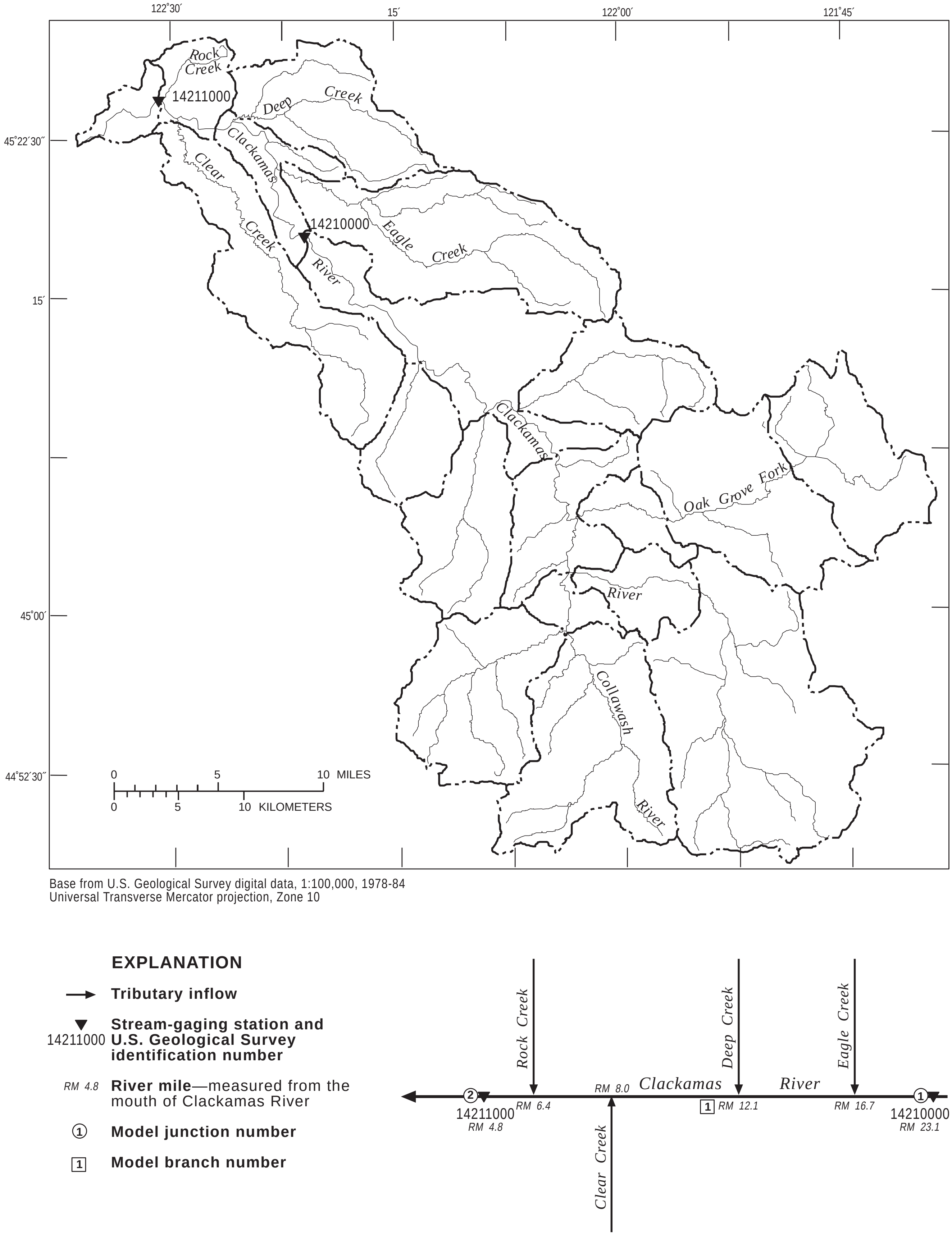


Figure 17. Clackamas River Basin, Oregon, and schematic diagram of the stream network.

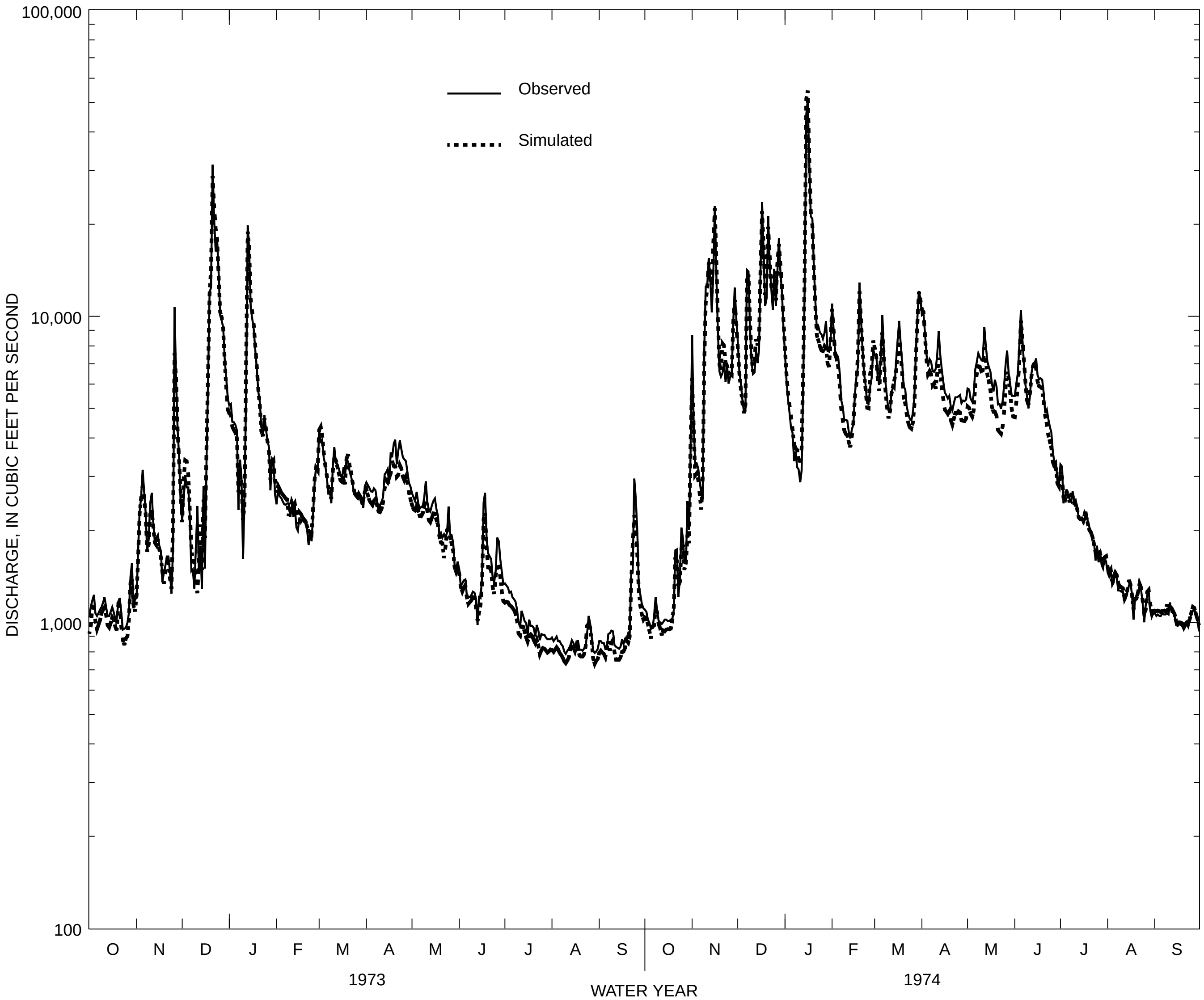


Figure 18. Observed and simulated discharge from combined Precipitation-Runoff Modeling System and Diffusion Analogy Flow model modeling for Clackamas River at Clackamas, Oregon (stream-gaging station 14211000), 1973–74 water years. (See Glossary for program descriptions.)

Tualatin River

The mapped and schematized Tualatin River stream network is shown on figure 19. The Tualatin River is schematized as a two-branch network with 12 tributary inflows and 1 diversion. A discharge hydrograph from observed data at the USGS stream-gaging station on the Tualatin River near Dilley (14203500) at RM 58.8 was used as the upstream boundary input. Subbasin hydrographs for tributary basins shown on figure 19 were simulated by PRMS modeling and input to the Willamette WDM file.

Figure 20 shows results of routing the input flow 57.0 miles downstream, where it can be compared to observed flow at the Tualatin River at West Linn stream-gaging station (14207500). PRMS was used to simulate 581 mi^2 of intervening drainage area (82 percent of the basin). Statistical results for calibration and verification time periods are shown in table 12. The absolute errors of 16.6 and 18.7 percent for calibration and verification periods, respectively, are within the expected accuracy for simulation when such a large part of the basin is simulated by rainfall-runoff modeling. The network modeling bias error was almost zero. Henry Hagg Lake provides irrigation water and flow augmentation in the summer, increasing flows from an average of about 30 ft^3/s to 100–300 ft^3/s. Low-flow simulations are unsatisfactory because no attempt was made to account for summertime irrigation withdrawals. Water-use information (Broad and Collins, 1996) indicate that the annual 1990 consumption of water in

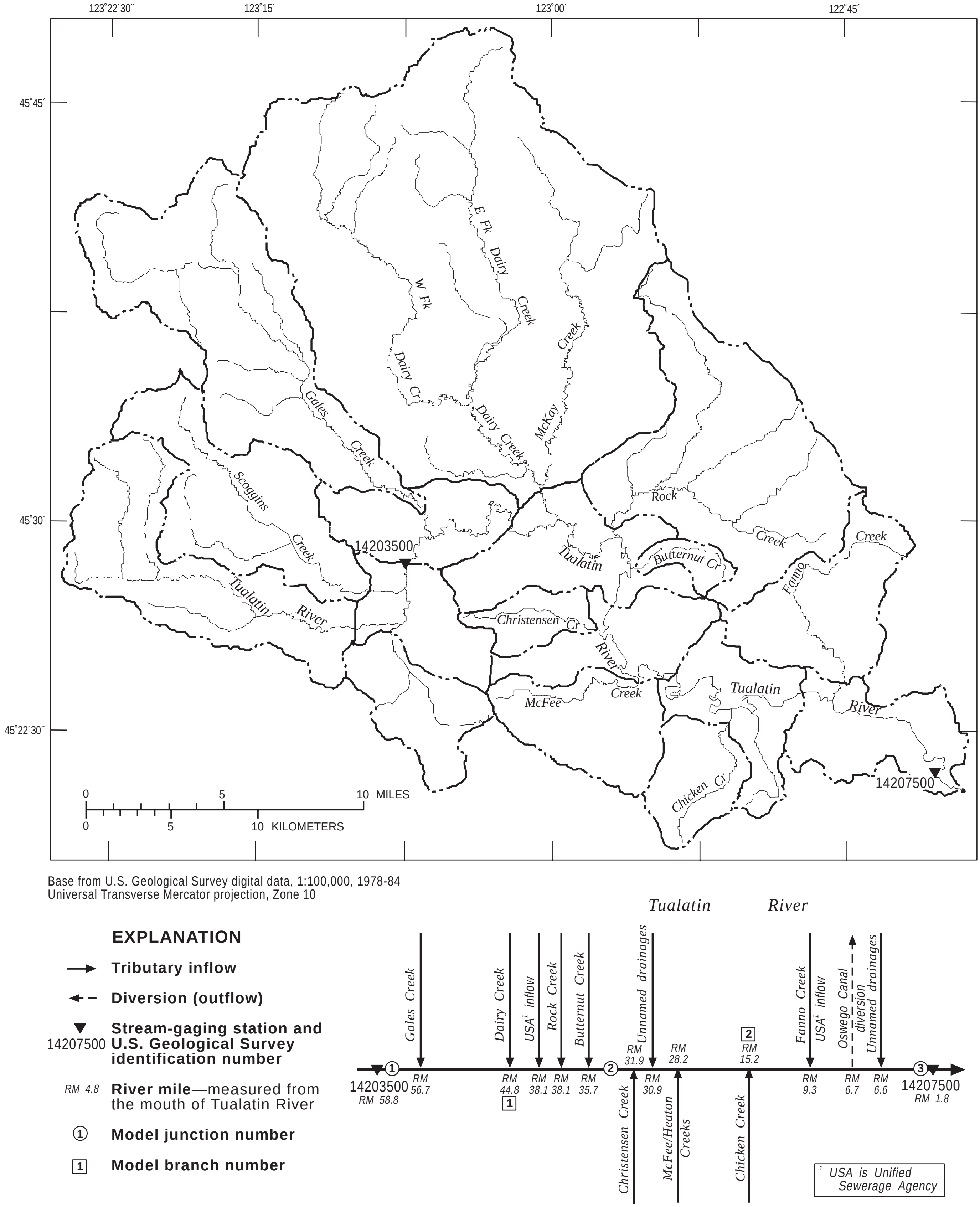


Figure 19. Tualatin River Basin, Oregon, and schematic diagram of the stream network.

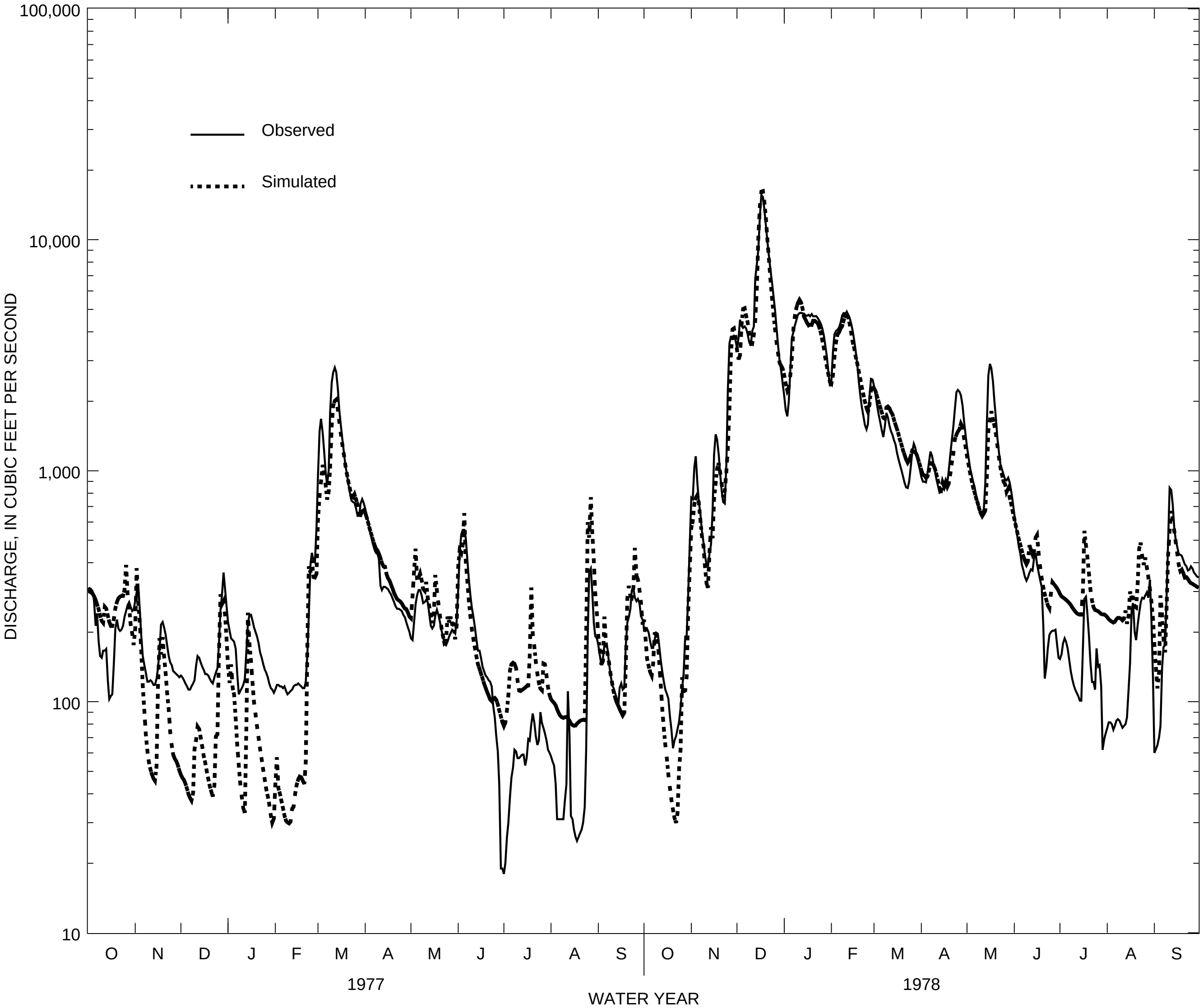


Figure 20. Observed and simulated discharge from combined Precipitation-Runoff Modeling System) and Diffusion Analogy Flow model modeling for the Tualatin River at West Linn, Oregon (stream-gaging station 14207500), 1977–78 water years. (See Glossary for program descriptions.)

the basin was about 90 ft^3/s for all water uses; therefore, the difference between observed and simulated flows of about 100 ft^3/s (fig. 20) for the summer months is a reasonable departure. Flow departure shown for the winter of 1976–77 is for additional water diverted into Lake Oswego at a point just upstream from the gage.

Molalla River

The mapped and schematized Molalla River stream network is shown on figure 21. The Molalla River is schematized as a five-branch network with 13 tributary inflows. Discharge hydrographs from observed data at the USGS stream-gaging station on the Molalla River above Pine Creek near Wilhoit (14198500) at RM 32.2, and the stream-gaging station on Silver Creek at Silverton (14200300, discontinued) at RM 52.8 on the Pudding River, were used as upstream boundary inputs. Subbasin hydrographs for the tributaries were simulated by PRMS modeling and input to the Willamette WDM file. These hydrographs were then input to the appropriate grid locations for DAFLOW modeling. The input file for this network can be found in Appendix 7.

Figure 22 shows the results of routing the input flow 26.2 miles downstream, where it can be compared to observed flow at the Molalla River at Canby stream-gaging station (14200000). PRMS was used to

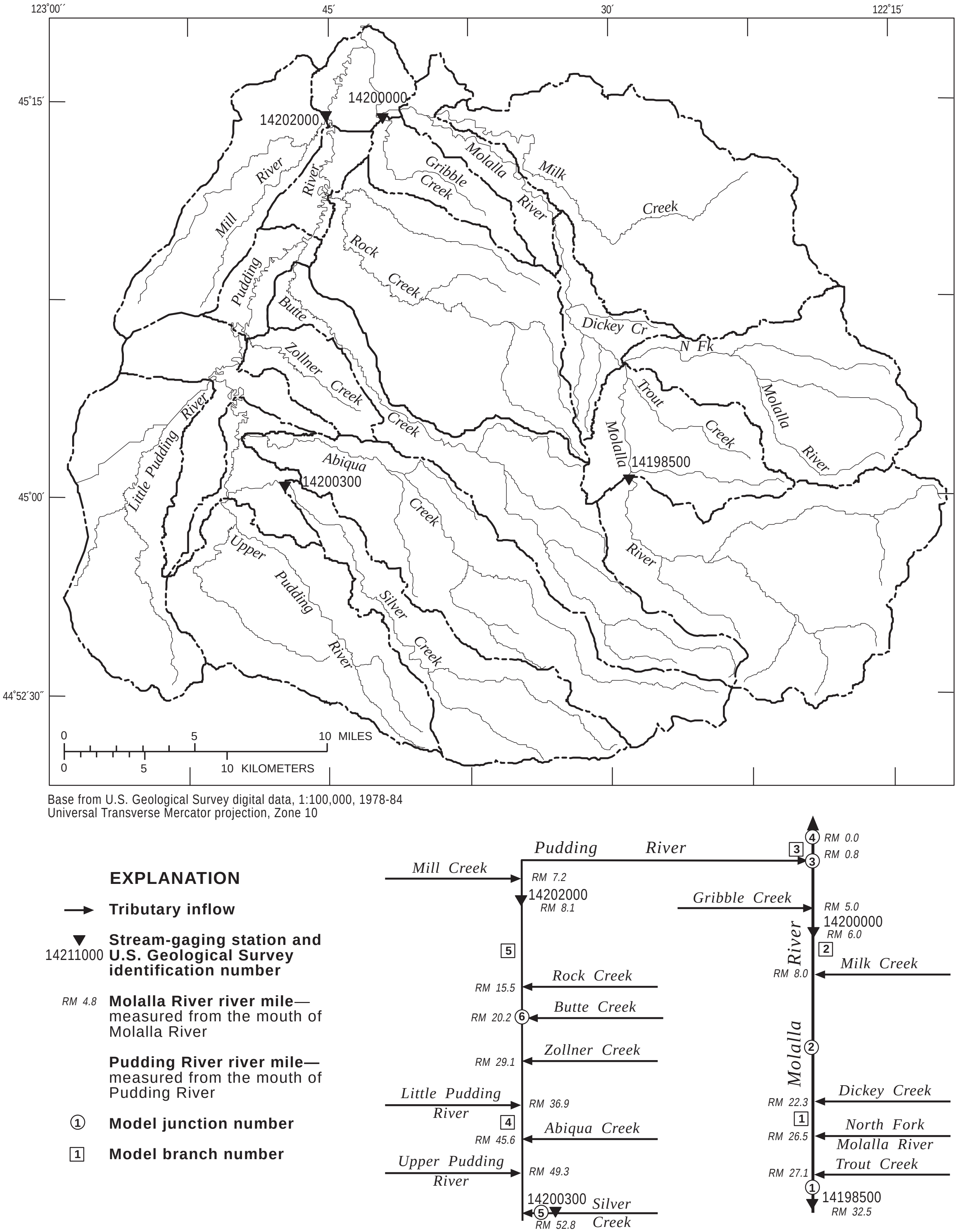


Figure 21. Molalla River Basin, Oregon, and schematic diagram of the stream network.

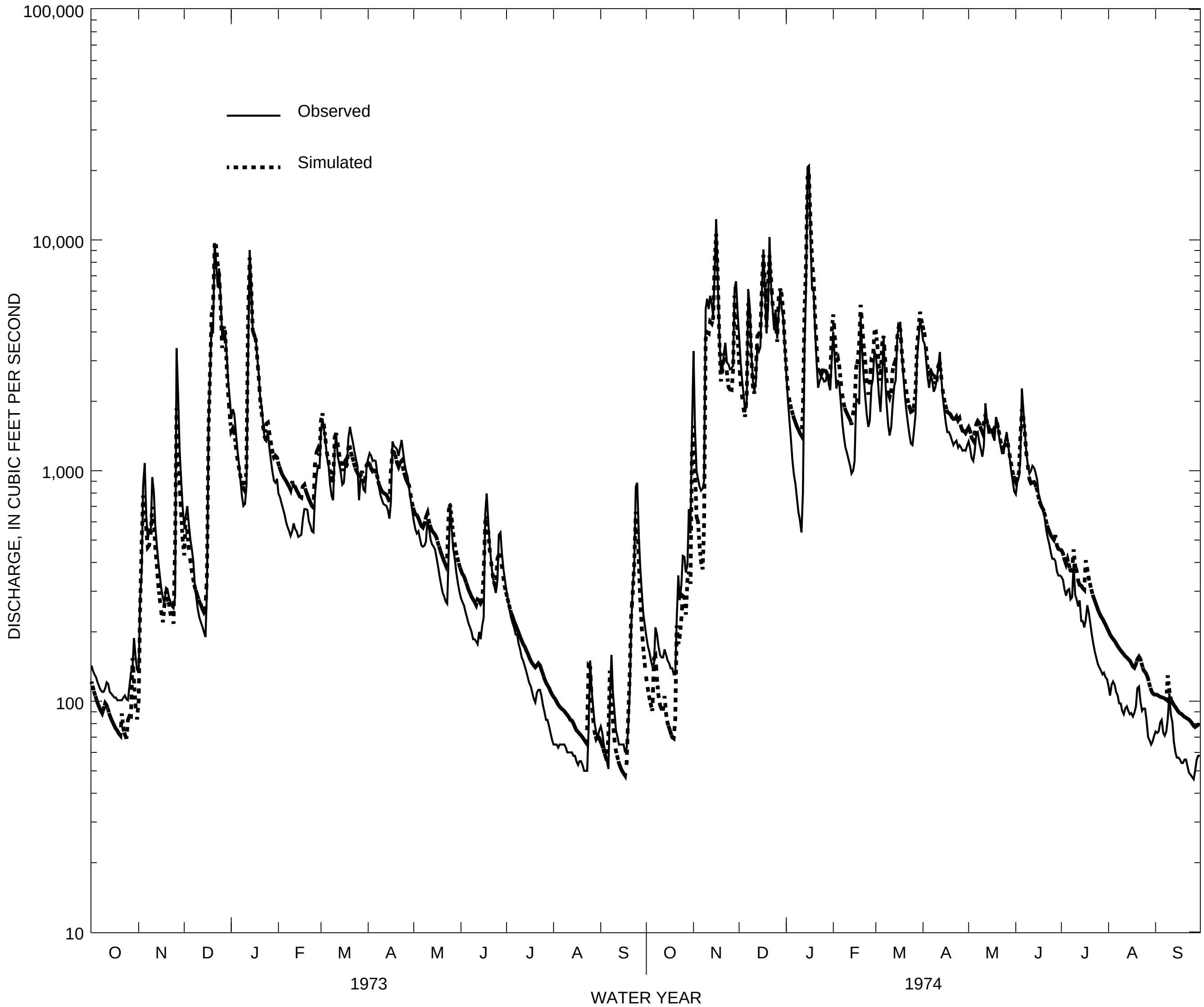


Figure 22. Observed and simulated discharge from combined Precipitation-Runoff Modeling System and Diffusion Analogy Flow (modeling for Molalla River at Canby, Oregon (stream-gaging station 14200000), 1973–74 water years. (See Glossary for program descriptions.)

simulate 226 mi^2 of intervening drainage area (70 percent of the basin). Statistical bias and error for the calibration and verification time periods are shown in table 12. The absolute errors of 16.3 and 20.7 percent for calibration and verification periods, respectively, are within the expected accuracy for simulation, when such a large part of the basin is simulated by rainfall-runoff modeling. The relatively large network modeling bias in verification is probably indicative of large variations in irrigation from year to year. Low-flow simulations are unsatisfactory because no attempt was made to account for summertime irrigation. Water-use information (Broad and Collins, 1996) is by major hydrologic unit (the entire Molalla River Basin is one unit), so data were not available to directly assess water use for this part of the basin. Water consumption in the Pudding River Basin, which flows into the Molalla River just downstream of the Canby gage, is probably larger by about a 3:1 ratio. Water-use information reported by Broad and Collins indicates a 1990 annual use of about 110 ft^3/s in the entire basin (including the Pudding River).

Yamhill River

The mapped and schematized Yamhill River stream network is shown on figure 23. The Yamhill River is schematized as a one-branch network with four tributary inflows. A discharge hydrograph from observed data at the USGS stream-gaging station on

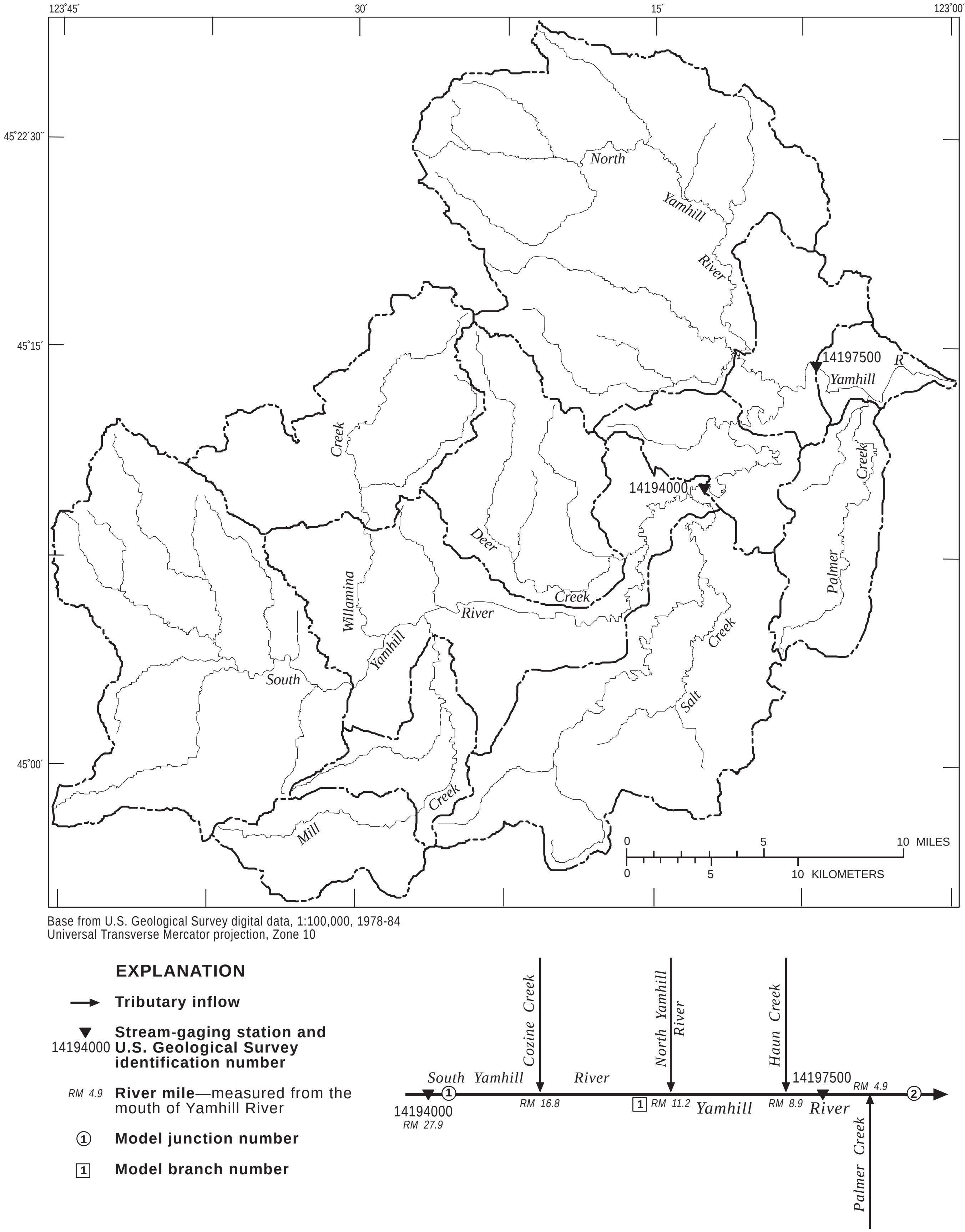


Figure 23. Yamhill River Basin, Oregon, and schematic diagram of the stream network.

the South Yamhill River near Whiteson (14194000) at RM 27.9 was used as the upstream boundary input. Subbasin hydrographs for Cozine, Hawn, and Palmer Creeks, and the North Yamhill River were simulated by PRMS modeling and input to the Willamette WDM file.

Figure 24 shows results of routing the input flow 23.4 miles downstream to the mouth (drainage area is approximately 780 mi^2). There were no downstream stream-gaging-station records with concurrent precipitation records available, so comparisons between simulated and observed flows could not be made. Although observed flow is available at Lafayette (14197500) from 1908–14 and 1929–32, precipitation data were not yet being collected in or near the basin. PRMS was used to simulate 269 mi^2 of intervening drainage area (35 percent of the basin). There were no statistical analyses for calibration or verification for this basin. Broad and Collins (1996) report that an average of about 45 ft^3/s was consumed in the basin in 1990. This magnitude of water consumption would probably decrease summer low flows such that simulated flows for this period would be higher than observed flows.

Santiam River

The mapped and schematized Santiam River stream network is shown on figure 25. The Santiam River is schematized as a three-branch network with six tributary inflows and four diversion outflows. Discharge hydrographs, from observed data at the USGS

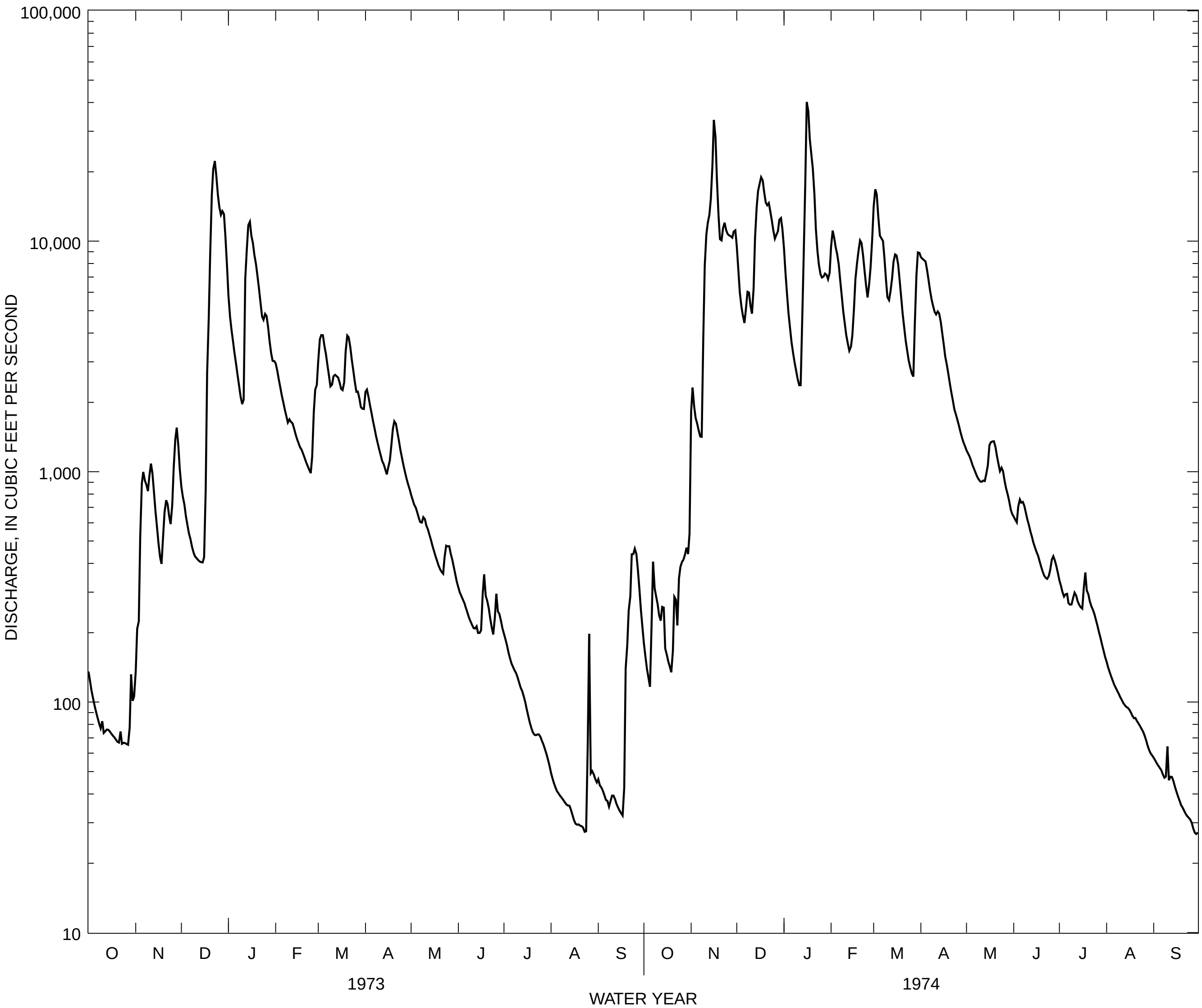


Figure 24. Simulated discharge from combined Precipitation-Runoff Modeling System and Diffusion Analog Flow modeling at the mouth of the Yamhill River, Oregon 1973–74 water years. (See Glossary for program descriptions.)

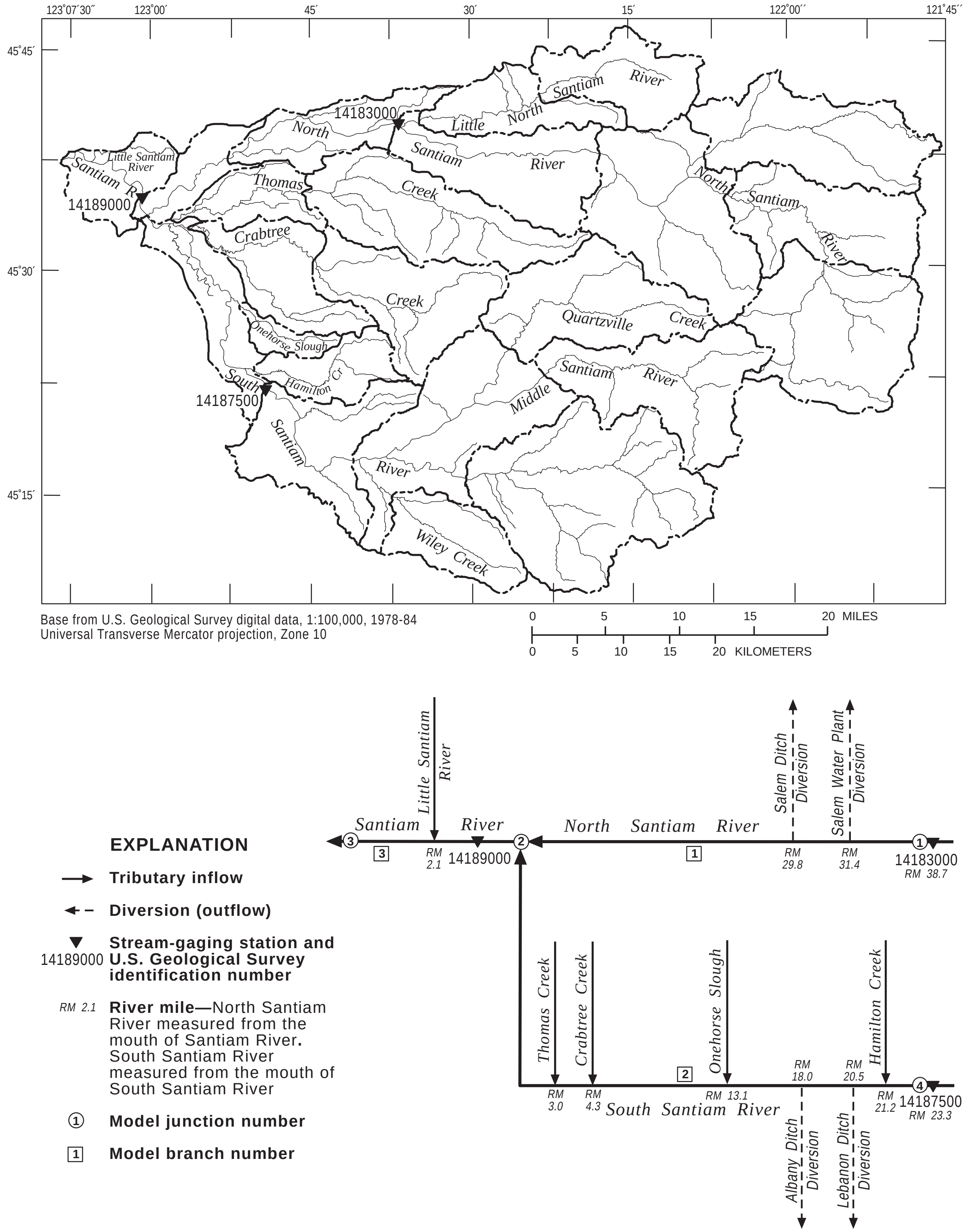


Figure 25. Santiam River Basin and schematic diagram of the stream network.

stream-gaging station on the North Santiam River at Mehama (14183000) at RM 38.7 and the stream-gaging station on the South Santiam River at Waterloo (14187500) at RM 21.2 on the South Santiam River, were used as upstream boundary inputs. Subbasin hydrographs for the tributaries shown on figure 26 were simulated by PRMS modeling and input to the Willamette WDM file. Data for two major diversions on the North Santiam River and two major diversions on the South Santiam River were provided from state records.

Figure 26 shows results of routing the input flow 38.7 miles downstream from Mehama on the North Santiam River and 23.3 miles downstream from Waterloo on the South Santiam River, where it can be compared to observed flow at the Santiam River at Jefferson stream-gaging station (14189000). PRMS was used to simulate 485 mi^2 of intervening drainage area (27 percent of the basin). Results of statistical analyses for the calibration and verification time periods indicate absolute errors of 7.4 and 6.5 percent, respectively, with a positive bias of about 3 percent for both periods (table 12). Departures between simulated and observed discharge in summer reflect water consumption from irrigation. Broad and Collins (1996) report that an average of 270 ft^3/s was consumed in 1990 for all water uses in the basin.

McKenzie River

The mapped and schematized McKenzie River stream network is shown on figure 27. The McKenzie

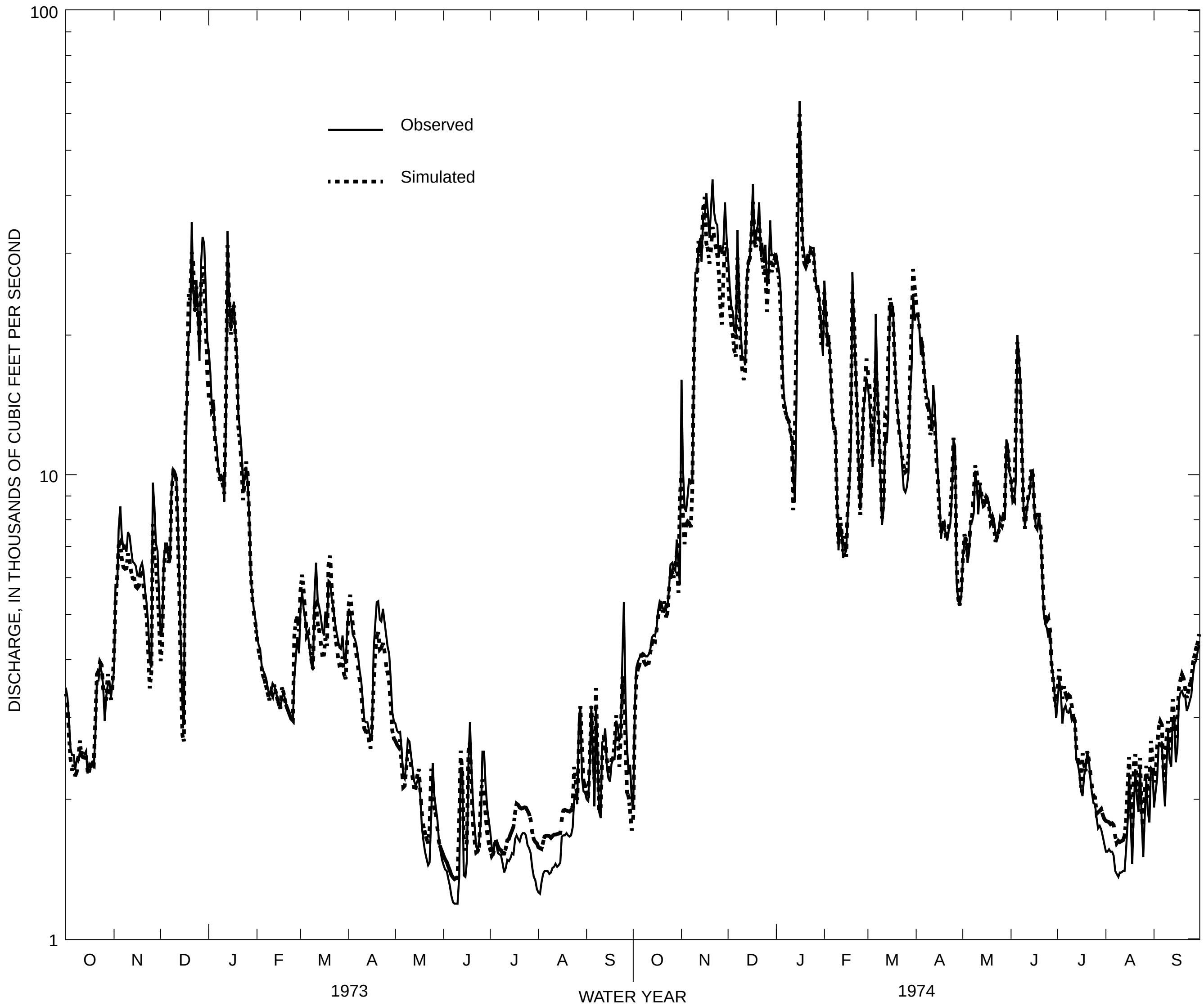


Figure 26. Observed and simulated discharge from combined Precipitation-Runoff Modeling System and Diffusion Analog Flow modeling for Santiam River at Jefferson, Oregon (stream-gaging station 14189000), 1973–74 water years. (See Glossary for program descriptions.)

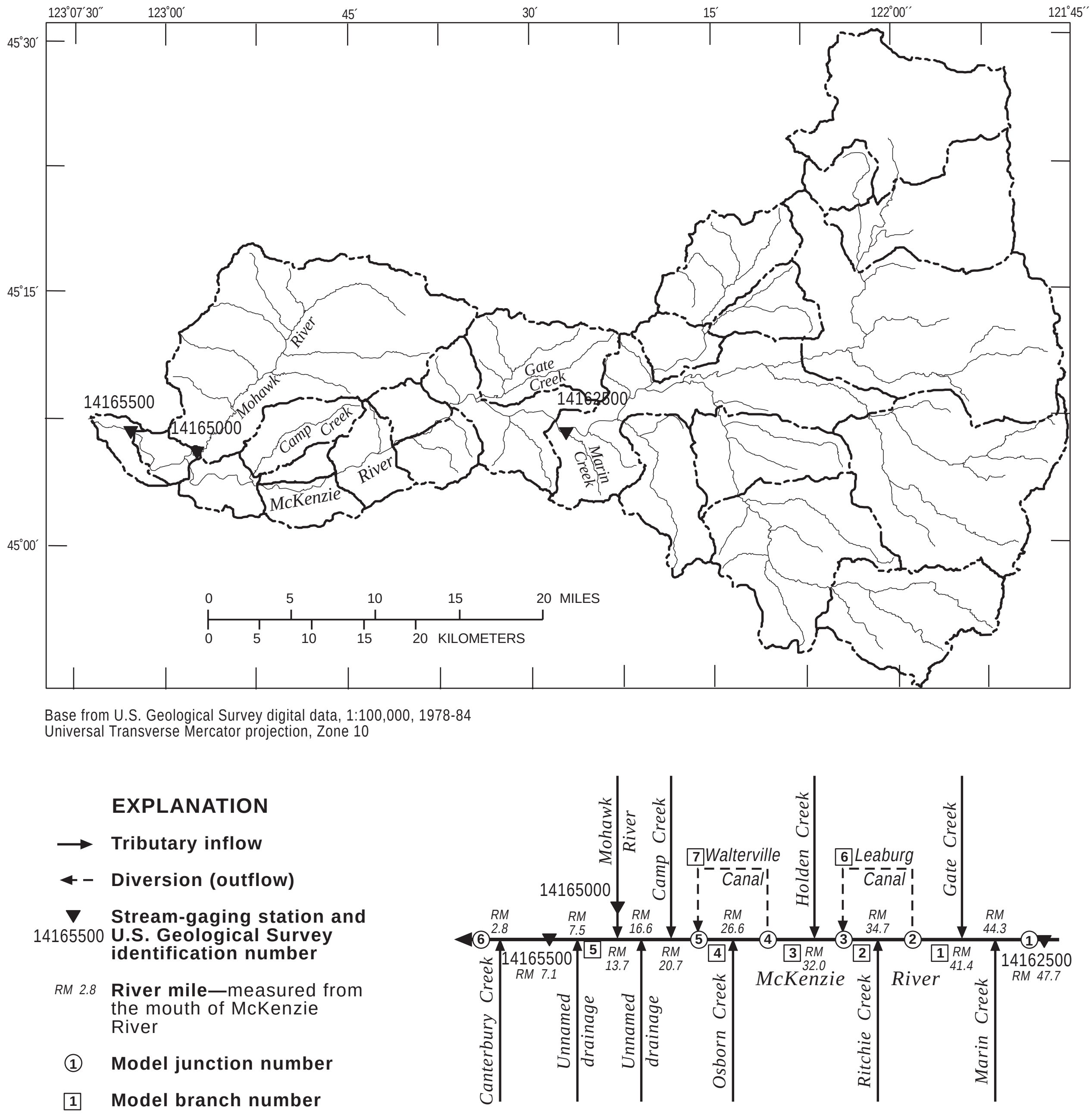


Figure 27. McKenzie River Basin, Oregon, and schematic diagram of the stream network.

River is schematized as a seven-branch network, with two of those branches as parallel canals that normally carry about 40 percent of the flow. Eleven tributaries flow into the network. The parallel canals are for power production and are operated by EWEB. Discharge hydrographs from observed data at the USGS stream-gaging station on the McKenzie River at Vida (14162500) at RM 47.7 were used as the upstream boundary input. Subbasin hydrographs for the tributaries shown on figure 27 were simulated by PRMS modeling and input to the Willamette WDM file.

Figure 28 shows results of routing the input flow 40.6 miles downstream from Vida, where it can be compared to observed flow at the McKenzie River at Coburg stream-gaging station (14165500, discontinued), where only 1 year of record was available for comparison purposes. PRMS was used to simulate 230 mi^2 of intervening drainage area (17 percent of the basin). Absolute error for the calibration period was 8.3 percent, and there was a positive bias of 4.7 percent (table 12). Broad and Collins (1996) report that an average of 260 ft^3/s was consumed in the basin in 1990.

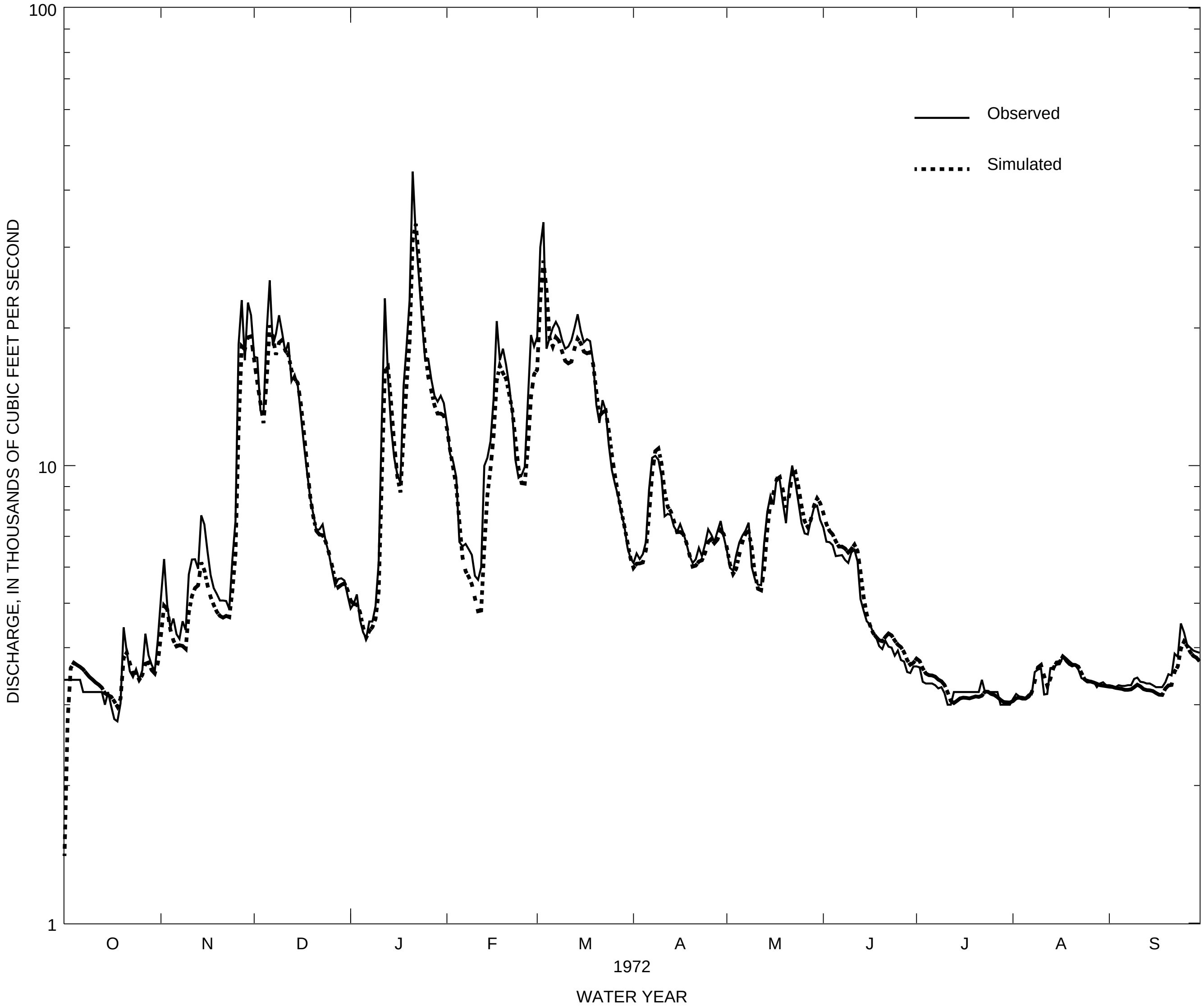


Figure 28. Observed and simulated discharge from combined Precipitation-Runoff Modeling System (PRMS) and Diffusion Analogy Flow (DAFLOW) modeling for the McKenzie River at Coburg, Oregon (stream-gaging station 14165500), 1972 water year. (See Glossary for program descriptions.)

Main-Stem Networks

For convenience, the main stem of the Willamette River was divided into four networks. River segments were divided into several branches and connected to one another similar to how the tributary networks were constructed. A starting hydrograph from observed streamflow was input at grid 1 of branch 1. Tributary inflow was simulated by PRMS modeling of the appropriate HRU's, which were input to corresponding grid locations in DAFLOW. Where major tributary inflow was required, such as flow from the McKenzie River, the flow from that network had to be simulated first to obtain the required input hydrograph. Input files for the following networks can be found in Appendix 7.

Willamette River from Jasper to Harrisburg

The mapped and schematized Willamette River from Jasper to Harrisburg stream network is shown on figure 29. For this reach, the Willamette River is schematized as a three-branch network with five tributary inflows. A flow hydrograph for the mouth of the McKenzie River was simulated by routing flow from the stream-gaging station at Vida and PRMS modeling of tributary basins and then input to the Willamette WDM file. A discharge hydrograph from observed data at the USGS stream-gaging station on the Middle Fork Willamette River at Jasper (14152000) at RM 195.0 was used as the upstream boundary input. Subbasin hydrographs for three minor tributaries were simulated by PRMS modeling and

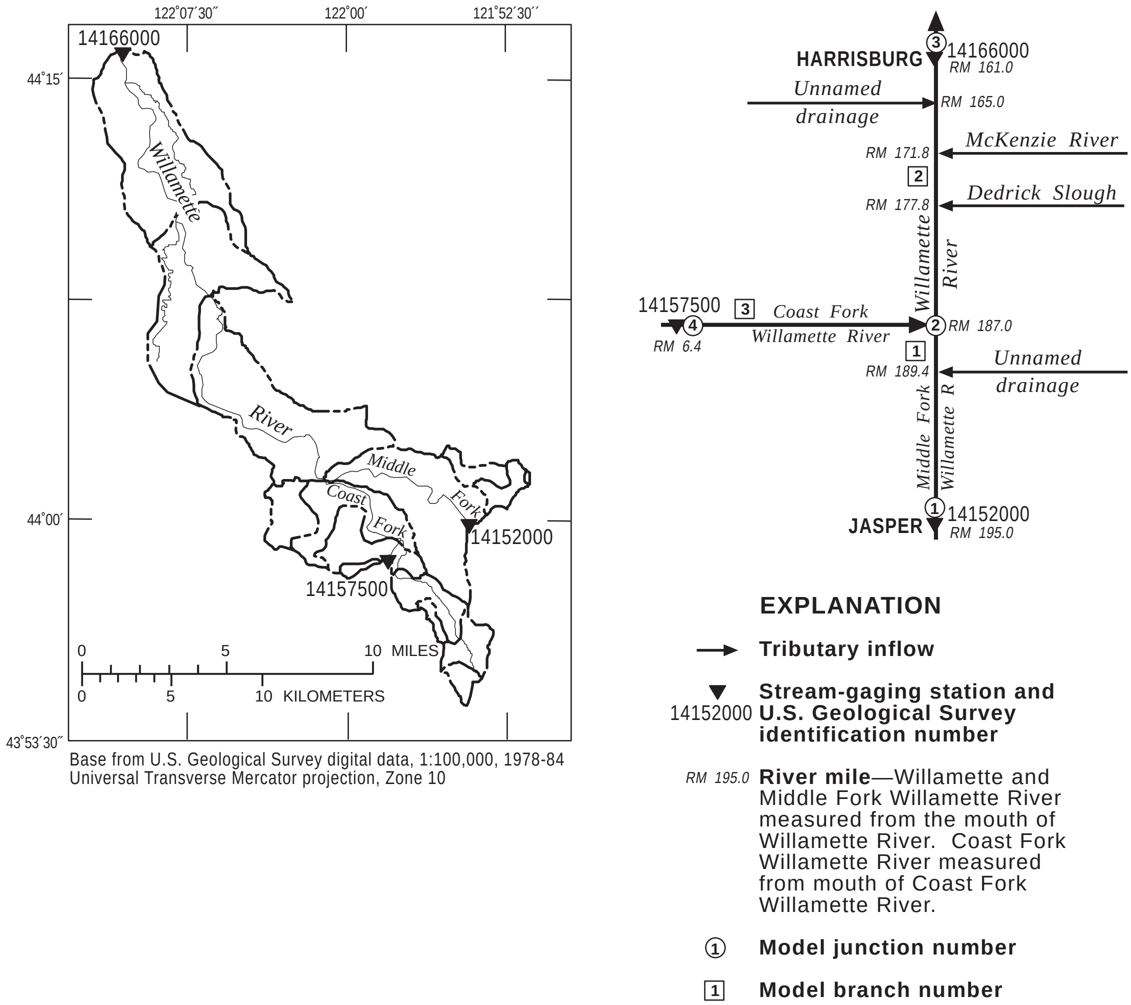


Figure 29. Willamette River and tributary basins from Jasper to Harrisburg, Oregon, and schematic diagram of the stream network.

input to the Willamette WDM file. These hydrographs were input to the appropriate grid locations for DAFLOW modeling. In one branch, flow was routed from the observed flow at the Coast Fork Willamette River at Goshen (14157500) downstream 6.4 miles.

Figure 30 shows results of routing the input flow 33.8 miles downstream, where it can be compared to observed flow at the Willamette River at Harrisburg stream-gaging station (14166000). PRMS was used to simulate 101 mi^2 of intervening drainage area (3 percent of the basin). Results of statistical analyses for calibration and verification time periods indicate absolute errors of 8.0 and 7.4 percent, respectively, and a positive bias of about 4.5 percent (table 12).

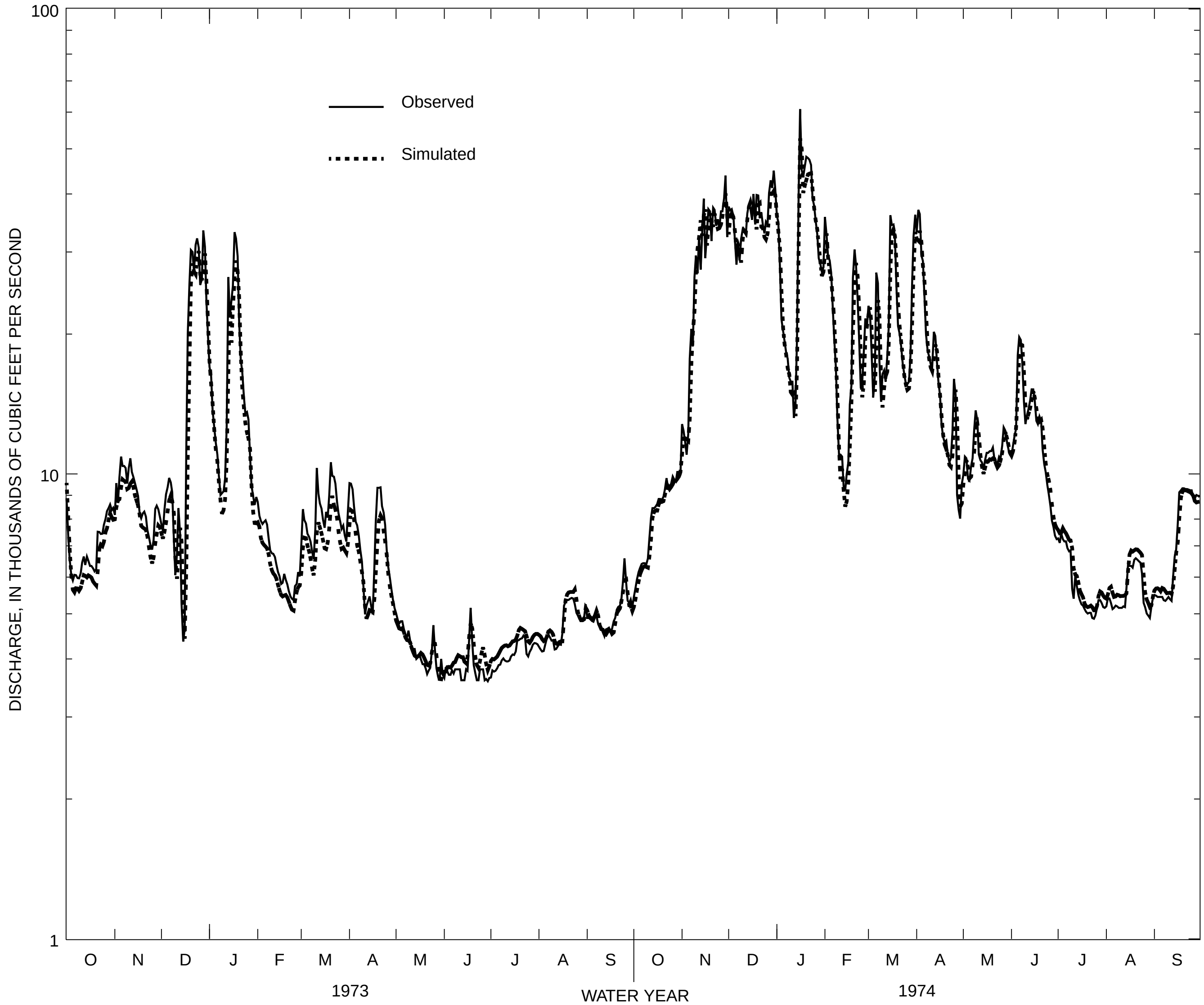


Figure 30. Observed and simulated discharge from combined Precipitation-Runoff Modeling System and Diffusion Analogy Flow modeling for Willamette River at Harrisburg, Oregon (stream-gaging station 14166000), 1973–74 water years. (See Glossary for program descriptions.)

Willamette River from Harrisburg to Albany

The mapped and schematized Willamette River from Harrisburg to Albany stream network is shown on figure 31. For this reach, the Willamette River is schematized as a three-branch network with six tributary inflows. A discharge hydrograph from observed data at the USGS stream-gaging station on the Willamette River at Harrisburg (14166000) at RM 161.2 was used as the upstream boundary input. Subbasin hydrographs for two minor tributaries and three major tributaries were simulated by PRMS modeling and input to the Willamette WDM file. These hydrographs were input to the appropriate grid locations for DAFLOW modeling. In branch 3, flow was routed from the observed flow at the Long Tom River at Monroe (14170000) to a site 4.7 miles downstream.

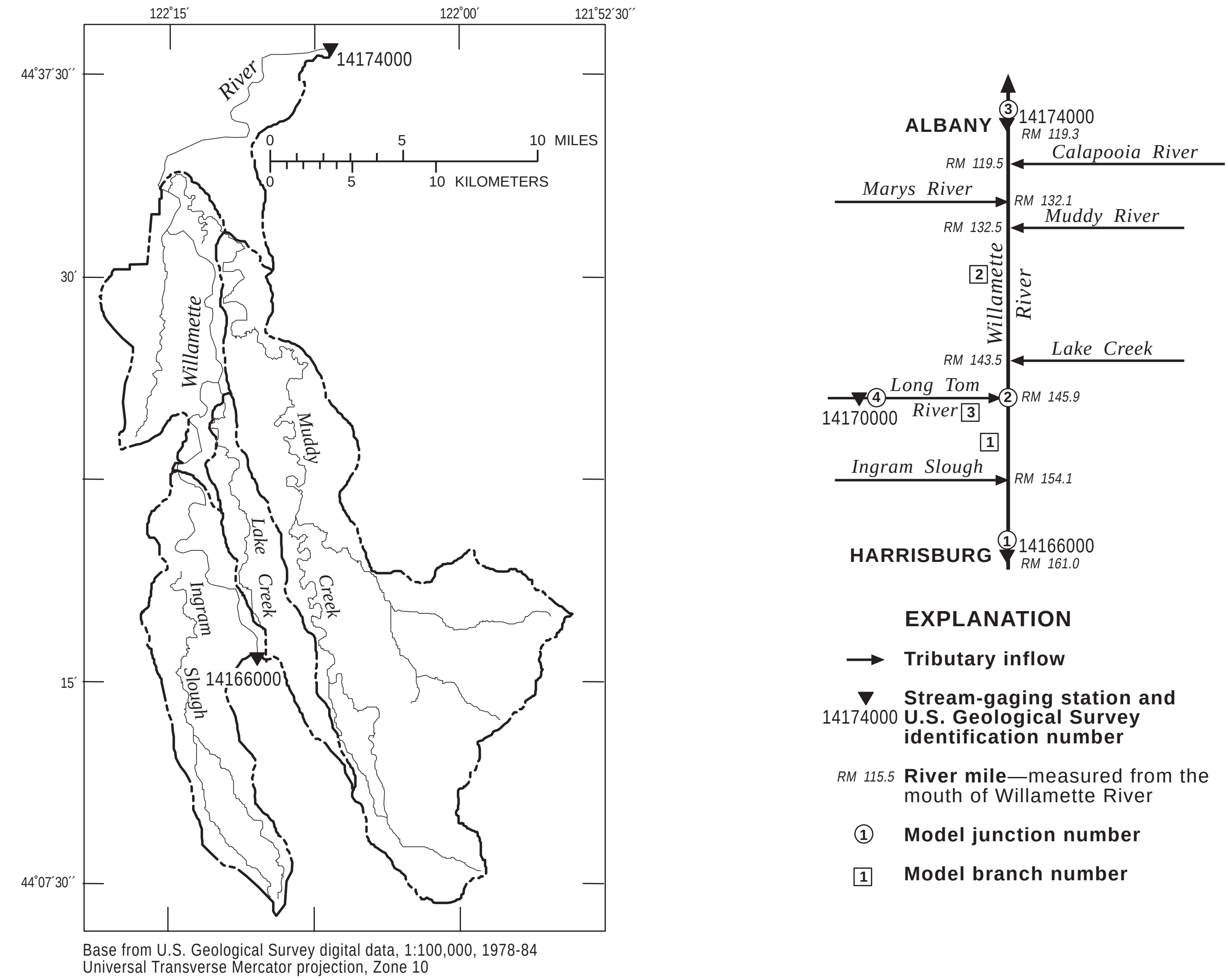


Figure 31. Willamette River and tributary basins from Harrisburg to Albany, Oregon, and schematic diagram of the stream network.

Figure 32 shows results of routing the input flow 41.9 miles downstream where it can be compared to observed flow at the Willamette River at Albany stream-gaging station (14174000). PRMS was used to simulate 1,029 mi^2 of intervening drainage area (21 percent of the basin). Results of statistical analyses for calibration and verification time periods indicate absolute errors of 5.4 and 5.3 percent, respectively, with a bias of about -1.4 percent (table 12).

Willamette River from Albany to Salem

The mapped and schematized Willamette River from Albany to Salem stream network is shown on figure 33. For this reach, the Willamette River is schematized as a three-branch network with eight tributary inflows. A discharge hydrograph constituted from data collected at the USGS stream-gaging station on the Willamette River at Albany (14174000) at RM 119.3 was used as the upstream boundary input. Subbasin hydrographs for four minor tributaries and two major tributaries were simulated by PRMS modeling and input to the Willamette WDM file. Inflow data for two diversions from the North Santiam River (Sydney Ditch and part of Pringle Creek flow) were estimated from State and local drainage district records. These hydrographs were input to the appropriate grid locations for DAFLOW modeling. In one branch, flow was routed from the observed flow at the Santiam River at Jefferson (14189000) downstream 9.6 miles.

Figure 34 shows results of routing the input flow 35.2 miles downstream, where it can be compared to observed flow at the Willamette River at Salem stream-gaging station (14191000). PRMS was used to

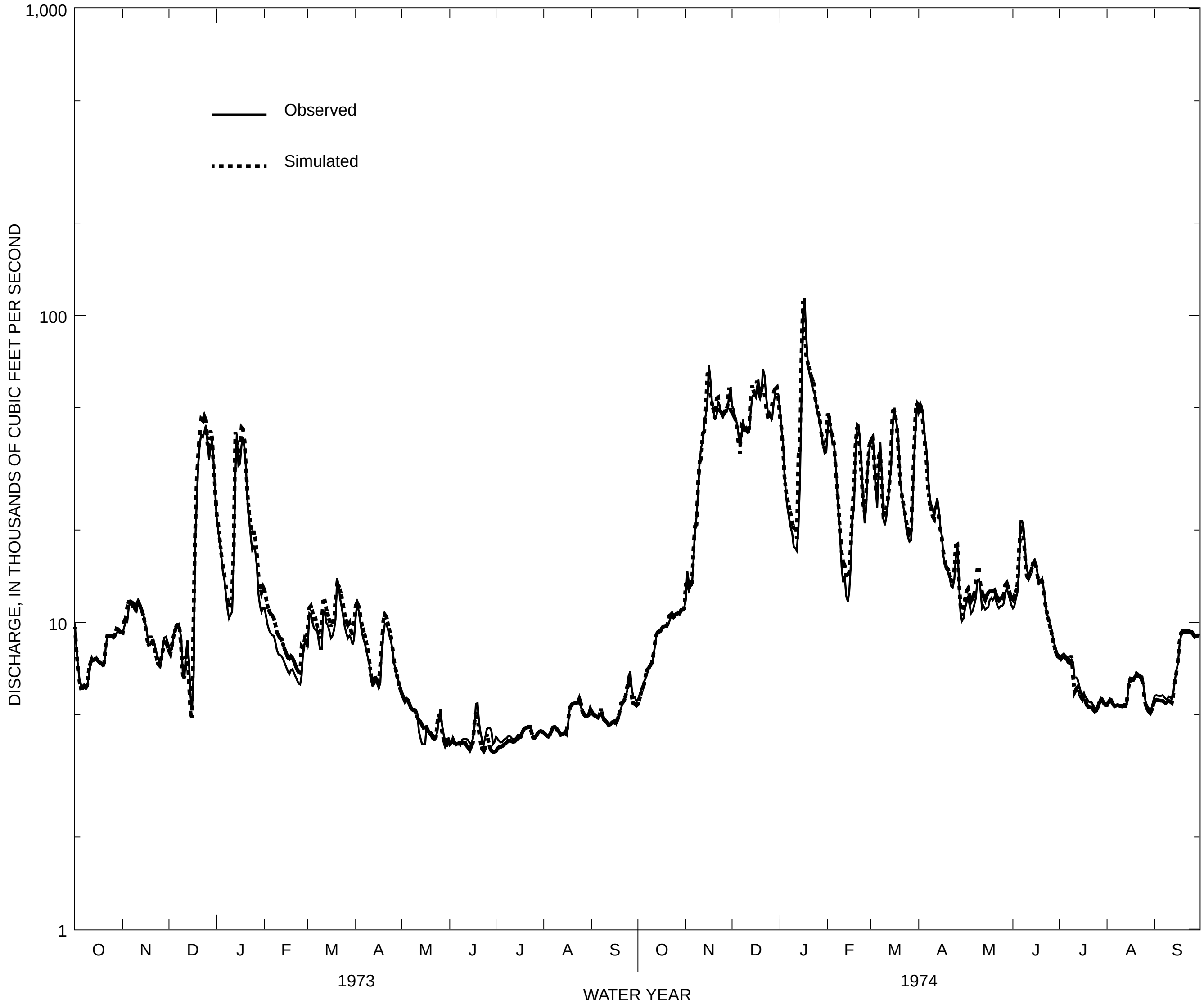


Figure 32. Observed and simulated discharge from combined Precipitation-Runoff Modeling System and Diffusion Analogy Flow modeling for Willamette River at Albany, Oregon (stream-gaging station 14174000), 1973–74 water years. (See Glossary for program descriptions.)

simulate 650 mi^2 of intervening drainage area (9 percent of the basin). Absolute error for the calibration and verification time periods was 3.2 and 3. 9 percent, respectively, and bias was nearly zero (table 12).

Willamette River from Salem to Willamette Falls

The mapped and schematized Willamette River from Salem to Willamette Falls stream network is shown on figure 35. For this reach, the Willamette River was schematized as a two-branch network with nine tributary inflows. Flow hydrographs for the mouth of the Yamhill River and the mouth of the Molalla River were simulated and input to the Willamette WDM file. A discharge hydrograph from observed data at the USGS stream-gaging station on the Willamette River at Salem (14191000) at RM 84.1 was used as the upstream boundary input. Subbasin hydrographs for six minor tributaries were simulated by PRMS modeling and input to the Willamette WDM file. Data for a diversion from the North Santiam River (part of the Mill Creek flow) was estimated from State and local drainage district records. A discharge hydrograph from observed data at the USGS stream-gaging station on the Tualatin River at West Linn (14207500) was used as tributary input from the WDM file. These hydrographs were input to the appropriate grid locations for DAFLOW modeling.

Figure 36 shows results of routing the input flow 45.6 miles downstream, where it can be compared to

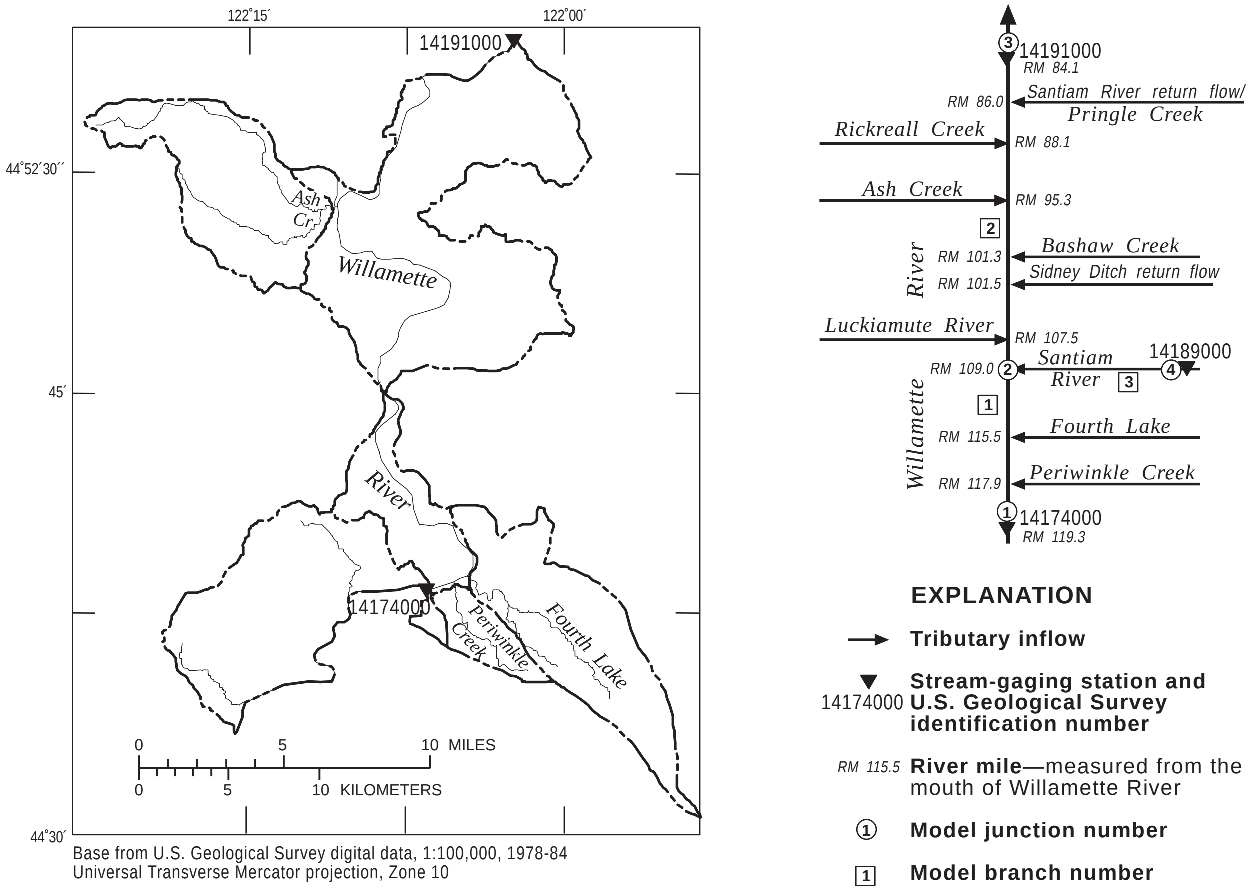


Figure 33. Willamette River and tributary basins from Albany to Salem, Oregon, and schematic diagram of the stream network.

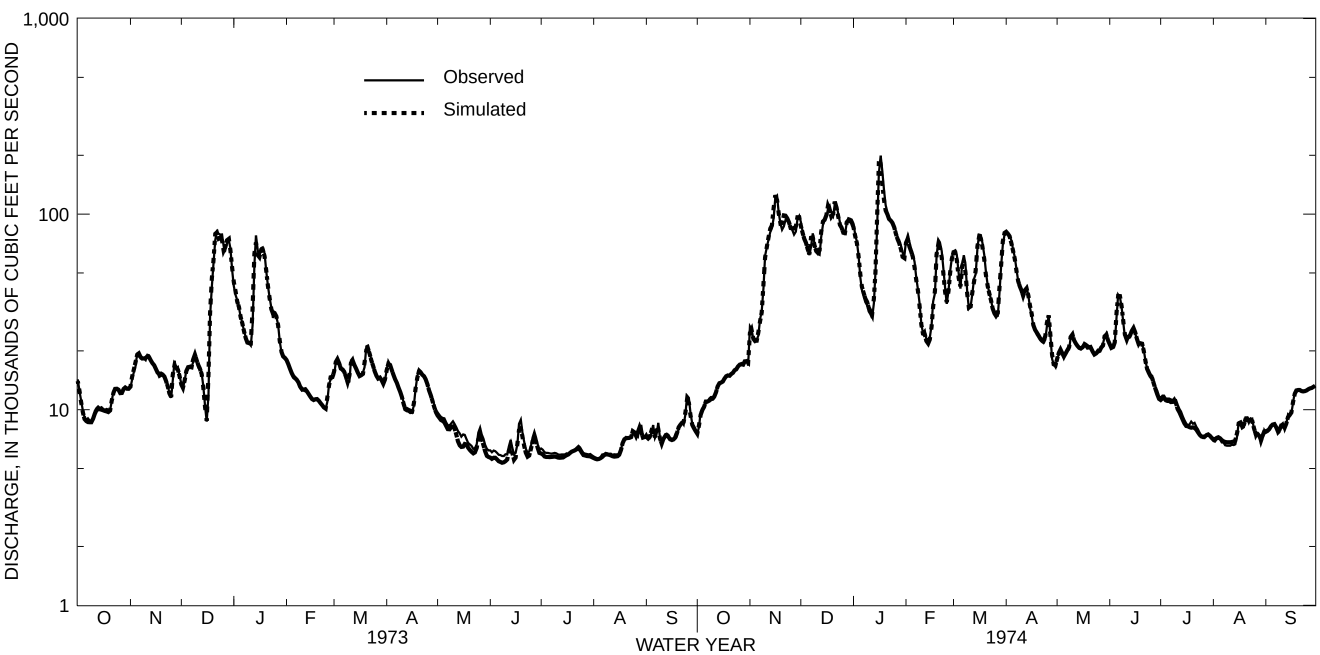


Figure 34. Observed and simulated discharge from combined Precipitation-Runoff Modeling System and Diffusion Analogy Flow modeling for Willamette River at Salem, Oregon (stream-gaging station 14191000), 1973–74 water years. (See Glossary for program descriptions.)

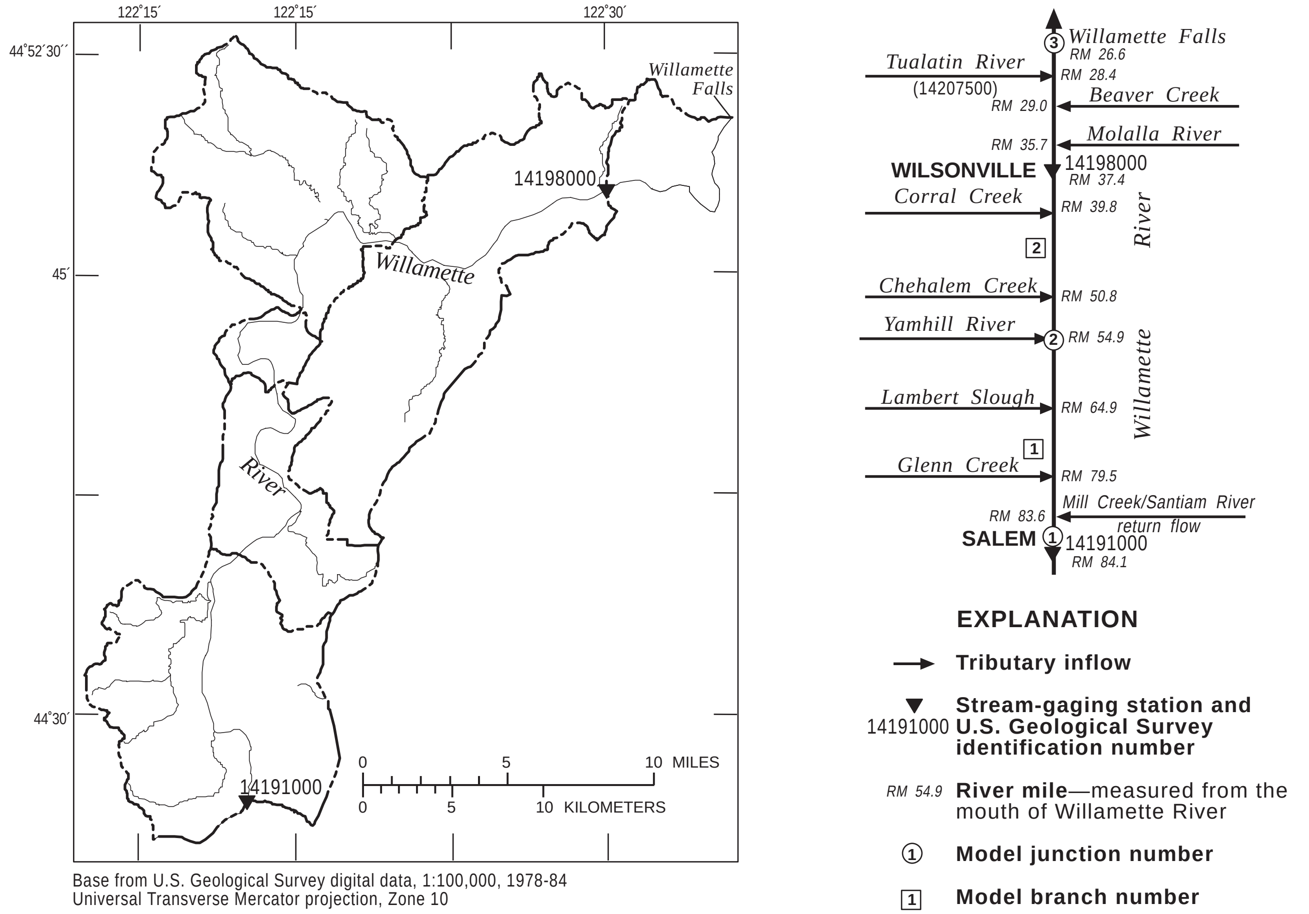


Figure 35. Willamette River and tributary basins from Salem to Willamette Falls, Oregon, and schematic diagram of the stream network.

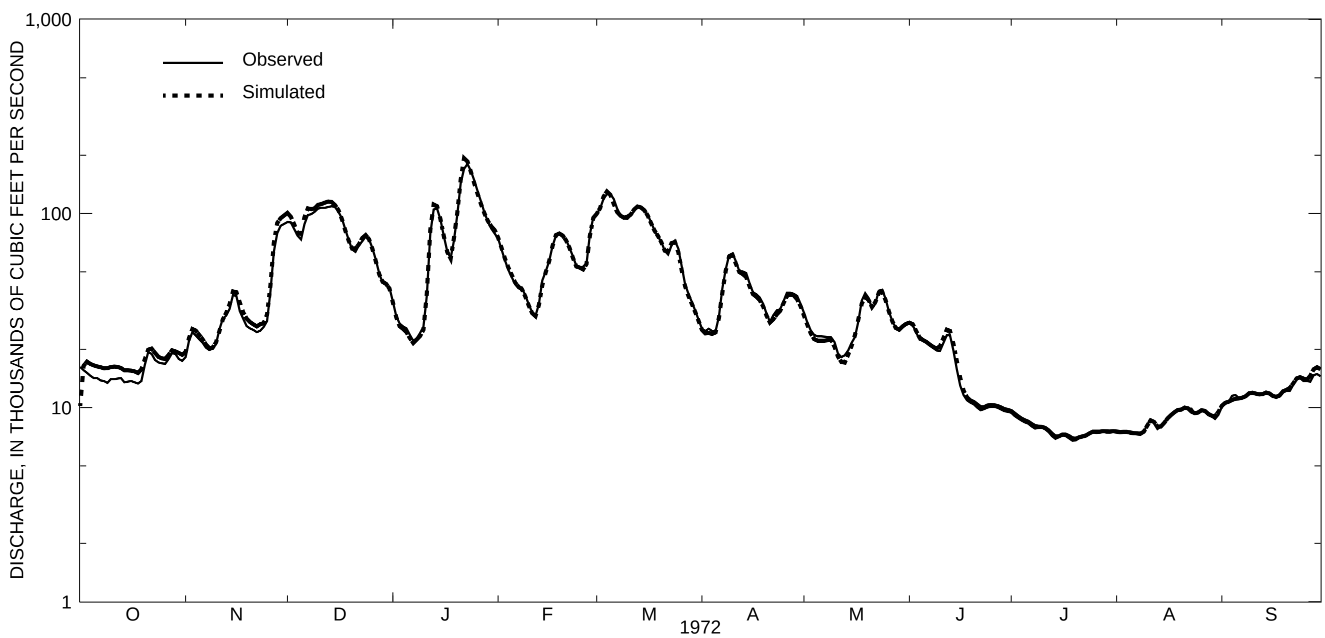


Figure 36. Observed and simulated discharge from combined Precipitation-Runoff Modeling System and Diffusion Analogy Flow modeling for Willamette River at Wilsonville, Oregon (stream-gaging station 14198000), 1972 water year. (See Glossary for program descriptions.)

observed flow at the Willamette River at Wilsonville stream-gaging station (14198000, discontinued), where only 1 year of record was available for comparison purposes. PRMS was used to simulate 350 mi^2 of intervening drainage area (4 percent of the basin). Statistical results for the calibration period indicate an absolute error of 3.3 percent and a small bias of about -1.5 percent (table 12).

AN EXAMPLE WATER-QUALITY APPLICATION

The ultimate goal of precipitation-runoff simulation and channel-flow routing is to model water quality in a basin context. There was no intent during this phase of the project to calibrate a water-quality model for a particular set of constituents; however, a linkage from the constructed hydrologic models to a water-quality model was developed. The following section describes an application of the model used for water-quality simulation. Flow data were supplied to DAFLOW by both measured inflows and by using the rainfall-runoff simulation of the Pudding River, a sub-basin of the Willamette River. The output of the DAFLOW model was used to drive the BLTM model by Jobson and Schoellhamer (1987) to simulate the injection and subsequent dispersion of dye. At this point, the model is ready to simulate other conservative constituents. Decay rates are required for the simulation of nonconservative constituents, such as nutrients or dissolved oxygen, whose fate and transport are linked to their consumption by biota and by chemical interactions. Field studies made to measure these decay rates are a prerequisite to nutrient or dissolved oxygen modeling.

Description of the Example Basin

The Pudding River is a highly sinuous stream incised in silt. The river drains primarily agricultural lands on the eastern, lower-elevation side of the Molalla River Basin (fig. 21). Basin characteristics are illustrated in figure 6. There is considerable State and Federal interest in major nonpoint sources of contamination from urban and agricultural areas in the Willamette River Basin, and the Pudding River Basin provides a good example of water-quality problems from these sources. The Pudding River has been targeted for intensive study by both ODEQ and the USGS. Point sources of contamination are also important in the basin, and although these sources have been identified, their effect on stream water quality is not well known.

During summer and fall periods, dissolved oxygen concentration in the Pudding River frequently is below 90 percent of saturation and at times is below 70 percent of saturation (Oregon Department of Environmental Quality, 1994). Excessive growth of algae contributes to dissolved oxygen problems in the main stem. In the summer, high concentrations of nutrients, warm temperatures, favorable light conditions, and low flows promote algal growth. In the late fall, winter, and spring, when high flow occurs, excessively high counts of bacteria and sediment concentrations occur frequently.

Sources of nutrients, sediment, bacteria, and oxygen-consuming substances in the Pudding River Basin are not well identified. Some of these contaminants come from identified point sources, including wastewater-treatment plants and food-processing industries. Nonpoint sources, however, also are known to be important. The major sources of sediment and bacteria in the Pudding River are probably nonpoint sources; the contaminants are the result of activities that disturb the land surface, which include farming, logging, and urbanization. Inputs of nutrients probably derive from similar sources; however, during the summer months, when nutrient inputs promote algal growth, shallow and deep ground water may also be a proportionally major nutrient source to the main-stem Pudding River and its tributaries. Water-quality transport modeling of this basin can provide valuable insight to the complex processes that occur and provide a tool for management.

Use of the Branched-Lagrangian Transport Model

A one-dimensional water-quality model based on the Lagrangian reference frame was developed for use in simulating the transport of conservative and nonconservative constituents and for applying reactions between constituents for branched river systems, tidal canal systems, and deltaic channels (Jobson and Schoellhamer, 1987). BLTM solves the convective-dispersion equation by using a Lagrangian reference frame in which the computational nodes move with the flow. Unsteady flow hydraulics must be supplied to the model, and constituent concentrations are assumed to have no effect on the hydraulics. A flow model such as DAFLOW can be used to supply the hydraulic information to the model. Reaction kinetics for non-conservative constituents can be supplied by the user.

One-dimensional transport theory is thoroughly explained in the BLTM user's manual (Jobson and Schoellhamer, 1987). The advantages of a Lagrangian approach are (1) the scheme accurately models the convection and dispersion terms in comparison to the usual Eulerian approach (Jobson, 1980; Thomson and others, 1984), and (2) the model directly represents the actual transport processes by using the concept of a fluid parcel, where chemical and biological reactions occur and move with the flow. The solution scheme starts with a series of parcels in the river (initial conditions at various input locations) and adds a new parcel at each external boundary node with flow into the system during each time step (boundary conditions).

Model Calibration

Data were collected from time-of-travel studies that defined the travel and dispersion of dye in the Pudding River for July 7–12, 1993 (Lee, 1995). These data were used to calibrate a solute transport model for the transport of conservative constituents. Figures 37–39 show simulation results of the calibrated BLTM model compared to observed data. Appendix 14 lists the input files used in DAFLOW and BLTM modeling.

For model calibration, DAFLOW input flows on the main stem and tributaries were interpolated from measurements of discharge made at the time of the dye studies. These discharge measurements were used rather than discharge simulations from PRMS precipitation-runoff modeling (table 13) because they provided a more accurate calibration of the BLTM model. On July 2, a convection storm occurred that was not logged on all precipitation-gage records used in the PRMS simulation. The differences between the measured and PRMS simulated flows shown in table 13 are typical of what can be expected from simulations when convection storms dominate the weather and irrigation occurs within the basin. Simulated flows were lower than measured flows at most locations because the rainfall distribution was not accurately portrayed by data from the precipitation-gage network used in modeling. Simulated flows were higher than measured flows on Mill and Zollner Creeks because simulations were not adjusted for irrigation of agricultural crops (Appendix 14 contains the *FLOW.IN* file used in calibration and lists the WDM files of interpolated flows that were used).

Table 13. Measured and Precipitation-Runoff Modeling System simulated discharge used to define flow distribution in the main stem of the Pudding River for Branch Lagrangian Transport Model modeling
[ft^3/s, cubic feet per second; RM, river mile]

River mile	Stream name	Date of measurement	Measured discharge, in ft^3/s	Simulated discharge,[1] in ft^3/s
6.2	Mill Creek at RM 0.1	07/08/93	6.2	19.4
8.1	Pudding River at Aurora (14202000)	07/07/93	279	215
		07/08/93	259	210
20.2	Butte Creek at RM 2.3	07/07/93	52.8	32.2
		07/09/93	35.7	31.4
27.0	Pudding River at bridge	07/07/93	187	130
29.1	Zollner Creek at RM 0.4	07/07/93	2.1	6.3
35.8	Pudding River at bridge	07/08/93	135	118
45.5	Abiqua Creek at RM 1.0	07/09/93	68.2	30.3
48.7	Pudding River at bridge	07/09/93	57.8	53.0

[1] Simulated by rainfall-runoff modeling using Precipitation-Runoff modeling System. Flows were underestimated because the source of the rain was a convection storm that affected only part of the basin.

Dye concentrations were simulated for three reaches on the main stem of the Pudding River from RM 45.5 to 31.5, RM 31.5 to 17.6, and RM 17.6 to 5.4 to coincide with the observed dye-study data. Observed dye-concentration data were adjusted to simulate a conservative substance by applying a recovery ratio. The recovery ratio was computed by techniques described by Hubbard and others (1982). The 15-minute flow data needed in BLTM modeling were linearly interpolated in the *BLTM.FLW* file from daily data. This is an appropriate method if flows are not rapidly changing. The input boundary used in modeling is not the point at which dye is injected, but rather the first downstream location where the dye is mixed laterally. This input is used because BLTM is a one-dimensional model that assumes total mixing in the cross section. In model calibration, peak timing is matched between observed and simulated values by adjustment of the A_0 parameter (cross-section area storage) in the

DAFLOW model, and peak amplitude is matched by adjustment of the DQQ parameter (dispersion coefficient) in the BLTM model. Appendix 14 contains the *BLTM.IN* input files used in calibration. The matching of simulated and observed dye peaks provided an opportunity to adjust the A_0 values that were more crudely calibrated in the DAFLOW model.

Calibration Results

For the three simulations, the observed and simulated data matched well (figs. 37–39). As the dye peaks progressed downstream, the simulated peaks were higher in amplitude and had less of a trailing edge than the observed peaks. This pattern was probably caused by a continuous exchange between ground and surface waters (causing additional dilution) occurring along the entire channel length, which is not simulated in the model. The streambed of the Pudding River is generally composed of fine material for most of its length, and there should be a relatively small exchange of water between ground and surface waters. Other streams in the Willamette River Basin have a high rate of exchange between the ground and surface waters, as discussed in the section "Gain-Loss Investigations." Examining the differences between the observed and simulated dye curves may give valuable insight to this flow exchange and may help in determining associated exchange rates.

Dye-concentration data also were generated by using flows simulated from rainfall that occurred in the basin in order to evaluate the associated error. Precipitation-runoff simulations were not used for calibration purposes because they predicted flow about 20 percent lower than what was observed for the period of study. These precipitation-runoff simulations resulted in an approximately 12-percent longer time of travel (fig. 40). The -20-percent error in flow prediction is within the $\pm$36-percent mean absolute error of the runoff model (table 11).

Determining Travel Time and Dilution of a Hypothetical Spill

For the Pudding River, the DAFLOW and BLTM models can be used to determine travel time and dispersion of a contaminant spill for any magnitude of stream discharge. The same dye-concentration hydrograph was simulated for selected discharges and

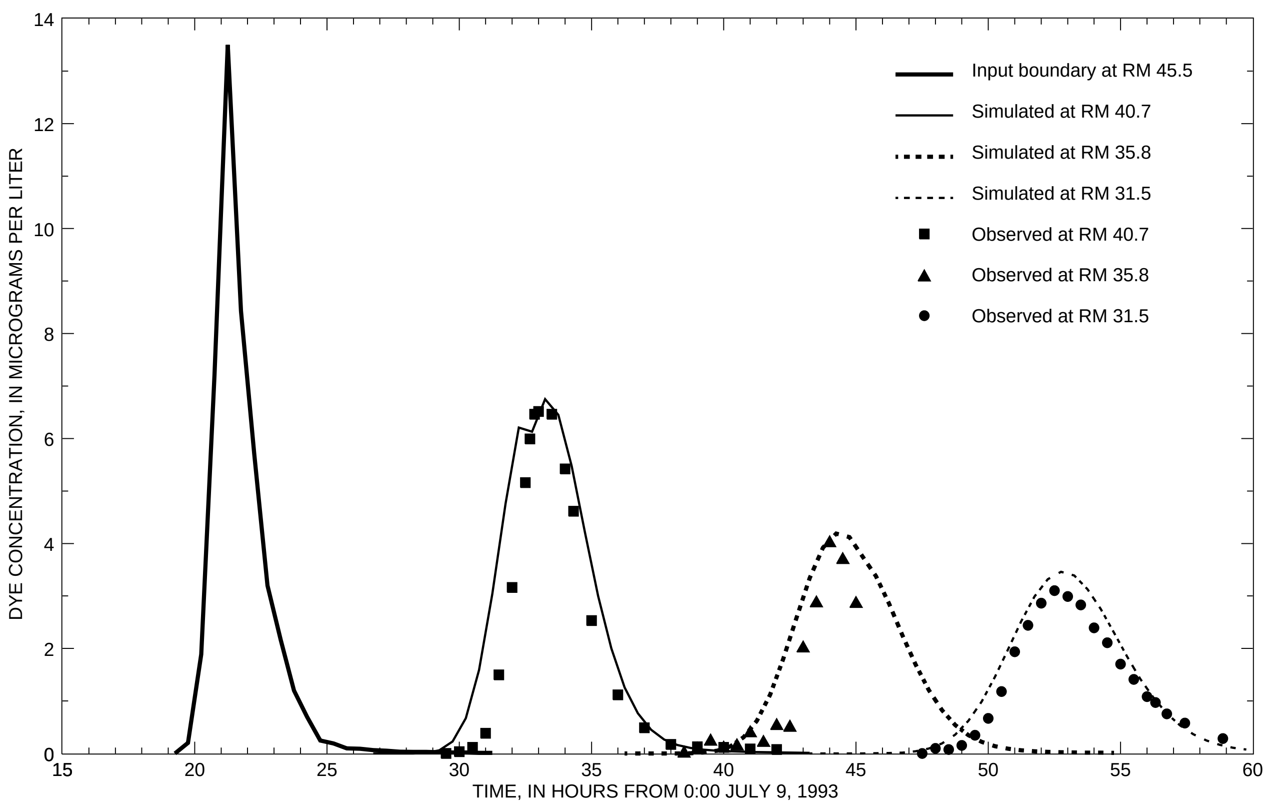


Figure 37. Branch Lagrangian Transport model simulation of dye transport in the Pudding River, Oregon, from river mile (RM) 45.5 to 31.5, July 9–11, 1993. (Observed values adjusted for dye loss from absorption by applying a dye recovery ratio. (See Glossary for program description.)

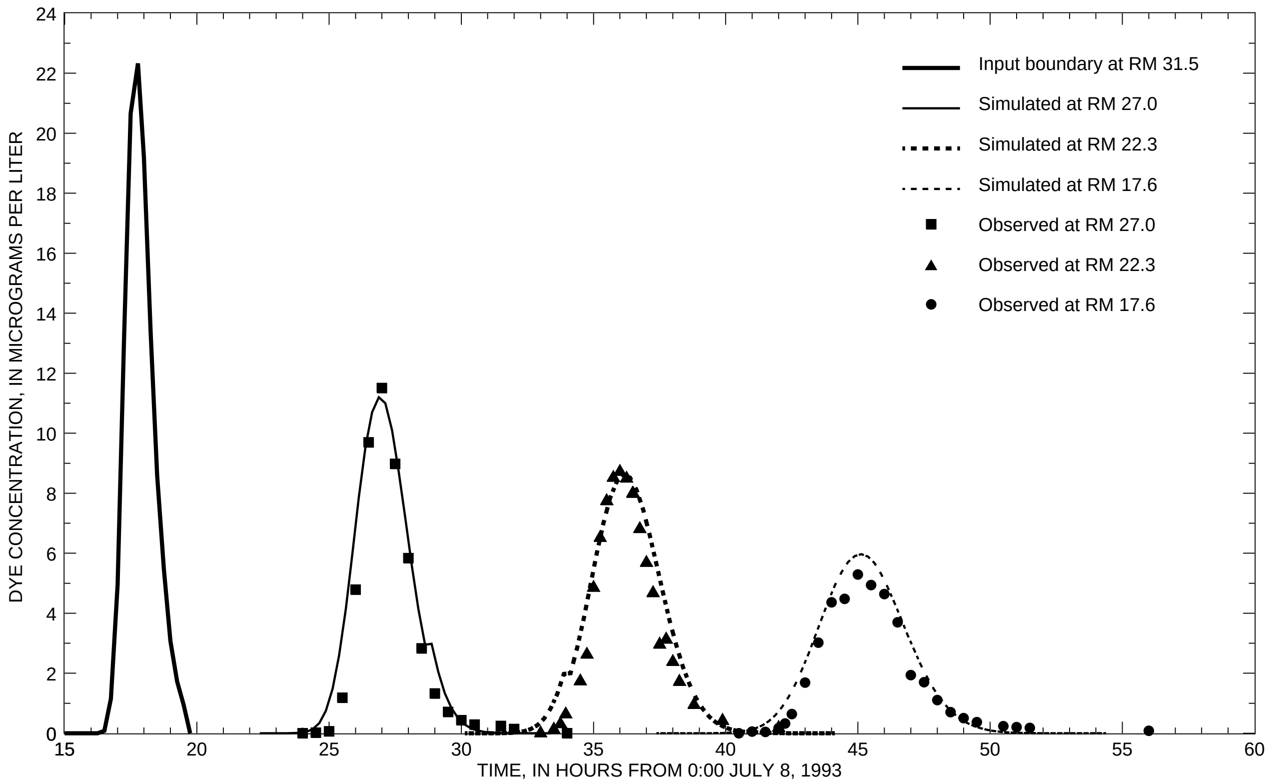


Figure 38. Branch Lagrangian Transport model simulation of dye transport in the Pudding River, Oregon, from river mile (RM) 31.5 to 17.6, July 8–9, 1993. (Observed values adjusted for dye loss from absorption by applying a dye recovery ratio. See Glossary for program description.)

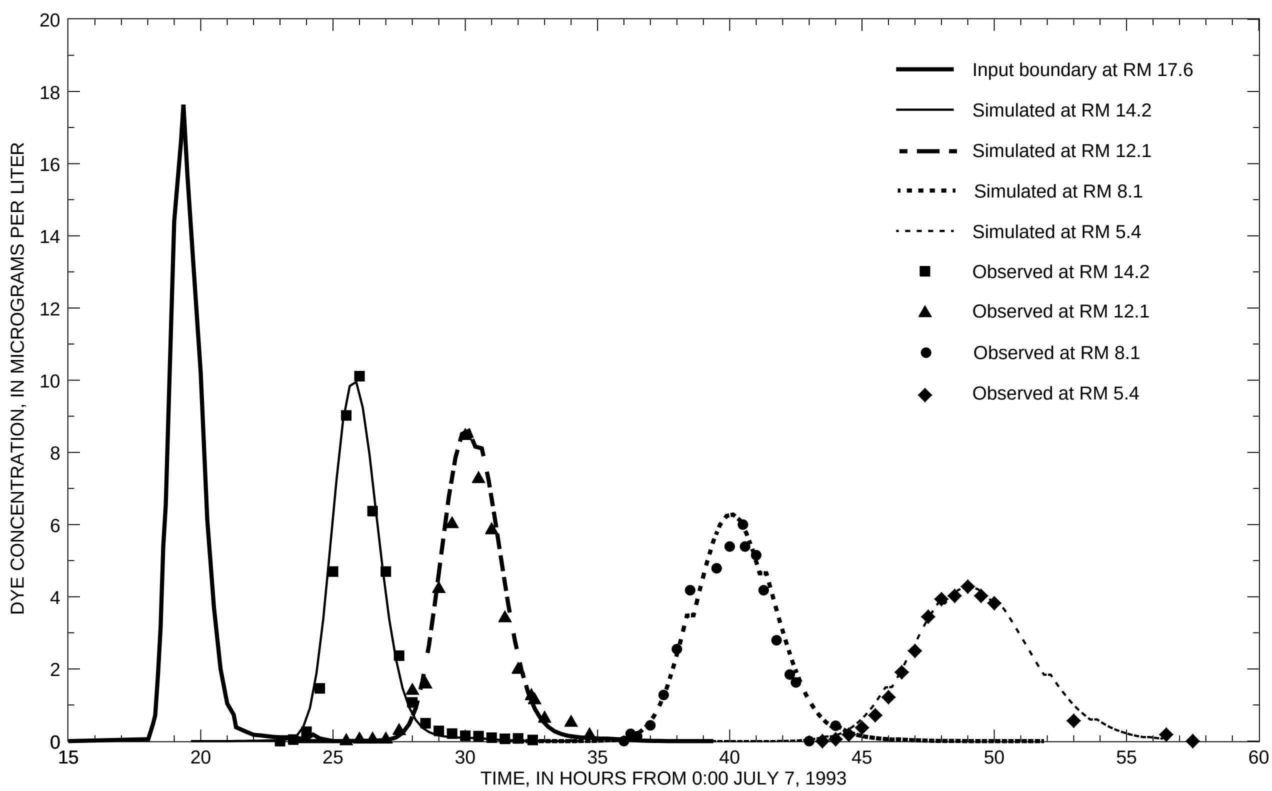


Figure 39. Branch Lagrangian Transport model simulation of dye transport in the Pudding River, Oregon, from river mile (RM) 17.6 to 5.4, July 7–9, 1993. (Observed values adjusted for dye loss from absorption by applying a dye recovery ratio. See Glossary for program description.)

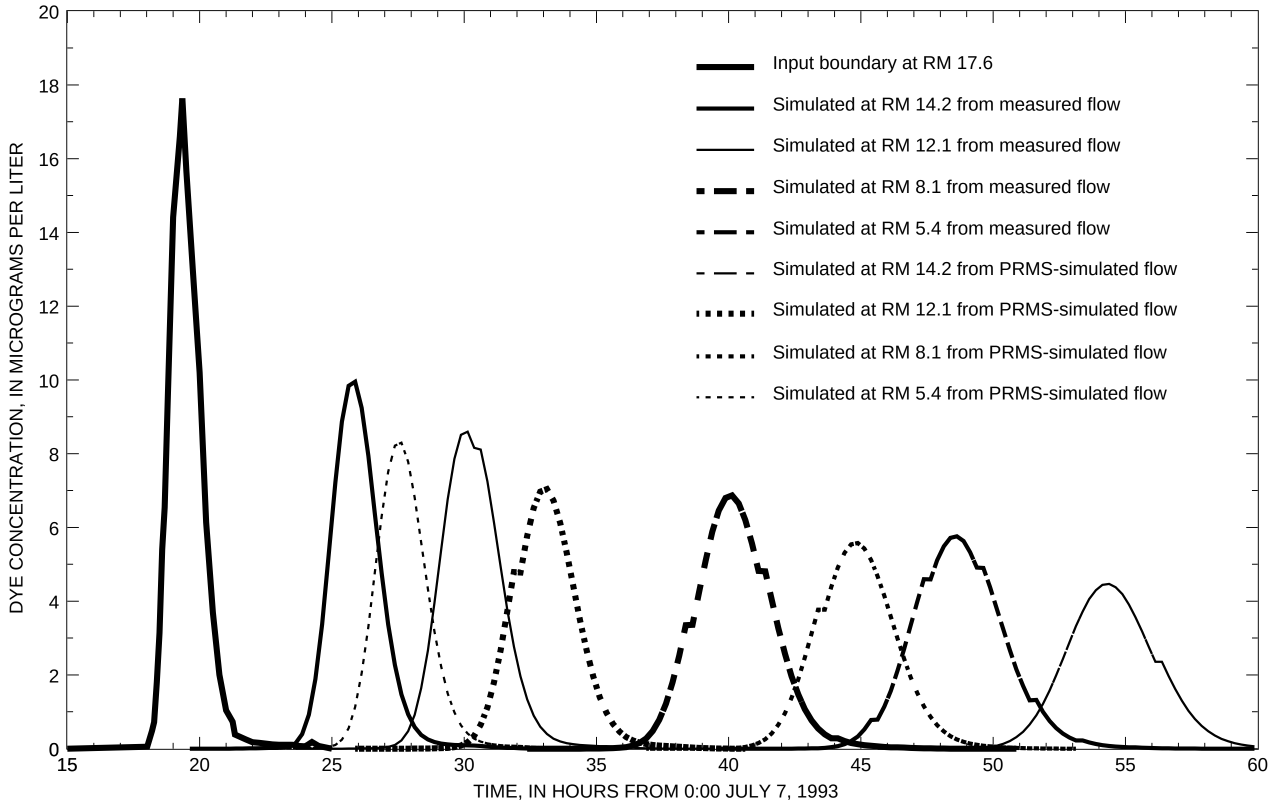


Figure 40. Branch Lagrangian Transport model simulation of dye transport in the Pudding River, Oregon, from river mile (RM) 17.6 to 5.4 using measured flow and using Precipitation-Runoff Modeling System (PRMS) simulated flow. (Simulated flows were 20 percent lower than observed flows and resulted in a 12 percent longer estimate of peak time. See Glossary for program descriptions.)

the output of peak travel time was used to create the curves presented in figure 41. These curves can be used to determine travel times (water velocity) of a spilled conservative constituent between any two stream locations on the main stem of the Pudding River for a given base discharge at the stream-gaging station at Aurora (14202000). Similar curves could be constructed to show the attenuation of the peak concentration as the constituent travels downstream.

FUTURE WATER-QUALITY MODELING

The next logical sequence in water-quality modeling is to incorporate a solute-transport model into the existing dynamic streamflow model of the Willamette River Basin for selected stream networks and specific applications by configuring and calibrating BLTM to operate with DAFLOW using dye-study data.

Further calibration should include providing reaction dynamics for the simulation of dissolved oxygen, bacteria, and water temperature, but such simulation would require additional data collection. With calibrated reaction dynamics, the model also can be used to determine the relation of dissolved oxygen and

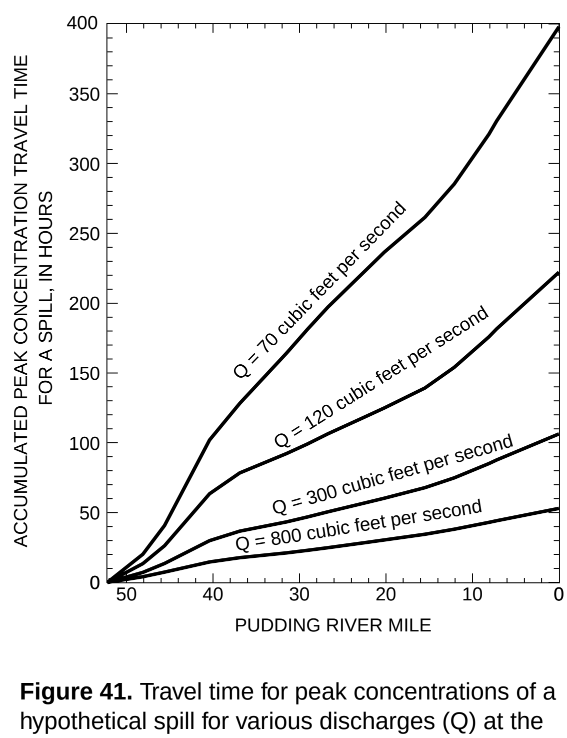


Figure 41. Travel time for peak concentrations of a hypothetical spill for various discharges (Q) at the Pudding River at Aurora, Oregon (stream-gaging station 14202000) beginning at river mile 52.2 at Kaufman Road bridge crossing.

water temperature to nutrient loading, sediment oxygen demand, reaeration rates, flow conditions, climatic conditions, algal growth rates, and riparian vegetation cover during summer months. Then, the model also can be used to assess the potential effectiveness of various management options for alleviating water-quality problems.

Fate and transport of toxic substances and trace elements still are not well understood. One major reason for the lack of understanding is that transport of toxic constituents usually occurs during dynamic (unsteady-state) conditions, which are difficult to measure and assess. The current solution to this problem is to assume transport under steady-state conditions. Further research and data collection will eventually define the dynamic transport processes involved and the reaction dynamics of these substances under unsteady conditions. Some of these substances will be transported in the suspended phase; therefore, a sediment-transport model will have to be linked to the flow model (Laenen, 1995). When all the dynamic and relevant processes are known and adequate data for calibration has been collected, unsteady-state flows will be suitable for water-quality modeling purposes, and flows simulated by precipitation runoff and streamflow routing will have to be used in the prediction process.

Eventually, overland- and subsurfpface-transport processes that carry substances into the stream will have to be defined so that source modeling can be done. These runoff-model elements are currently in the research stage, but can be incorporated in future modeling when they become usable.

LINKING DATA AND MODELS

In preceding sections, different components of programs required to model flows in the Willamette River Basin have been discussed. This section describes the links between all data requirements and all model components.

Geographic information system programs (ARC-INFO) and spatial data layers are required to determine HRU's needed to define the discrete spatial inputs to PRMS. Data-base management programs (ANNIE) are required to input, output, and manage data files in a master WDM file. A model application program (SCENARIO GENERATOR) is used to display the WDM file for PRMS. River-network applications are run with the streamflow-routing model DAFLOW by using the WDM file. Files from the DAFLOW model can be used to drive water-quality models such as BLTM. (A newer version of BLTM, identified as CBLTM, was used in this study.) Programs in ANNIE can be used to output graphs and statistics. A flowchart of the files and programs used in this study are shown in figure 42.

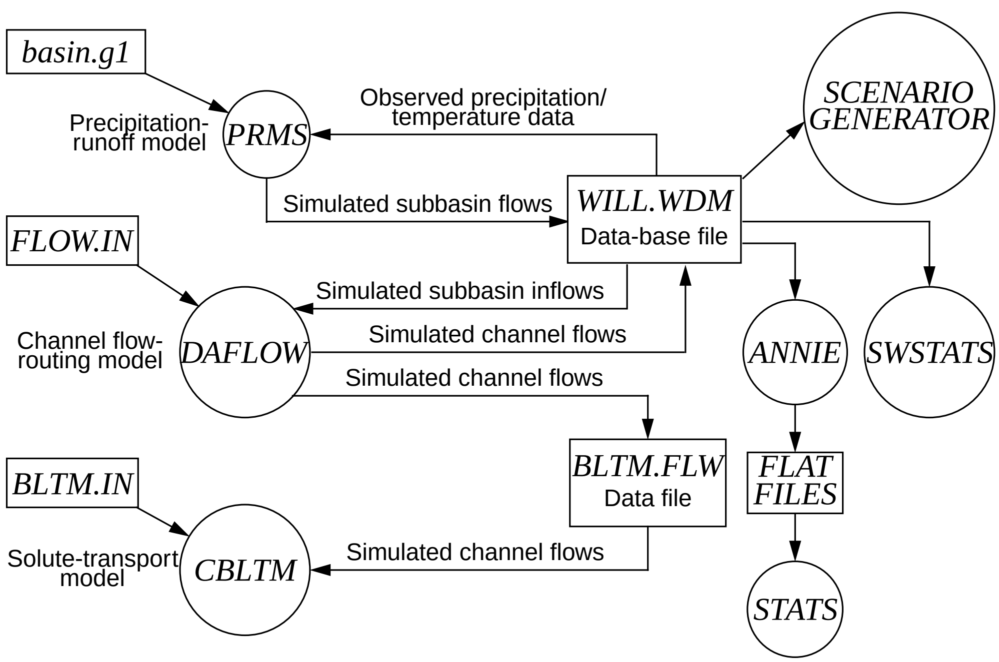


Figure 42. Programs and files used to link the Precipitation-Runoff Modeling System (PRMS), the Diffusion Analogy Flow model (DAFLOW), and the Branched Lagrangian Transport Model (BLTM) for simulated operations. (A circle denotes a computer program, and a rectangle denotes a computer file. See Glossary for program descriptions.)

ARC-INFO and Geographic Information System Files

For a user-specified basin, several data layers and associated attributes are used to delineate and define discrete HRU's. (For this study, data layers of land use, slope and aspect, geology, and soils were merged by using ARC-INFO programs [fig. 43] into an HRU data layer.) In turn, codes attached to the individual HRU polygons are related to tables of PRMS parameter values (tables 6 and 7) by using an AML program (Appendix 2). Characteristics such as average annual precipitation, average elevation, and dominant aspect are determined for each HRU as required input to PRMS. A postprocessing program (G1MAKER) merges the files created by the AML program. Minor editing is subsequently required to add rain, temperature, and streamflow locations, rain adjustments, lapse rate tables, and input and output file designations.

A directory and data dictionary for GIS files are presented in Appendix 12. Execution of the AML program can be done in the directory where the AML resides. For the AML simulation, only subbasins listed in the data dictionary in Appendix 12 can be used. The AML program will create three output flat files after it has been executed. The three files contain the 36- through 38-line HRU inputs needed in the PRMS parameter file. The three files must be reformatted by the HRU input formatting program. To create a new PRMS parameter file, the user must manually assemble the necessary non-HRU and HRU inputs by using a file editor. Input formatting information for the PRMS parameter files is provided in the PRMS manual (Leavesley and others, 1983). Modifications to PRMS made for this study are presented in Appendix 8.

Delineation of HRU's and definition of associated PRMS model parameters is done infrequently; however, these tasks occasionally may be redone for specific subbasins in order to consider parameter requirements in future water-quality modeling. For example, if agricultural runoff is to be studied in a specific subbasin, the land-use data layer may have to be expanded to include different crop types; HRU's would have to be redefined, and the relational tables would need to be modified to redefine old and include new PRMS parameter values. Individual basins can be modified and modeled independently and need not involve other Willamette River subbasins or their calibration.

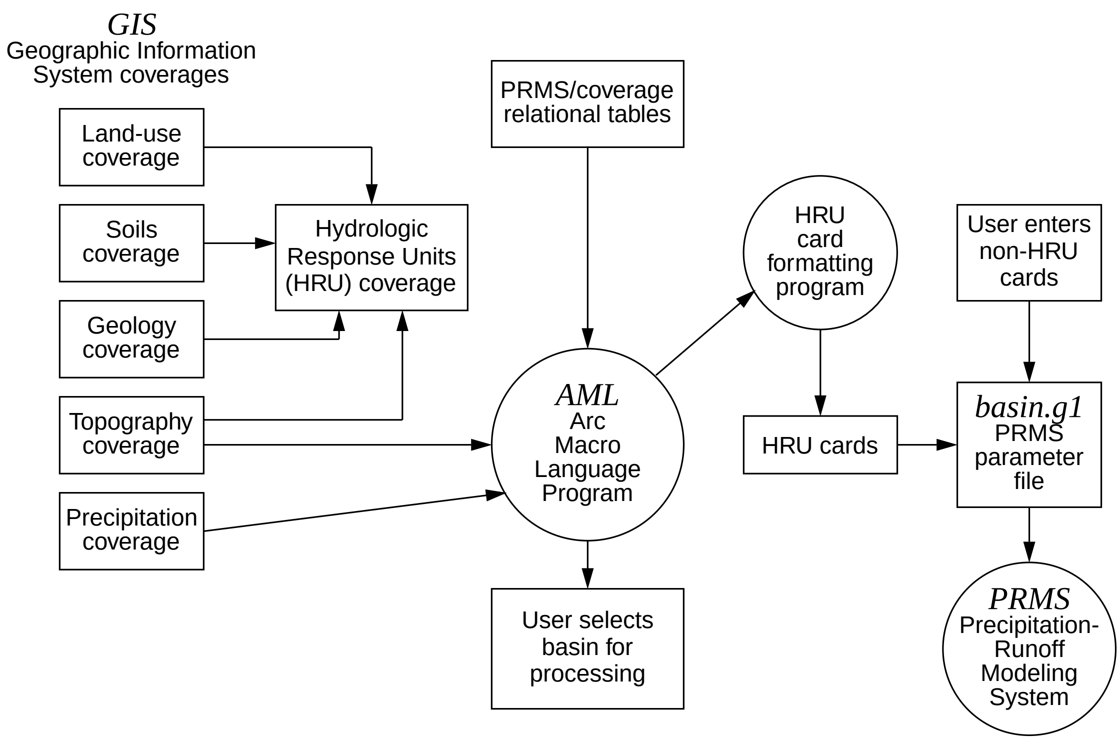


Figure 43. Programs and files used to interface geographic information system (GIS) coverages with the Precipitation-Runoff Modeling System (PRMS). (A circle denotes a computer program, and a rectangle denotes a computer file. See Glossary for program descriptions.)

ANNIE and Water Data Management Files

ANNIE is an interactive Fortran program used for data management of the WDM file. ANNIE can list the time-series data contained in each Data Set Number (DSN) to both the screen and to ASCII files (which can be sent to the printer or used for further analyses). ANNIE can also create on-screen and post-script-file graphs of time-series data. Complete information about the ANNIE program is provided by Lumb and others (1989).

A WDM file titled *WILL.WDM* is used as a central data base for storing all observed and simulated time-series data used by the PRMS and DAFLOW programs. Time-series data for any station is identified by its DSN. Complete information about WDM files is provided by Lumb and others (1989). The program IOWDM is used to create new WDM files from various input formats; for example, WATSTORE or flat (ASCII) files. The user will not need to use this program, however, if the *WILL.WDM* file is used in future simulations. WDM files can contain up to 32,000 separate time-series data sets. Appendix 13 is the directory for the *WILL.WDM* file. A program called FLTWDM is used to enter new time-series data into new DSN's and also update existing DSN's with additional data. A diagram illustrating the operation of FLTWDM is shown in figure 44. The necessary steps used to enter additional data into the WDM file are described in Appendix 7.

SWSTAT (Lumb and others, 1989) is a interactive program used for computing surface-water statistics. These statistics include flow-duration tables and curves, annual series of n-day high or low flows, frequency analysis, and minimum, maximum, mean, and standard deviation of a time series can be computed. SWSTAT can retrieve time-series data directly from the WDM file. Statistical output and graphs from SWSTAT can be viewed on screen or directed to computer output files.

Precipitation-Runoff Modeling System and Diffusion Analogy Flow Model and Files

Simulation of each network application can be executed by using a computer-command script program. The program executes both PRMS and DAFLOW in a sequential order. A script program is located in each network subdirectory. The names of programs are an abbreviation of their corresponding network name.

The PRMS program also can be executed by using a manager file, which tells the program the specific names of parameter, data, and output files used for the simulation (fig. 45). The time-series data file is always *WILL.WDM*. The parameter file, identified as *basinname.g1*, contains the starting and ending times

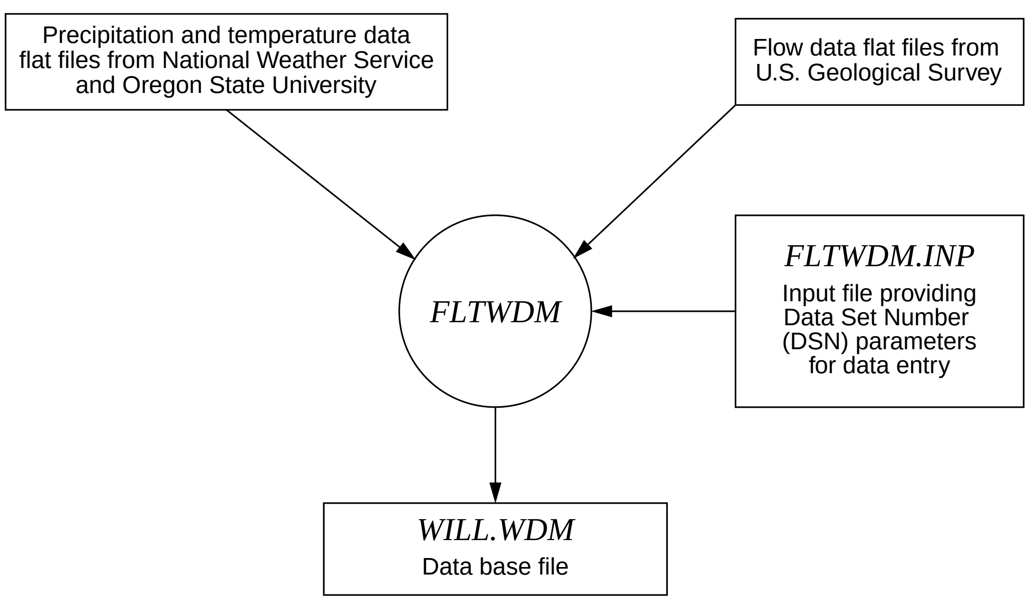


Figure 44. Program and files used to update the Water Data Management (WDM) data-base file. (A circle denotes a computer program, and a rectangle denotes a computer file. See Glossary for program descriptions.)

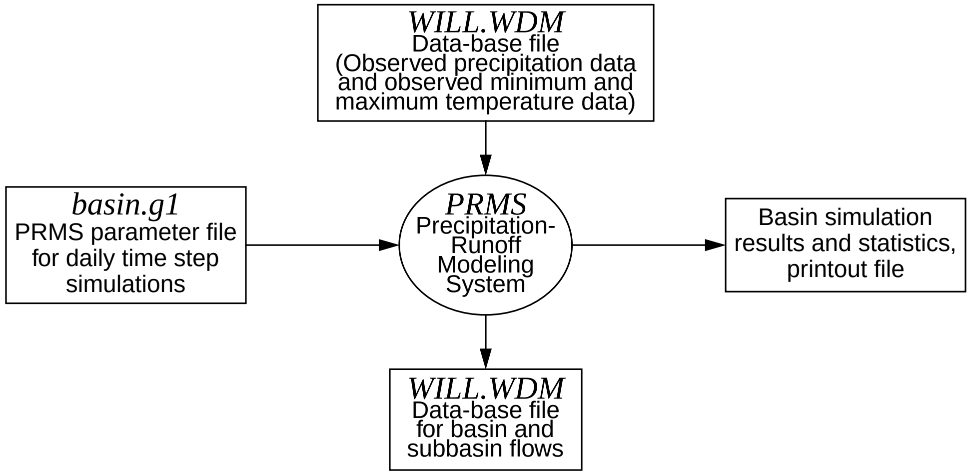


Figure 45. Programs and files used in PRMS simulations. (A circle denotes a computer program, and a rectangle denotes a computer file. See Glossary for program descriptions.)

of the simulation, the DSN's of observed input data and simulated output data, and HRU and non-HRU parameter values. The file also identifies which HRU simulated flows are clustered together as an individual subbasin flow. The combined flow from an HRU cluster (subbasin) is then directed to a specific DSN in the WDM file. Only *basinname.g1* is needed for daily time-step simulations with PRMS. To simulate a smaller time step for the parameter input file, it is necessary to use additional parameter files described in the PRMS manual (Leavesley and others, 1983). The PRMS simulation also creates an ASCII printout file that contains a listing of all parameter values that were used by the program, observed and simulated flows for each time step, water-energy budget components, and statistical results. Steps for using PRMS are provided in Appendix 11.

Execution of the DAFLOW program automatically calls the parameter and control file, labeled *FLOW.IN*, and located in the same directory of the model execution. The *FLOW.IN* file contains the starting date and time of the simulation, number of time steps in the simulation, time-step size in hours, WDM file name, channel configuration, channel-geometry parameters for grid cross section, and location of all inflows and outflows and their corresponding DSN's. A diagram of the files used in DAFLOW simulations is shown in figure 46. Two ASCII output files are automatically created after a DAFLOW simulation. The *BLTM.FLW* file contains simulated flow, stage, and channel cross-sectional area for every grid location for every time step. This file is used as an input file to the solute-transport model (fig. 47). The *FLOW.OUT* file contains similar information in a more user-readable format. Steps for using DAFLOW are provided in Appendix 9. Additional information about operation of DAFLOW is provided in Jobson (1989).

SCENARIO GENERATOR Files

The SCENARIO GENERATOR is interactive computer software used to efficiently display time-series data from the WDM file for presentation purposes. The main menu of the program provides the user with a GIS on-screen map showing the location of all the stations and their respective basins. The user can select a station directly from the map and generate hydrographs and flow-duration graphs of time-series data from that station for viewing on-screen or for storage in a postscript file (fig. 48). The specific set of stations and DSN's used in a SCENARIO GENERATOR session are determined by a control file, which can be edited by the user. The necessary steps to operate the SCENARIO GENERATOR and formatting for the control file are provided in Appendix 13.

Statistics Package

The SWSTAT program is used to compute error statistics to aid the user in comparing observed and simulated flow. A regression analysis computes a coefficient of determination, which is equivalent to R^2. Error statistics used in the program are mostly identical to those already provided in the PRMS program. The user need only use the SWSTAT program for analyzing DAFLOW simulation results (fig. 48). A description of these statistics is provided on pages 54–57 of the PRMS manual (Leavesley and others,

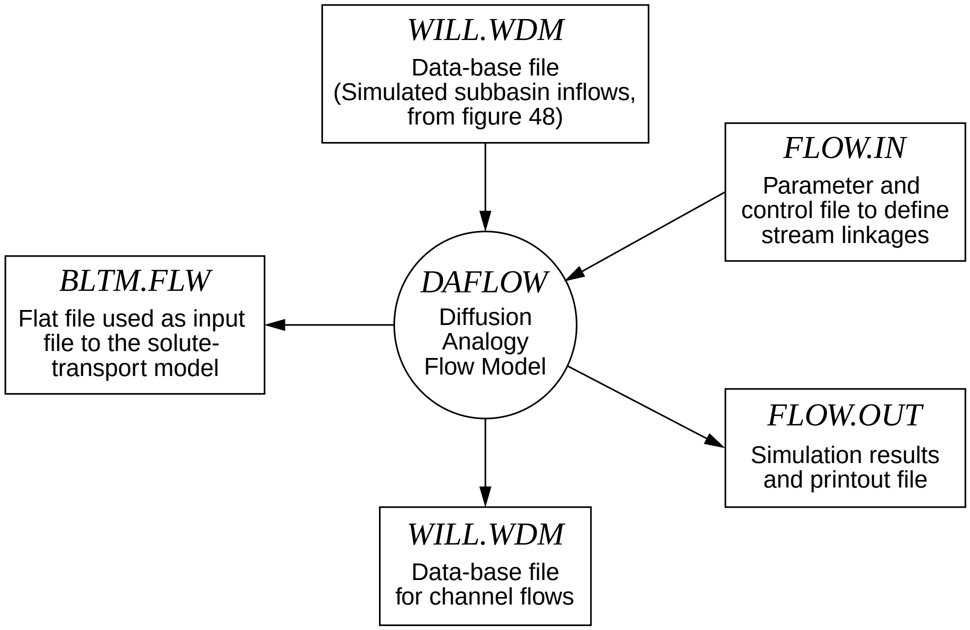


Figure 46. Program and files used for Diffusion Analogy Flow (DAFLOW) model simulated operations. (A circle denotes a computer program, and a rectangle denotes a computer file. See Glossary for program descriptions.)

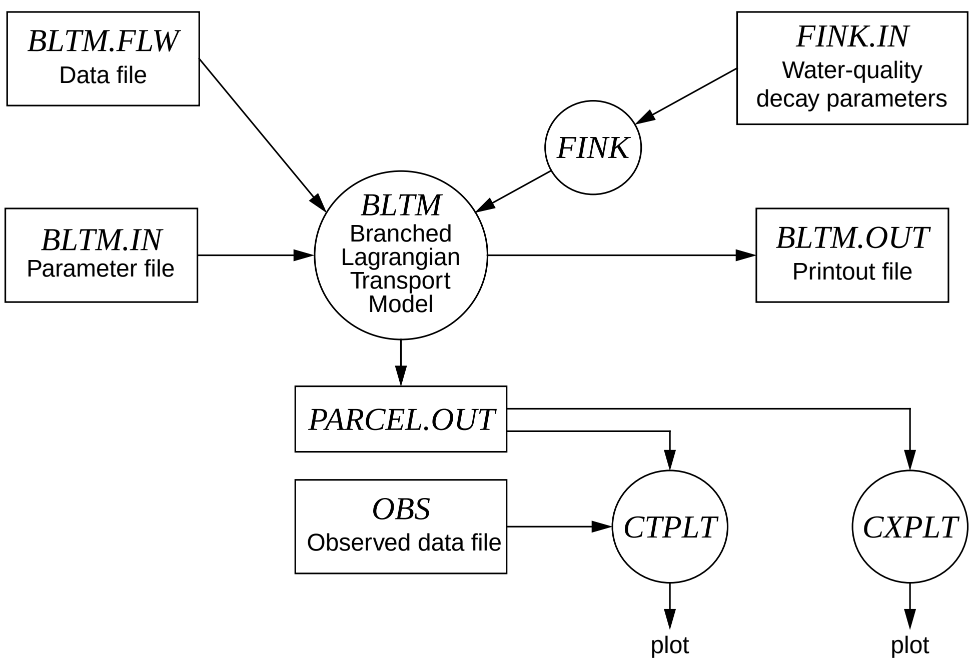


Figure 47. Programs and files used in Branch Lagrangian Transport Model (BLTM) simulations. (A circle denotes a computer program, and a rectangle denotes a computer file. See Glossary for program descriptions.)

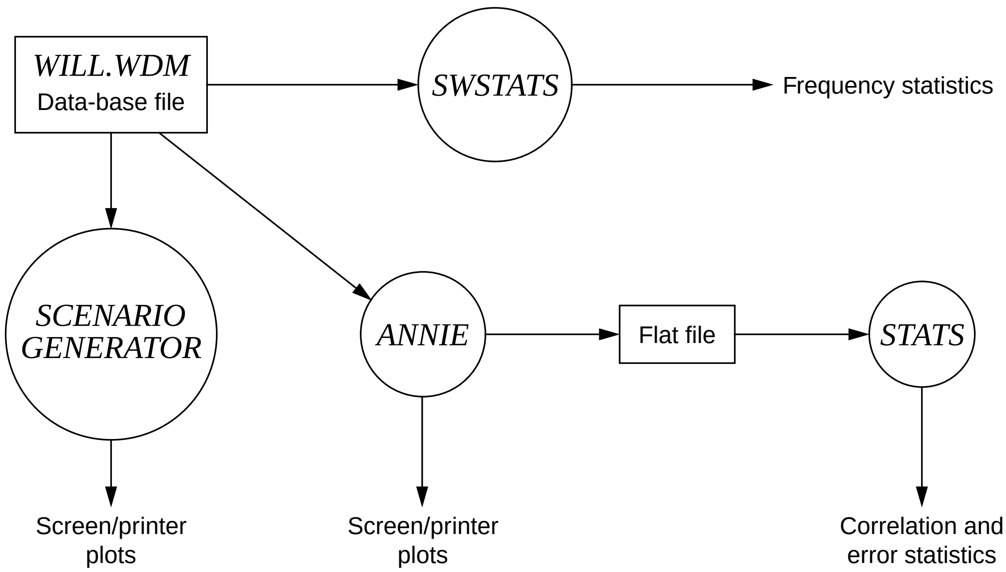


Figure 48. Programs and files used in Diffusion Analogy Flow model post-simulation analysis. (A circle denotes a computer program, and a rectangle denotes a computer file. See Glossary for program descriptions.)

1983). After a DAFLOW simulation, the user creates a flat file from ANNIE containing a listing of observed and simulated time-series flow data for a particular station. The column of observed data must be positioned to the left of the column of simulated data. The flat file is entered directly into the SWSTAT program to compute error statistics.

SUMMARY AND CONCLUSIONS

Precipitation-runoff and streamflow-routing models were constructed for the Willamette River Basin to provide streamflow hydrographs for use in water-quality data analysis. An instream model of the Pudding River main stem that simulated the transport of conservative constituents was used as an example of a water-quality application. Runoff and routing models described in this report can simulate streamflow at nearly 500 discrete stream locations and can output hydrographs for surface runoff, subsurface flow, and ground-water flow for 1–10 HRU classes in each of 253 subbasins; such a capability can facilitate the assessment of water-quality data. Models that can be run either separately or together to determine unsteady-state flow in a daily time step were constructed for 11 individual stream networks. To complete modeling of the Willamette River Basin, files for 10 remaining networks still must be assembled using parameter values that already have been established.

The Precipitation-Runoff Modeling System (PRMS) and the Diffusion Analogy Flow Model (DAFLOW) are used in combination to simulate streamflow at selected locations. PRMS is used to determine the runoff response from ungaged areas, and DAFLOW is used to route flows in the Willamette River main stem and major tributaries. PRMS and DAFLOW use the same water data-management (WDM) file, and the systems are linked by computer script commands that are transparent to the user. The entire Willamette River system could be simulated in one model run, but this would require completing the setup of 10 remaining networks and integrating them into the existing basin network. To improve accuracy for instream flows, most model network simulations would use an inflow hydrograph as a starting boundary condition and precipitation-runoff simulations for ungaged tributary inflow; however, upstream boundary conditions also may be simulated by precipitation-runoff modeling. All 253 model subbasins can be simulated separately, and flows from the individual hydrologic response units (HRU's) within the subbasins can be output separately. As a first step in water-quality modeling, it is envisioned that flow in small subbasins, such as the Pudding River (479 mi^2) or smaller tributaries such as Zollner Creek (15 mi^2), will be simulated by flow models.

In this study, for each subbasin, spatial data layers of precipitation, land use, soils, geology, and topography were used in a geographic information system to define the homogeneous hydrologic response units (HRU's), which are the basic computational units of PRMS. These spatial data were used by an Arc Macro Language (AML) program to produce model input values representing interception, evapotranspiration, infiltration, and subsurface and ground-water flow rates. This AML program can be used at any time in the future to redefine model parameters with newer and better defined spatial data layers. It is envisioned that redefining HRU's (for example, dividing agricultural land into finer units that delineate crop types) will be done first for small drainages in order to evaluate their significance in evaluating water-quality data differences.

Precipitation-runoff model calibrations and verifications were done for the 1972–78 period, because this was the period of greatest streamflow record density. More than one-half the stream-gaging stations in operation from 1972–78 in the Willamette River Basin are no longer in operation. For future simulation of flows for other periods, the data base must be updated with precipitation, temperature, and flow data for the intended simulation time. Network accuracy depends on the proportion of the basin that has been simulated with precipitation-runoff models. For example, to estimate flow in the Molalla River at Canby, the 70 percent of the basin that was ungaged had to be simulated with precipitation and temperature data. The simulation resulted in a flow estimate with an average absolute error of about 21 percent. In a network where flows are primarily routed, the Willamette River (Albany to Salem) network, only 9 percent of the basin had to be simulated with precipitation and temperature data, resulting in a flow estimate with an average absolute error of about 4 percent.

The Branched Lagrangian Transport Model (BLTM) and DAFLOW were used to simulate the dispersion of dye in the main stem of the Pudding River to give an example of a water-quality application and to show model linkages. For water-quality modeling in the Willamette River Basin, the data generated by dye studies conducted for this project still must be used in the calibration of other stream networks.

Dye modeling in the Pudding River has resulted in a close fit to observed data; however, this may not prove to be the case for all streams. The Pudding River has a streambed that consists of fine material, and there is little transfer between the stream and the ground-water system. As evidenced in the gain-loss investigations made in the Willamette River, other streams can have a large exchange of water occurring between the river and the streambed. The BLTM model probably will yield less accurate results in streams that exhibit a large exchange of water between river and streambed; however, the differences that occur can give insight to the contributing volumes from these exchanges and identify the fluxes needed in model application.

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APPENDIXES

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APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS

[RM, river mile; mi, miles; ft, feet, ft^3/s, cubic feet per second; ft/s, feet per second; ft^2, square feet, hrs, hours. Formula: Area = A0 + A1(Discharge)^{A2}; Width = W1(Discharge)^{W2}]

Amazon Creek from Eugene (RM 12.3) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	21.7		Mouth	303.00											
0.8	20.9	0.8	Drains (RB)	310.00	0.001657	10.0	30	0.32	31	3.6	4800	150	7.3	662	0.2
1.7	20.0	0.9	Drain (LB)	322.00	0.002525	9.0	30	0.30	30	4.4	4700	150	7.2	654	0.2
3.2	18.5	1.5	Trib. (RB)	330.00	0.001010	8.0	20	0.28	29	8.0	4600	120	7.1	646	0.3
5.8	15.9	2.6	Airport Drain (RB)	346.00	0.001166	7.0	20	0.28	25	13.5	4400	100	7.0	626	0.5
9.1	12.6	3.3	Clear Lake Outlet	359.00	0.000746	6.0	15	0.28	22	17.5	4400	80	7.1	624	0.7
10.2	11.5	1.1	Clear Lake Inlet	359.20	0.000034	5.0	200	0.03	191	61.6	4000	80	3.7	1086	0.4
10.3	11.4	0.1	Trib. (RB)	360.00	0.001515	5.0	12	0.26	19	0.6	4000	80	4.4	914	0.0
11.3	10.4	1.0	Trib. (RB)	365.00	0.000947	4.0	10	0.27	15	5.4	3700	75	4.6	799	0.3
13.3	8.4	2.0	Diversion Weir	374.50	0.000900	2.5	10	0.26	10	11.4	3400	75	5.1	668	0.6
13.4	8.3	0.1	Gage 14169500	379.00	0.008523	1.6	10	0.20	8	0.7	2500	60	10.0	251	0.0
14.3	7.4	0.9	Willow Creek	384.00	0.001052	1.4	8	0.32	4	4.1	1900	40	11.4	166	0.1
15.6	6.1	1.3	Paragon Rd	395.00	0.001603	1.2	8	0.11	11	18.0	1700	40	9.8	173	0.2
16.9	4.8	1.3	Oak Patch Rd	405.00	0.001457	1.0	8	0.16	6	11.6	1500	35	10.5	142	0.2
20.1	1.6	3.2	24th Ave	425.00	0.001184	0.4	6	0.11	4	41.6	900	30	9.8	92	0.5
21.7	0.0	1.6	Gage 14169300	445.00	0.002367	0.2	5	0.13	2	17.9	644	30	5.8	110	0.4

River Mile	DAFLOW Parameter Values: Area A1	Area A2	A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
0.8	4.00	0.60	15	17.0	0.260	98	9403
1.7	4.00	0.60	15	17.0	0.260	59	6075
3.2	4.00	0.60	15	12.0	0.260	192	21177
5.8	4.00	0.60	12	12.0	0.260	151	17760
9.1	4.00	0.60	10	9.0	0.260	280	36990
10.2	3.80	0.66	180	9.0	0.260	5308	746876
10.3	3.80	0.66	8	9.0	0.260	121	16974
11.3	3.50	0.66	6	9.0	0.260	164	25637
13.3	3.10	0.66	4	9.0	0.260	122	25349
13.4	1.40	0.66	6	9.0	0.240	9	2492
14.3	1.12	0.66	3	8.0	0.220	77	21439
15.6	1.20	0.66	10	8.0	0.220	45	12907
16.9	1.10	0.66	5	8.0	0.200	43	14905
20.1	1.00	0.66	3	7.4	0.200	27	13179
21.7	1.53	0.66	1	7.4	0.200	8	5042

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Amazon Creek Diversion from Weir (RM 13.3) to Fern Ridge Dam

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Time (hrs)	DAFLOW Parameter Values Area A1	A2	A0	Width W1	W2	Low Diffusion Coefficient
0.0	2.8		Fern Ridge Lake& Dam	374.00												
2.8		2.8	Amazon Creek Weir	374.50	0.0000	5.0	20	0.26	19	15.6	3.10	0.66	10	17.0	0.100	3702

Calapooia River from Holley (RM 45.4) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	45.4		Mouth	175.00											
3.0	42.4	3.0	Gage 14173500	183.00	0.000505	22	80	0.44	50	10.0	40000	540	5.6	7084	0.8
3.6	41.8	0.6	Oak Creek (RB)	185.00	0.000631	22	60	0.44	50	2.0	40000	540	5.6	7084	0.2
6.2	39.2	2.6	Tributary (RB)	193.00	0.000583	20	80	0.43	47	9.0	32000	500	5.2	6114	0.7
8.8	36.6	2.6	Lake Creek (RB)	202.00	0.000656	20	80	0.43	47	9.0	32000	500	5.2	6114	0.7
14.0	31.4	5.2		217.00	0.000546	18	75	0.42	43	18.3	29500	500	5.2	5705	1.5
19.5	25.9	5.5	Gage, 14172500	253.00	0.001240	18	60	0.42	42	19.0	29500	500	5.3	5616	1.5
19.8	25.6	0.3	Butte Creek (RB)	254.00	0.000631	18	50	0.43	42	1.0	28700	480	5.3	5427	0.1
21.9	23.5	2.1	Shedd Slgh (LB)	257.10	0.000280	17	35	0.42	40	7.3	14400	320	4.2	3443	0.7
22.1	23.3	0.2	Spoon Creek (LB)	257.40	0.000284	17	35	0.42	40	0.7	14400	320	4.2	3443	0.1
22.8	22.6	0.7	Spoon Cr.(LB)	258.20	0.000216	16	35	0.41	39	2.5	9000	300	3.6	2525	0.3
24.2	21.2	1.4	Wltn Slgh/Spn Cr, LB	260.10	0.000257	15	35	0.41	37	5.1	8600	300	3.5	2450	0.6
28.4	17.0	4.2	Sodom Div. (RB)	279.30	0.000866	15	35	0.41	36	15.0	8600	300	3.6	2410	1.7
32.8	12.6	4.4	Brwnvlle Drain(RB)	308.40	0.001253	18	50	0.32	56	20.2	22100	400	8.5	2593	0.8
35.9	9.5	3.1	Brwnvlle Div.(RB)	346.00	0.002297	18	50	0.30	61	15.4	22100	400	7.4	2988	0.6
36.0	9.4	0.1	Warren Creek (RB)	348.00	0.003788	22	50	0.33	66	0.4	22100	400	7.4	2988	0.0
40.4	5.0	4.4	Brush Creek (LB)	408.90	0.002621	21	55	0.32	65	19.9	21000	380	7.3	2895	0.9
45.4	0.0	5.0	Strmgage, 14172000	501.00	0.003489	20	55	0.43	46	16.9	17300	340	12.1	1425	0.6

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Calapooia River from Holley (RM 45.4) to mouth—Continued

River Mile	DAFLOW Parameter Values: Area A1	Area A2	A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
3.0	6.50	0.66	0	30.0	0.250	335	93338
3.6	6.50	0.66	0	30.0	0.250	268	74670
6.2	6.50	0.66	0	30.0	0.250	270	68427
8.8	6.50	0.66	0	30.0	0.250	240	60824
14.0	6.40	0.66	0	25.0	0.250	320	82403
19.5	6.30	0.66	0	20.0	0.250	176	45394
19.8	6.20	0.66	0	15.0	0.255	455	110600
21.9	6.20	0.66	0	15.0	0.255	984	149400
22.1	6.20	0.66	0	15.0	0.255	969	147028
22.8	6.20	0.66	0	15.0	0.255	1215	135966
24.2	6.20	0.66	0	15.0	0.255	975	110685
28.4	6.10	0.66	0	9.6	0.255	452	51343
32.8	5.20	0.62	25	22.1	0.269	149	27072
35.9	6.00	0.62	25	22.9	0.269	79	14246
36.0	6.00	0.62	25	23.7	0.269	53	8348
40.4	6.00	0.62	25	24.5	0.269	72	11241
45.4	3.30	0.62	25	24.5	0.269	52	7331

Sodom Ditch (Calapooia River) from Sodom Dam diversion (RM 28.4) to mouth of Butte Creek

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	7.8		Mouth of Butte Cr	254.00											
7.8	0.0	7.8	Sodom Diversion	279.00	0.000607	2.5	40	0.06	42	190.7	13500	340	5.2	2576	2.2

River Mile	DAFLOW Parameter Values: Area A1	Area A2	A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
7.8	9.00	0.62	0	14.4	0.260	113	65139

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Clackamas River from Estacada (RM 23.1) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	23.1		Mouth	4.65											
4.8	18.3	4.8	Gage 14211000	44.20	0.001561	700	461	0.57	1232	12.4	120000	1757	16.6	7234	0.4
6.4	16.7	1.6	Rock Cr-RB	61.00	0.001989	700	357	0.57	1232	4.1	120000	1360	16.6	7234	0.1
8.0	15.1	1.6	Clear Cr-LB	72.00	0.001302	690	312	0.56	1230	4.2	112000	1059	16.1	6964	0.1
12.1	11.0	4.1	Deep Cr	137.00	0.003003	685	240	0.67	1029	9.0	108000	660	16.3	6627	0.4
16.7	6.4	4.6	Eagle Cr-Rb	200.00	0.002594	680	239	0.87	782	7.8	104000	509	20.2	5151	0.3
23.1	0.0	6.4	Gage 14210000	315.00	0.003403	660	233	0.97	679	9.6	86900	284	19.1	4556	0.5

River Mile	DAFLOW Parameter Values: Area A1	Area A2	Width A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
4.8	4.70	0.64	180	49.0	0.200	1234	75634
6.4	5.90	0.64	0	45.0	0.220	926	51164
8.0	5.90	0.64	0	45.0	0.220	1398	74047
12.1	6.20	0.66	0	41.0	0.230	624	30734
16.7	4.30	0.66	0	38.0	0.240	714	32631
23.1	3.60	0.64	320	26.0	0.250	747	29048

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Coast Fork Willamette River from Cottage Grove (RM 29.4) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	29.4		Mouth	436.00											
1.3	28.1	1.3	Berkshire Sl - LB	444.00	0.001166	275	200	0.70	393	2.7	32000	265	9.8	3260	0.2
4.3	25.1	3.0	Up end Brkshre SL-LB	464.00	0.001263	275	150	0.75	367	5.9	32000	265	9.8	3260	0.4
5.7	23.7	1.4	Tribut-RB	471.00	0.000947	275	150	0.80	344	2.6	32000	265	9.8	3260	0.2
6.4	23.0	0.7	Gage 14157500	475.00	0.001082	275	150	0.95	289	1.1	32000	265	9.8	3260	0.1
8.6	20.8	2.2	Bear Cr-RB	493.00	0.001550	275	200	1.00	275	3.2	32000	265	13.1	2450	0.2
9.0	20.4	0.4	Camas Swale Cr-LB	496.50	0.001657	273	100	1.10	248	0.5	31500	260	13.0	2420	0.0
10.6	18.8	1.6	Up end Isle	507.00	0.001243	272	100	1.20	227	2.0	31000	260	12.9	2400	0.2
10.9	18.5	0.3	Hill Cr-LB	509.00	0.001263	272	150	1.32	206	0.3	31000	260	12.9	2400	0.0
16.9	12.5	6.0	Gettings CR-Sl-RB	550.00	0.001294	270	100	0.90	300	9.8	30500	260	12.8	2380	0.7
18.0	11.4	1.1	Lynx Hollow Flood	562.50	0.002152	268	200	0.80	335	2.0	30000	260	14.5	2070	0.1
20.7	8.7	2.7	Row R-RB	588.00	0.001789	268	150	0.80	335	5.0	30000	260	14.5	2070	0.3
23.2	6.2	2.5	Silk Cr-LB	613.00	0.001894	114	100	0.80	143	4.6	14000	125	10.8	1300	0.3
25.4	4.0	2.2	Martin Cr-LB	634.00	0.001808	110	75	0.80	138	4.0	13000	125	10.4	1250	0.3
29.4	0.0	4.0	Gage 14153500	718.00	0.003977	105	75	0.80	131	7.3	12000	125	10.2	1180	0.6

River Mile	DAFLOW Parameter Values: Area A1	Area A2	A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
1.3	5.00	0.62	150	21.0	0.244	1427	52015
4.3	5.00	0.62	150	21.0	0.244	1317	48014
5.7	5.00	0.62	150	21.0	0.244	1756	64019
6.4	5.00	0.62	150	21.0	0.244	1537	56017
8.6	3.80	0.62	90	21.0	0.244	1073	39123
9.0	3.80	0.62	90	21.0	0.244	998	36149
10.6	3.80	0.62	90	21.0	0.244	1327	47619
10.9	3.80	0.62	90	21.0	0.244	1306	46875
16.9	3.80	0.62	90	21.0	0.244	1267	45173
18.0	3.40	0.62	40	21.0	0.244	758	26827
20.7	3.40	0.62	40	21.0	0.244	912	32278
23.2	3.40	0.62	40	35.0	0.133	458	29664
25.4	3.40	0.62	40	35.0	0.133	465	29143
29.4	3.40	0.62	40	35.0	0.133	203	12359

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Johnson Creek from Sycamore (RM 10.2) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	10.2		Mouth	3.36											
0.7	9.5	0.7	Gage 14211550	20.00	0.004502	15.0	30	1.40	10.8	0.7	4300	70	9.6	450	0.1
1.3	8.9	0.6	Crystal Springs	40.00	0.006313	15.0	25	1.40	10.8	0.6	4300	70	9.6	450	0.1
2.9	7.3	1.6	Pepco RR Bridge	95.00	0.006510	2.0	25	0.63	3.2	3.7	4200	64	8.5	492	0.3
5.5	4.7	2.6	Hwy 213 Bridge (82nd	185.00	0.006556	1.9	20	0.57	3.4	6.7	4150	54	7.7	537	0.5
6.2	4.0	0.7	I 205 Bridge	195.00	0.002706	1.9	20	0.52	3.7	2.0	4100	54	7.0	582	0.1
7.0	3.2	0.8	Beggars Tick Marsh	202.00	0.001657	1.8	20	0.41	4.4	2.9	4100	53	5.6	727	0.2
7.6	2.6	0.6	LB Trib. (112th St.)	205.00	0.000947	1.6	15	0.44	3.7	2.0	3970	44	6.2	638	0.1
9.2	1.0	1.6	LB Trib. (Deardorff	224.00	0.002249	1.4	15	0.42	3.4	5.6	3770	44	6.1	617	0.4
10.2	0.0	1.0	Gage 14211500	229.00	0.000947	1.2	15	0.40	3.0	3.7	3570	44	6.0	595	0.2

River Mile	DAFLOW Parameter Values Area A1	Area A2	Width A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
0.7	1.90	0.64	6	12.1	0.210	78	6811
1.3	1.90	0.64	4	13.8	0.210	49	4259
2.9	3.00	0.64	28	9.4	0.180	14	7644
5.5	2.20	0.62	13	13.1	0.200	10	4566
6.2	2.20	0.62	4	17.6	0.260	17	4951
7.0	3.00	0.62	9	15.0	0.180	33	18450
7.6	3.00	0.62	17	16.2	0.180	48	29116
9.2	4.00	0.60	26	18.2	0.260	16	5412
10.2	4.10	0.60	12	15.7	0.200	39	23381

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Long Tom River from Alvadore (25.5) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	25.5		Mouth (upstream mouth	238.80											
0.6	24.9	0.6	Junction w ds mouth	242.00	0.001010	39	180	0.11	343	7.7	13000	235	5.7	2272	0.2
2.8	22.7	2.2	Slough	252.00	0.000861	39	200	0.09	434	35.9	13000	211	6.6	1957	0.5
3.3	22.2	0.5	Oliver Slough (RB)	254.00	0.000758	39	100	0.07	528	9.9	13000	194	7.2	1798	0.1
4.7	20.8	1.4	Gage 14170000	258.00	0.000541	39	80	0.06	622	32.8	13000	177	7.9	1638	0.3
6.2	19.3	1.5	Lake RB	260.00	0.000253	39	80	0.05	720	40.6	13000	166	8.1	1614	0.3
6.5	19.0	0.3	Base of Dam	261.00	0.000631	39	80	0.06	622	7.0	13000	166	7.9	1638	0.1
6.6	18.9	0.1	Dam	265.00	0.007576	39	100	0.91	43	0.2	13000	174	6.6	1972	0.0
6.8	18.7	0.2	Gage 14170000	265.50	0.000473	40	100	0.06	720	5.3	13000	173	8.1	1614	0.0
9.4	16.1	2.6	Base of Dam	276.00	0.000765	40	90	0.06	720	68.6	13000	173	8.1	1614	0.5
9.5	16.0	0.1	Dam	280.00	0.007576	40	150	0.92	43	0.2	13000	174	6.6	1972	0.0
11.9	13.6	2.4	Ferguson Creek LB	282.00	0.000158	40	90	0.06	720	63.4	13000	166	8.1	1614	0.4
12.0	13.5	0.1	Base of Dam	282.10	0.000189	39	90	0.05	720	2.7	13000	166	8.1	1614	0.0
12.1	13.4	0.1	Dam	300.00	0.033902	40	120	0.92	43	0.2	13000	164	6.6	1972	0.0
12.3	13.2	0.2	Drain outlet (RB)	300.50	0.000473	40	100	0.06	720	5.3	13000	159	8.1	1614	0.0
13.3	12.2	1.0	Ferguson Cr Alt (LB)	302.50	0.000379	39	90	0.06	620	23.3	11600	159	7.9	1467	0.2
13.6	11.9	0.3	Amazon Creek RB	303.00	0.000316	38	120	0.07	521	6.0	11300	151	8.1	1399	0.1
13.9	11.6	0.3	Bear Creek LB	304.00	0.000631	37	90	0.09	422	5.0	11000	152	8.3	1330	0.1
17.0	8.5	3.1		311.00	0.000428	36	60	0.11	323	40.8	10400	146	8.1	1286	0.6
20.1	5.4	3.1	Base of Dam	320.00	0.000550	36	60	0.89	40	5.1	10400	144	6.1	1702	0.7
20.2	5.3	0.1	Dam	321.00	0.001894	36	100	0.89	40	0.2	10400	144	6.1	1702	0.0
20.3	5.2	0.1	Coyote Creek RB	321.20	0.000379	36	60	0.05	719	2.9	10400	132	7.0	1488	0.0
20.4	5.1	0.1	Base of Dam	321.40	0.000379	35	60	0.05	718	3.0	9800	132	6.7	1458	0.0
20.5	5.0	0.1	Dam	324.00	0.004924	35	100	0.88	40	0.2	9800	131	6.0	1637	0.0
20.8	4.7	0.3	Base of Dam	324.80	0.000505	36	70	0.05	719	8.8	9800	132	6.7	1458	0.1
20.9	4.6	0.1	Dam	326.00	0.002273	36	90	0.89	40	0.2	9800	131	6.0	1637	0.0
22.5	3.0	1.6	Gage 14169000	330.00	0.000473	37	90	0.05	719	45.6	9800	125	6.7	1458	0.3

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Long Tom River from Alvadore (25.5) to mouth—Continued

River Mile	DAFLOW Parameter Values Area			Width		Diffusion Coefficient	
	A1	A2	A0	W1	W2	Low	High
0.6	3.80	0.66	300	20.0	0.260	372	27409
2.8	3.00	0.66	400	18.0	0.260	485	35733
3.3	2.50	0.66	500	20.0	0.240	534	44168
4.7	2.00	0.66	600	22.0	0.220	732	67940
6.2	1.76	0.66	700	25.0	0.200	1484	154839
6.5	2.00	0.66	600	25.0	0.200	594	61936
6.6	3.80	0.66	0	14.8	0.260	67	4939
6.8	1.76	0.66	700	130.0	0.030	291	79478
9.4	1.76	0.66	700	130.0	0.030	180	49201
9.5	3.80	0.66	0	14.8	0.260	68	4939
11.9	1.76	0.66	700	125.0	0.030	908	247971
12.0	1.76	0.66	700	125.0	0.030	738	206642
12.1	3.80	0.66	0	14.0	0.260	16	1167
12.3	1.76	0.66	700	120.0	0.030	315	86101
13.3	1.80	0.66	600	120.0	0.030	384	96364
13.6	1.90	0.66	500	95.0	0.050	528	118156
13.9	2.00	0.66	400	60.0	0.100	340	57257
17.0	2.20	0.66	300	23.0	0.200	894	83132
20.1	3.80	0.66	0	13.0	0.260	992	65673
20.2	3.80	0.66	0	13.0	0.260	288	19066
20.3	1.76	0.66	700	100.0	0.030	427	104015
20.4	1.76	0.66	700	100.0	0.030	415	98189
20.5	3.80	0.66	0	12.0	0.260	118	7603
20.8	1.76	0.66	700	100.0	0.030	320	73642
20.9	3.80	0.66	0	12.0	0.260	260	16472
22.5	1.76	0.66	700	95.0	0.030	369	82686

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Luckiamute River from Suver (RM 13.5) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	13.5		Mouth	154.00											
2.0	11.5	2.0	Soap Creek - RB	156.20	0.000208	20	70	0.40	50	7.3	35000	300	5.8	6057	0.5
7.4	6.1	5.4	Davidson Creek LB	165.00	0.000309	20	60	0.30	67	26.4	35000	300	5.8	6057	1.4
13.5	0.0	6.1	Gage 14190500	172.60	0.000236	20	60	0.30	67	29.8	35000	300	5.8	6057	1.5

River Mile	DAFLOW Parameter Values: Area A1	Area A2	Width A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
2.0	6.02	0.66	50	21.0	0.260	1049	263392
7.4	6.02	0.66	50	21.0	0.260	708	177789
13.5	6.02	0.66	50	21.0	0.260	926	232547

Marys River from Philomath (RM 9.4) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	11.8		Mouth	193.40											
1.1	10.7	1.1	Oak Creek - LB	198.00	0.000792	18	100	0.13	140	12.6	25000	557	5.1	4895	0.3
1.3	10.5	0.2	Squaw Creek-LB	199.00	0.000947	17	100	0.12	139	2.4	24000	551	5.0	4768	0.1
1.8	10.0	0.5	Slough-LB	200.00	0.000379	17	125	0.12	139	6.0	23000	545	5.0	4638	0.1
2.5	9.3	0.7	Mill Race-RB distrb.	202.00	0.000541	17	100	0.12	139	8.4	23000	545	5.0	4638	0.2
2.7	9.1	0.2	Head of island	203.00	0.000947	18	100	0.13	140	2.3	23000	545	5.0	4638	0.1
5.6	6.2	2.9	Muddy Cr-Rb	212.00	0.000588	18	100	0.13	140	33.2	23000	545	5.0	4638	0.9
9.4	2.4	3.8	Gage 14171000	228.00	0.000797	15	80	0.11	136	50.5	14500	483	4.2	3447	1.3
11.8	0.0	2.4	Covered Bridge	242.00	0.001105	15	80	0.11	136	31.9	14500	483	4.2	3447	0.8

River Mile	DAFLOW Parameter Values: Area A1	Area A2	Width A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
1.1	6.00	0.66	100	40.0	0.260	134	28357
1.3	6.00	0.66	100	40.0	0.260	107	23011
1.8	6.00	0.66	100	40.0	0.260	269	55743
2.5	6.00	0.66	100	40.0	0.260	188	39020
2.7	6.00	0.66	100	40.0	0.260	112	22297
5.6	6.00	0.66	100	40.0	0.260	181	35923
9.4	6.00	0.66	100	40.0	0.260	116	18820
11.8	6.00	0.66	100	40.0	0.260	84	13584

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

McKenzie River from Vida (RM 47.7) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	47.7		Mouth	340.00											
1.0	46.7	1.0	Distrib. drain RB	346.00	0.001136	2600	300	2.49	1044	0.6	125000	1052	11.7	10696	0.1
2.8	44.9	1.8	Canterbury Cr dr-RB	359.00	0.001368	2600	300	2.49	1044	1.1	125000	1052	11.7	10696	0.2
3.6	44.1	0.8	Distrib. ch-LB	365.00	0.001420	2580	300	2.49	1036	0.5	123000	1047	11.6	10585	0.1
4.2	43.5	0.6	Distrib. dr-LB	370.00	0.001578	2580	200	2.49	1036	0.4	123000	1047	11.6	10585	0.1
5.9	41.8	1.7	Distrib. dr-LB	385.00	0.001671	2580	300	2.49	1036	1.0	123000	1047	11.6	10585	0.2
6.4	41.3	0.5	Canterbury Cr dr-RB	390.00	0.001894	2580	250	2.49	1036	0.3	123000	1047	11.6	10585	0.1
7.1	40.6	0.7	Gage 14165500	395.00	0.001353	2540	250	2.49	1020	0.4	122000	1045	11.6	10529	0.1
7.5	40.2	0.4	Drain-LB	398.00	0.001420	2540	200	2.20	1155	0.3	121000	1042	13.3	9110	0.0
10.1	37.6	2.6	Slough-RB	418.00	0.001457	2540	300	2.20	1155	1.7	121000	1042	13.3	9110	0.3
13.7	34.0	3.6	Mohawk River RB	445.00	0.001420	2540	225	2.20	1155	2.4	121000	1042	13.3	9110	0.4
15.0	32.7	1.3	Slough-LB	457.00	0.001748	2500	250	1.46	1712	1.3	105000	1000	12.6	8321	0.2
16.6	31.1	1.6	Drain-LB	472.00	0.001776	2500	300	3.21	779	0.7	105000	1000	12.6	8321	0.2
17.8	29.9	1.2	Slough-RB	485.00	0.002052	2500	200	3.21	779	0.5	105000	1000	12.6	8321	0.1
20.7	27.0	2.9	Camp Cr-RB	517.00	0.002090	2500	250	3.21	779	1.3	105000	1000	12.6	8321	0.3
20.8	26.9	0.1	Wltrvlle Pwr Plnt-RB	518.00	0.001894	2500	100	3.21	779	0.0	105000	1000	12.6	8321	0.0
26.6	21.1	5.8	Osborne Cr-LB	580.00	0.002025	680	250	1.20	567	7.1	103000	951	11.9	8690	0.7
28.5	19.2	1.9	Wltrvlle Cnl divr-RB	602.00	0.002193	680	300	1.20	567	2.3	103000	951	11.9	8690	0.2
30.1	17.6	1.6	Up end Isle	620.00	0.002131	2500	200	3.07	814	0.8	101000	762	13.9	7265	0.2
30.7	17.0	0.6	Tributary-LB	625.00	0.001578	2500	200	3.07	814	0.3	101000	603	13.9	7265	0.1
32.0	15.7	1.3	Holden Cr-RB	638.00	0.001894	2500	250	3.07	814	0.6	101000	603	13.9	7265	0.1
33.2	14.5	1.2	Return W&E Canal	650.00	0.001894	670	200	1.20	558	1.5	101000	559	11.8	8581	0.1
33.3	14.4	0.1	Trib LB	651.00	0.001894	670	200	1.20	558	0.1	101000	479	11.8	8581	0.0
34.7	13.0	1.4	Ritchie Cr-LB	665.00	0.001894	670	300	1.20	558	1.7	99000	479	11.7	8472	0.2
36.6	11.1	1.9	Goose Creek LB	685.00	0.001994	670	200	1.20	558	2.3	97000	478	11.6	8362	0.2
38.7	9.0	2.1	Base of Dam	721.00	0.003247	660	200	1.20	550	2.6	97000	478	11.6	8362	0.3
38.8	8.9	0.1	Leaburg Dam W&E Cana	742.00	0.039773	660	200	1.20	550	0.1	94000	437	11.5	8196	0.0
39.7	8.0	0.9	Finn Cr-RB	743.00	0.000210	2390	400	1.14	2096	1.2	94000	398	15.2	6165	0.1
40.9	6.8	1.2	Indian CR-RB	748.00	0.000789	2380	300	1.14	2088	1.5	91000	317	15.0	6078	0.1
41.4	6.3	0.5	Gate Cr-RB	755.00	0.002652	2370	200	3.04	780	0.2	87500	301	17.1	5116	0.0
42.9	4.8	1.5	Tom Cr-LB	775.00	0.002525	2330	300	3.04	766	0.7	78500	301	16.4	4792	0.1
44.3	3.4	1.4	Marin Cr-LB	795.00	0.002706	2320	300	3.04	763	0.7	75500	300	16.1	4681	0.1
46.9	0.8	2.6	Bear Cr-RB	835.00	0.002914	2310	100	3.04	760	1.3	72500	300	15.9	4568	0.2
47.7	0.0	0.8	Gage 14162500	860.00	0.005919	2300	200	3.04	757	0.4	69500	300	15.6	4454	0.1

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

McKenzie River from Vida (RM 47.7) to mouth—Continued

River Mile	DAFLOW Parameter Values Area A1	A2	A0	Width W1	W2	Diffusion Coefficient Low	High
1.0	4.54	0.66	200	35.0	0.290	3342	52263
2.8	4.54	0.66	200	35.0	0.290	2776	43418
3.6	4.54	0.66	200	35.0	0.290	2659	41334
4.2	4.54	0.66	200	35.0	0.290	2393	37201
5.9	4.54	0.66	200	35.0	0.290	2260	35134
6.4	4.54	0.66	200	35.0	0.290	1994	31000
7.1	4.54	0.66	200	35.0	0.290	2761	43150
7.5	3.90	0.66	285	35.0	0.290	2630	40856
10.1	3.90	0.66	285	35.0	0.290	2564	39834
13.7	3.90	0.66	285	35.0	0.290	2630	40856
15.0	3.90	0.66	285	35.0	0.290	2113	30015
16.6	3.90	0.66	285	35.0	0.290	2080	29554
17.8	3.90	0.66	285	35.0	0.290	1800	25575
20.7	3.90	0.66	285	35.0	0.290	1767	25109
20.8	3.90	0.66	285	35.0	0.290	1950	27706
26.6	5.38	0.64	0	300.0	0.100	292	26735
28.5	5.38	0.64	0	300.0	0.100	269	24681
30.1	3.90	0.65	285	270.0	0.090	1075	31119
30.7	3.90	0.65	285	240.0	0.080	1765	53033
32.0	3.90	0.65	285	240.0	0.080	1471	44195
33.2	5.38	0.64	0	280.0	0.060	428	47699
33.3	5.38	0.64	0	240.0	0.060	499	55649
34.7	5.38	0.64	0	240.0	0.060	499	54612
36.6	5.38	0.64	0	240.0	0.060	474	50896
38.7	5.38	0.64	0	240.0	0.060	287	31252
38.8	5.38	0.64	0	220.0	0.060	26	2702
39.7	2.80	0.64	1900	200.0	0.060	17804	561768
40.9	2.80	0.64	1900	160.0	0.060	5911	181633
41.4	3.32	0.64	285	240.0	0.020	1594	54756
42.9	3.32	0.64	285	240.0	0.020	1646	51692
44.3	3.32	0.64	285	240.0	0.020	1530	46439
46.9	3.32	0.64	285	240.0	0.020	1415	41442
47.7	3.32	0.64	285	240.0	0.020	693	19574

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Eugene W&E Canal (McKenzie River) from Leaburg Dam (RM 38.8) to RM 33.3

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	5.0		Return to McKenzie	650.00											
0.1	4.9	0.1	Power Plant	723.00	0.138258	1820	20	12.80	142	0.0	4300	41	17.2	250	0.0
1.3	3.7	1.2	Johnson Creek RB	727.40	0.000694	1820	80	2.05	888	0.9	4300	83	3.0	1430	0.6
3.0	2.0	1.7	Cogswell Creek RB	733.00	0.000624	1815	80	2.05	885	1.2	2800	82	2.5	1122	1.0
5.0	0.0	2.0	Leaburg Dam & Divers	740.00	0.000663	1810	80	2.05	883	1.4	1810	81	2.0	886	1.4

River Mile	DAFLOW Parameter Values: Area A1	Area A2	Width A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
0.1	1.00	0.66	0	35.0	0.020	162	376
1.3	5.00	0.66	180	70.0	0.020	16110	37414
3.0	5.00	0.66	180	70.0	0.020	17884	27352
5.0	5.00	0.66	180	70.0	0.020	16787	16787

Walterville Canal (McKenzie River) from diversion (RM 28.5) to RM 20.8

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	6.3		Return to McKenzie	518.00											
2.6	3.7	2.6	Base of Dam	550.00	0.002331	1820	120	2.05	888	1.9	3000	223	2.6	1166	1.5
2.7	3.6	0.1	Power Plant	590.00	0.075758	1820	20	12.80	142	0.0	2500	29	14.3	175	0.0
6.3	0.0	3.6	Diversion	602.00	0.000631	1820	80	2.64	689	2.0	2000	110	2.1	934	2.5

River Mile	DAFLOW Parameter Values: Area A1	Area A2	Width A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
2.6	5.00	0.66	180	100.0	0.100	1843	2890
2.7	1.00	0.66	0	25.0	0.020		
6.3	5.00	0.66	180	70.0	0.060		

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Mill Creek from Stayton (RM 19.0) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	19.0		Mouth	110.60											
0.4	18.6	0.4		140.00	0.013920	80	35	0.92	87	0.6	1900	40	5.7	331	0.1
1.4	17.6	1.0	Base of Dam	159.00	0.003598	80	35	0.92	87	1.6	1900	40	5.7	331	0.3
1.5	17.5	0.1	Dam	162.00	0.005682	80	35	0.92	87	0.2	1900	48	5.7	331	0.0
1.7	17.3	0.2		165.00	0.002841	80	90	0.23	341	1.3	1900	102	3.1	614	0.1
2.1	16.9	0.4	Gage 14192000	171.00	0.002841	80	35	0.84	95	0.7	1900	48	4.6	415	0.1
2.2	16.8	0.1	Base of Dam	172.00	0.001894	80	35	0.84	95	0.2	1900	48	4.6	415	0.0
2.3	16.7	0.1	Dam and Mill Ditch	178.00	0.011364	80	35	0.84	95	0.2	1900	102	4.6	415	0.0
2.4	16.6	0.1	Base of Dam	180.00	0.003788	90	90	0.26	349	0.6	2500	108	3.4	737	0.0
2.5	16.5	0.1	Dam	185.00	0.009470	90	45	1.01	89	0.1	2500	108	5.2	477	0.0
3.3	15.7	0.8	base of dam	190.00	0.001184	90	90	0.25	358	4.7	2500	108	3.0	825	0.4
3.4	15.6	0.1	Shelton Ditch & dam	195.00	0.009470	90	80	1.50	69	0.1	2500	108	5.5	457	0.0
5.0	14.0	1.6		210.00	0.001776	110	80	0.66	167	3.6	9500	108	7.0	1366	0.3
6.8	12.2	1.8	Gage 14191500	232.00	0.002315	110	70	1.65	67	1.6	9500	108	7.5	1266	0.4
9.6	9.4	2.8	Battle Creek LB	267.00	0.002367	110	60	1.65	67	2.5	9500	108	7.5	1266	0.5
11.8	7.2	2.2	Beaver Creek RB	298.00	0.002669	100	60	1.60	63	2.0	8000	103	7.1	1130	0.5
15.0	4.0	3.2	Aumsville	360.00	0.003670	90	20	1.54	58	3.0	6500	98	6.6	985	0.7
17.7	1.3	2.7	Salem Ditch LB	400.00	0.002806	90	20	1.54	58	2.6	6500	98	6.6	985	0.6
19.0	0.0	1.3	Stayton	428.00	0.004079	15	15	0.84	18	2.3	6500	98	6.6	985	0.3

River Mile	DAFLOW Parameter Values: Area A1	Area A2	Width A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
0.4	5.00	0.66	0	24.0	0.040	100	2102
1.4	5.00	0.66	0	24.0	0.040	389	8133
1.5	5.00	0.66	0	24.0	0.040	246	5151
1.7	2.26	0.66	60	28.8	0.040	410	8585
2.1	2.26	0.66	60	28.8	0.040	410	8585
2.2	7.30	0.66	0	15.0	0.260	451	4697
2.3	7.30	0.66	0	15.0	0.260	75	783
2.4	7.30	0.66	0	15.0	0.260	246	2877
2.5	7.30	0.66	0	15.0	0.260	98	1151
3.3	7.30	0.66	0	15.0	0.260	787	9207
3.4	7.30	0.66	0	15.0	0.260	98	1151
5.0	2.70	0.66	0	14.0	0.260	647	17536
6.8	4.70	0.66	0	13.0	0.260	530	14368
9.6	4.50	0.66	0	10.0	0.260	684	18544
11.8	4.50	0.66	0	15.0	0.260	377	9657
15.0	3.60	0.64	0	18.0	0.260	207	4910
17.7	2.85	0.64	0	13.0	0.260	389	9230
19.0	3.00	0.64	0	4.0	0.260	230	20523

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Shelton Ditch (mill Creek) from I-5 (RM 2.6) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	2.6		Mouth	110.80											
1.2	1.4	1.2		150.00	0.006187	20	35	0.92	22	1.9	7000	44	6.8	1035	0.3
2.6	0.0	1.4	Confluence w Mill Cr	190.00	0.005411	20	35	0.92	22	2.2	7000	44	6.8	1035	0.3

River Mile	DAFLOW Parameter Values: Area A1	Area A2	A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
1.2	2.80	0.66	0	41.0	0.040	35	9589
2.6	7.70	0.66	0	20.0	0.040	81	22470

Mill Ditch (Mill Creek) from gage (RM 1.4) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	1.4		Mouth	110.80											
1.4	0.0	1.4	Confluence w Mill Cr	178.00	0.009091	10	25	0.73	14	2.8	600	30	2.9	205	0.7

River Mile	DAFLOW Parameter Values: Area A1	Area A2	A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
1.4	10.50	0.66	0	13.7	0.040	37	1865

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER AT SELECTED INTERVALS—CONTINUED

Molalla River from Wilhoit (RM 32.2) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	32.2		Mouth	54.75											
0.8	31.4	0.8	Pudding River LB	64.00	0.002190	161	230	0.39	413	3.0	109300	1624	12.6	8679	0.1
5.0	27.2	4.2	Cribble Cr-LB	95.00	0.001398	89	145	0.44	204	14.1	44000	725	9.7	4540	0.6
6.0	26.2	1.0	Gage 14200000	110.00	0.002841	89	145	0.44	204	3.4	43600	724	9.7	4514	0.2
8.0	24.2	2.0	Milk Cr	130.00	0.001894	89	112	0.44	204	6.7	43600	563	9.7	4514	0.3
14.4	17.8	6.4	Ore. Hwy 215 bridge	230.00	0.002959	81	187	0.41	199	23.1	40000	1201	9.4	4271	1.0
18.6	13.6	4.2	Gage 14199500	300.00	0.003157	81	172	0.41	199	15.1	40000	865	9.4	4271	0.7
18.8	13.4	0.2	Woodcock Cr-RB	310.00	0.009470	80	157	0.50	161	0.6	40000	700	10.5	3805	0.0
22.3	9.9	3.5	Dickey Cr-RB	400.00	0.004870	79	101	0.49	161	10.4	39500	349	10.5	3775	0.5
24.0	8.2	1.7	Little Cedar Cr-LB	415.00	0.001671	78	99	0.49	160	5.1	39000	302	10.4	3744	0.2
25.2	7.0	1.2	Cedar Cr-LB	450.00	0.005524	77	120	0.48	160	3.7	38600	325	10.4	3719	0.2
26.5	5.7	1.3	N. Fork Molalla R-RB	518.00	0.009907	76	101	0.48	159	4.0	37600	240	10.3	3657	0.2
27.1	5.1	0.6	Trout Cr	540.00	0.006944	52	88	0.52	101	1.7	26000	186	10.3	2520	0.1
32.0	0.2	4.9	Pine Cr	756.00	0.008349	50	86	0.50	100	14.3	24500	159	10.1	2426	0.7
32.1	0.1	0.1	Shotgun Cr-LB	763.00	0.013258	48	82	0.49	99	0.3	23000	134	9.9	2329	0.0
32.2	0.0	0.1	Gage 14198500	770.00	0.013258	46	73	0.47	98	0.3	21500	99	9.6	2230	0.0

River Mile	DAFLOW Parameter Values Area A1	A2	Width A0	W1	W2	Diffusion Coefficient Low	High
0.8	4.00	0.64	120	35.0	0.180	421	88339
5.0	4.00	0.64	120	35.0	0.180	405	65623
6.0	4.00	0.64	120	35.0	0.180	200	32050
8.0	3.40	0.66	40	41.0	0.180	255	41039
14.4	3.40	0.66	40	41.0	0.180	151	24473
18.6	3.40	0.66	40	41.0	0.180	142	22944
18.8	3.40	0.66	40	41.0	0.180	47	7648
22.3	2.90	0.66	0	33.0	0.140	133	27925
24.0	2.52	0.66	20	80.0	0.100	189	50679
25.2	3.00	0.66	60	55.0	0.120	75	17888
26.5	3.00	0.66	60	55.0	0.120	41	9746
27.1	3.00	0.66	60	55.0	0.120	42	10050
32.0	3.00	0.66	60	55.0	0.120	34	7933
32.1	3.00	0.66	60	55.0	0.120	21	4726
32.2	3.00	0.66	60	55.0	0.120	20	4453

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER AT SELECTED INTERVALS—CONTINUED

North Yamhill River from Pike (RM 20.5) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	20.5		Mouth	73.00			50								
3.4	17.1	3.4	Panther Creek RB	81.00	0.000446	16	50	0.13	119	37.0	23500	225	9.8	2402	0.5
9.9	10.6	6.5	Base of Dam	120.00	0.001136	12	40	0.10	115	91.7	23500	225	9.8	2402	1.0
10.0	10.5	6.6	Dam & Carlton Lk	135.00	0.001550	12	30	0.10	115	93.1	17400	211	8.8	1987	1.1
13.2	7.3	3.2	Yamhill Cr-LB	139.00	0.000237	12	150	0.04	310	121.2	16700	182	11.4	1463	0.4
16.0	4.5	2.8	Salt & Hutchcroft Cr	153.00	0.000947	12	20	0.17	71	24.4	14000	88	11.1	1259	0.4
20.5	0.0	7.3	Gage 14197000	215.00	0.001972	11	20	0.16	71	68.8	11100	85	10.2	1089	1.1

River Mile	DAFLOW Parameter Values: Area A1	Area A2	Width A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
3.4	3.00	0.66	100	30.0	0.200	344	117416
9.9	3.00	0.66	100	30.0	0.200	107	46045
10.0	3.00	0.66	100	30.0	0.200	79	26550
13.2	1.90	0.66	300	150.0	0.020	161	193582
16.0	2.20	0.66	60	25.4	0.130	181	84126
20.5	2.20	0.66	60	25.4	0.130	80	33015

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER AT SELECTED INTERVALS—CONTINUED

Pudding River from Silverton (RM 52.8, RM 3.5 on Silver Creek) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	52.8		Mouth at Molalla R.	64.00											
5.4	47.4	5.4	Bridge	69.00	0.000175	72	100	0.16	461	50.7	27700	129	8.0	3478	1.0
7.2	45.6	1.8	Mill Creek LB	73.00	0.000421	72	100	0.16	461	16.9	27700	129	8.0	3478	0.3
8.1	44.7	0.9	Gage 14202000	77.40	0.000926	70	100	0.14	499	9.4	26200	125	7.7	3407	0.2
12.1	40.7	4.0	Bridge	84.20	0.000322	69	90	0.16	421	35.8	26200	128	7.7	3410	0.8
14.2	38.6	2.1	Bridge	86.80	0.000234	69	90	0.19	361	16.1	26200	133	7.8	3350	0.4
15.5	37.3	1.3	Rock Creek (RB)	88.40	0.000233	69	90	0.23	301	8.3	26200	153	8.0	3290	0.2
17.6	35.2	2.1	Bridge	91.60	0.000289	55	85	0.25	224	12.5	24300	166	7.7	3150	0.4
20.2	32.6	2.6	Butte Creek (RB)	96.90	0.000386	55	85	0.32	174	12.0	24300	181	7.8	3100	0.5
22.3	30.5	2.1	Bridge	100.60	0.000334	39	75	0.24	162	12.8	22300	180	7.8	2862	0.4
27.0	25.8	4.7	Bridge	105.10	0.000181	39	75	0.24	160	28.4	22300	181	8.0	2788	0.9
29.1	23.7	2.1	Zollner Creek (RB)	107.20	0.000189	39	75	0.22	179	14.2	22300	199	8.2	2734	0.4
31.5	21.3	2.4	Bridge	109.50	0.000182	33	75	0.21	158	16.9	21300	193	9.9	2143	0.4
35.8	17.0	4.3	Bridge	119.50	0.000440	33	75	0.22	151	28.9	21300	187	13.0	1640	0.5
36.9	15.9	1.1	L. Pudding River LB	121.60	0.000362	33	75	0.22	149	7.3	21300	160	14.2	1496	0.1
40.4	12.4	3.5	Gage 14201000	128.00	0.000346	29	60	0.20	148	26.1	20300	158	14.0	1453	0.4
40.7	12.1	0.3	Bridge	128.50	0.000316	29	60	0.19	156	2.4	20300	158	15.3	1324	0.0
45.5	7.3	4.8	Abiqua Creek (RB)	148.00	0.000769	29	55	0.18	158	38.5	20300	158	13.2	1533	0.5
49.3	3.5	3.8	Upper Pudding/Silver	150.00	0.000100	18	25	1.11	16	5.0	12000	126	10.2	1182	0.5
52.8	0.0	3.5	Gage 14200300 (Silve	215.00	0.003517	9	12	0.88	10	5.8	6000	96	8.0	748	0.6

River Mile	DAFLOW Parameter Values: Area A1	Area A2	A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
5.4	3.60	0.66	400	42.0	0.110	3054	610359
7.2	3.60	0.66	400	42.0	0.110	1272	254316
8.1	3.60	0.66	440	37.0	0.120	614	112797
12.1	3.70	0.66	360	34.0	0.130	1818	318859
14.2	3.70	0.66	300	32.0	0.140	2542	420184
15.5	3.70	0.66	240	30.0	0.160	2506	367857
17.6	3.80	0.66	170	27.0	0.180	1716	253225
20.2	3.80	0.66	120	24.0	0.200	1332	174010
22.3	3.70	0.66	120	22.0	0.210	1231	185507
27.0	3.60	0.66	120	20.0	0.220	2402	339732
29.1	3.50	0.66	140	18.0	0.240	2374	295831
31.5	2.80	0.66	130	16.0	0.250	2371	303565
35.8	2.10	0.66	130	14.0	0.260	1078	129403
36.9	1.90	0.66	130	12.0	0.260	1532	183906
40.4	1.90	0.66	130	12.0	0.260	1454	185292
40.7	1.70	0.66	140	12.0	0.260	1595	203292
45.5	2.00	0.66	140	12.0	0.260	654	83402
49.3	2.40	0.66	0	11.0	0.260	3871	475947
52.8	2.40	0.66	0	10.0	0.260	72	8884

Rickreall Creek from Dallas (RM 19.1) to mouth

						Low Flow					High Flow				
River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Disch. (ft^3/s)	Width (ft)	Vel. (ft/s)	Area (ft^2)	Time (hrs)	Disch. (ft^3/s)	Width (ft)	Vel. (ft/s)	Area (ft^2)	Time (hrs)
0.0	19.1		Mouth	115.00											
0.6	18.5	0.6	Hayden Slough RB	125.00	0.003157	5.6	30	0.60	9.4	1.5	9700	109	7.6	1283	0.1
1.8	17.3	1.2	McNary Creek LB	128.00	0.000473	5.6	30	0.60	9.4	2.9	9600	108	7.5	1275	0.2
4.2	14.9	2.4	Baskett Slough LB	150.00	0.001736	5.6	15	0.60	9.4	5.9	9500	108	7.5	1266	0.5
8.3	10.8	7.7	Rickreall Gage	186.00	0.001663	5.2	30	0.58	8.9	19.3	8800	106	7.3	1204	1.5
13.8	5.3	5.5	North Fork RB	295.00	0.003753	5.2	60	0.58	8.9	13.8	8800	106	7.3	1204	1.1
17.1	2.0	3.3	Ellendale Creek LB	385.00	0.005165	5.0	60	0.58	8.7	8.4	8400	105	7.2	1167	0.7
19.1	0.0	2.0	Gage 14190700	460.00	0.007102	4.2	30	0.54	7.7	5.4	7000	100	6.8	1035	0.4

River Mile	DAFLOW Parameter Values: Area A1	A2	Width A0	W1	W2	Diffusion Coefficient Low	High
0.6	3.00	0.66	0	10.0	0.260	57	14124
1.8	3.00	0.66	0	10.0	0.260	378	93443
4.2	3.00	0.66	0	10.0	0.260	103	25288
8.3	3.00	0.66	0	10.0	0.260	102	24946
13.8	3.00	0.66	0	10.0	0.260	45	11052
17.1	3.00	0.66	0	10.0	0.260	32	7760
19.1	3.00	0.66	0	10.0	0.260	20	4931

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER AT SELECTED INTERVALS—CONTINUED

Santiam River from Niagara (RM 57.3) to mouth of Santiam River

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	57.3		Mouth	157.40			200								
2.1	55.2	2.1	L. Santiam River RB	167.00	0.000866	1930	200	1.47	1313	2.1	158000	1101	18.0	8756	0.2
9.6	47.7	7.5	Gage 14189000	202.00	0.000884	1880	300	1.47	1279	7.5	158000	1101	18.0	8756	0.6
11.7	45.6	2.1	Confl. S. Santiam	210.00	0.000722	1880	400	2.20	855	1.4	158000	1101	18.0	8756	0.2
11.9	45.4	0.2	Spring Branch (LB)	213.00	0.002841	1580	200	2.90	545	0.1	68000	421	14.7	4641	0.0
14.6	42.7	2.7	Gage 14184100	242.00	0.002034	1570	200	1.17	1342	3.4	68000	421	14.7	4641	0.3
14.7	42.6	0.1	Jffrsn Dch Intk.(RB)	243.00	0.001894	1570	200	1.17	1342	0.1	65000	416	14.4	4504	0.0
22.8	34.5	8.1	S.Pac. Rr. Spur Brdg	347.00	0.002432	1570	150	2.05	766	5.8	65000	416	14.4	4504	0.8
22.9	34.4	0.1	Bear Branch (LB)	348.00	0.001894	1570	150	2.05	766	0.1	65000	416	14.4	4504	0.0
28.4	28.9	5.5	Stayton Brdg.	428.50	0.002772	1560	100	1.90	821	4.2	62000	411	14.2	4366	0.6
29.8	27.5	1.4	Salem Ditch	435.00	0.000879	1560	100	1.90	821	1.1	62000	411	14.2	4366	0.1
30.6	26.7	0.8	Valentine Creek (RB)	467.50	0.007694	1635	100	2.49	657	0.5	62000	411	14.2	4366	0.1
31.4	25.9	0.8	Salem WP Diversion	481.50	0.003314	1625	75	2.49	653	0.5	59000	405	14.0	4226	0.1
36.4	20.9	5.0	Stout Creek (RB)	567.50	0.003258	1670	250	3.08	542	2.4	59000	405	14.0	4226	0.5
38.7	18.6	2.3	Gage 14183000	612.50	0.003706	1660	250	3.08	539	1.1	56000	400	13.7	4082	0.2
39.2	18.1	0.5	L.N. Sant. R. (RB)	627.50	0.005682	1660	225	3.08	539	0.2	56000	400	13.7	4082	0.1
47.1	10.2	7.9	Mill City brdg.	795.00	0.004016	1260	225	2.64	477	4.4	21700	331	9.5	2284	1.2
49.3	8.0	2.2	Rock Creek (LB)	821.00	0.002238	1260	200	2.93	430	1.1	21700	215	9.0	2411	0.4
51.0	6.3	1.7	Gates Bridge	886.00	0.007242	1220	200	2.12	575	1.2	21100	214	8.9	2372	0.3
51.8	5.5	0.8	Mad Creek (LB)	911.00	0.005919	1220	175	2.12	575	0.6	21100	214	8.9	2372	0.1
55.3	2.0	3.5	Sevenmile Creek (LB)	1010.00	0.005357	190	150	1.32	144	3.9	20600	214	8.8	2340	0.6
57.3	0.0	2.0	Gage 14181500	1083.00	0.006913	1150	100	1.32	871	2.2	20000	214	8.7	2300	0.3

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Santiam River from Niagara (RM 57.3) to mouth of Santiam River—Continued

River Mile	DAFLOW Parameter Values Area A1	A2	A0	Width W1	W2	Diffusion Coefficient Low	High
2.1	2.80	0.66	1200	49.0	0.260	3182	82863
9.6	2.80	0.66	1200	49.0	0.260	3057	81172
11.7	2.80	0.66	1200	49.0	0.260	3745	99436
11.9	3.00	0.66	0	23.3	0.260	1759	28459
14.6	3.00	0.66	0	23.3	0.260	2444	39744
14.7	3.00	0.66	0	23.3	0.260	2626	41286
22.8	3.00	0.66	0	23.3	0.260	2045	32156
22.9	3.00	0.66	0	23.3	0.260	2626	41286
28.4	3.00	0.66	0	23.3	0.260	1785	27239
29.8	3.00	0.66	0	23.3	0.260	5628	85868
30.6	3.00	0.66	0	23.3	0.260	666	9814
31.4	3.00	0.66	0	23.3	0.260	1539	21960
36.4	3.00	0.66	0	23.3	0.260	1598	22343
38.7	3.00	0.66	0	23.3	0.260	1398	18898
39.2	3.00	0.66	0	23.3	0.260	912	12325
47.1	3.00	0.66	100	100.0	0.120	666	8153
49.3	2.90	0.66	300	144.0	0.040	1469	22578
51.0	2.90	0.66	300	144.0	0.040	440	6793
51.8	2.90	0.66	300	144.0	0.040	539	8312
55.3	2.90	0.66	300	144.0	0.040	100	8974
57.3	2.90	0.66	300	144.0	0.040	436	6760

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

South Santiam River from Waterloo (RM 23.3) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	23.3		Mouth	210.50											
2.6	20.7	2.6	Mill Creek (LB)	225.80	0.001115	310	200	0.70	443	5.4	90000	958	14.7	6137	0.3
3.0	20.3	0.4	Thomas Creek (RB)	228.20	0.001136	310	200	0.70	443	0.8	83000	937	14.2	5841	0.0
4.3	19.0	1.3	Crabtree Crk.(RB)	236.50	0.001209	280	175	0.70	400	2.7	66000	880	15.7	4214	0.1
7.6	15.7	3.3	Ore hwy 226 Sand.br.	257.90	0.001228	255	175	0.70	364	6.9	53000	828	14.2	3737	0.3
13.1	10.2	5.5	1 Horse slgh. (RB)	305.00	0.001622	255	200	0.41	622	19.7	53000	828	14.2	3737	0.6
13.2	10.1	0.1	Upper end isle.	306.00	0.001894	250	175	0.41	610	0.4	51000	820	13.9	3660	0.0
15.2	8.1	2.0	Drain (LB)	318.50	0.001184	250	250	0.41	610	7.2	51000	820	13.9	3660	0.2
16.4	6.9	1.2	Slough (LB)	328.40	0.001563	250	200	0.41	610	4.3	51000	820	13.9	3660	0.1
16.7	6.6	0.3	Slough (RB)	330.00	0.001010	250	100	0.41	610	1.1	51000	820	13.9	3660	0.0
17.3	6.0	0.6	Slough (LB)	334.00	0.001263	250	75	0.41	610	2.1	51000	820	13.9	3660	0.1
18.0	5.3	0.7	Albny Dtch Dvr. (LB)	341.00	0.001894	250	300	0.41	610	2.5	51000	820	13.9	3660	0.1
18.2	5.1	0.2	Slough (RB)	343.00	0.001894	270	300	0.41	659	0.7	51000	631	10.5	4845	0.0
20.8	2.5	2.6	Dam & Lebanon Ditch	367.50	0.001785	270	300	0.60	450	6.4	51000	443	11.0	4645	0.3
21.2	2.1	0.4	Hamilton Creek (RB)	372.80	0.002509	290	300	0.46	630	1.3	51000	443	11.0	4645	0.1
23.3	0.0	2.1	Gage 14187500	392.00	0.001732	250	250	0.46	543	6.7	46500	439	10.6	4399	0.3

River Mile	DAFLOW Parameter Values: Area A1	Area A2	Width A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
2.6	3.96	0.64	270	41.6	0.275	690	42133
3.0	3.96	0.64	270	41.6	0.275	677	38966
4.3	3.00	0.64	570	41.6	0.275	591	31013
7.6	3.00	0.64	570	41.6	0.275	544	26044
13.1	3.00	0.64	570	41.6	0.275	412	19722
13.2	3.00	0.64	570	41.6	0.275	348	16425
15.2	3.00	0.64	570	41.6	0.275	556	26280
16.4	3.00	0.64	570	41.6	0.275	421	19909
16.7	3.00	0.64	570	41.6	0.275	652	30796
17.3	3.00	0.64	570	41.6	0.275	521	24637
18.0	3.00	0.64	570	41.6	0.275	348	16425
18.2	4.15	0.64	570	100	0.170	275	21325
20.8	4.15	0.64	370	150	0.100	288	32221
21.2	4.15	0.64	370	150	0.100	219	22914
23.3	4.15	0.64	370	150	0.100	277	30559

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Tualatin River from Farmington (RM 33.3) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	33.3		Mouth	54.13											
1.8	31.5	1.8	Gage 14207500	83.00	0.003038	140	115	1.72	81	1.5	31500	246	8.7	3614	0.3
3.4	29.9	1.6	Oswego Div. Dam	99.70	0.001977	140	170	0.82	171	2.9	31500	246	8.7	3614	0.3
6.7	26.6	3.3	Oswego Canal Div.	100.00	0.000017	140	180	0.18	778	26.9	31500	397	6.8	4623	0.7
9.6	23.7	2.9	Fanno Creek (LB)	100.20	0.000013	200	175	0.12	1667	35.4	31700	693	6.2	5146	0.7
15.4	17.9	5.8	Chicken Cr.	100.50	0.000010	205	140	0.14	1464	60.8	31100	632	6.1	5097	1.4
21.0	12.3	5.6		100.80	0.000010	205	110	0.15	1367	54.8	30900	575	6.9	4476	1.2
28.2	5.1	7.2	McFee/Heaton Crs.	101.20	0.000011	200	110	0.15	1333	70.4	30800	519	6.9	4469	1.5
31.0	2.3	2.8	Miscl. Creeks	101.60	0.000027	200	90	0.22	909	18.7	30600	462	7.6	4030	0.5
33.3	0.0	2.3	Gage 14206500	102.00	0.000033	195	60	0.28	696	12.0	30400	406	7.6	4015	0.4

River Mile	DAFLOW Parameter Values: Area A1	Area A2	Width A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
1.8	3.70	0.66	170	64.0	0.130	189	21076
3.4	3.70	0.66	170	64.0	0.130	291	32386
6.7	4.00	0.66	900	50.0	0.200	30264	2305022
9.6	4.20	0.66	1220	46.8	0.260	41256	1751902
15.4	4.20	0.66	1220	42.9	0.260	61115	2512442
21.0	4.00	0.66	800	39.1	0.260	64743	2648886
28.2	4.00	0.66	800	35.3	0.260	67899	2822469
31.0	3.80	0.66	560	31.5	0.260	29591	1224124
33.3	3.80	0.66	560	27.7	0.260	27128	1137938

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Willamette River from Albany (RM 119.5) to mouth

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	201.2		Mouth	1.80											
1.2	200.0	1.2	Columbia SL-RB	1.84	0.000006	8350	1400	0.17	49118	10.4	385000	3500	5.4	71944	0.3
3.4	197.8	2.2	Multnomah Ch-LB	1.90	0.000005	8330	1700	0.17	49000	19.0	385000	3000	5.4	71944	0.6
7.0	194.2	3.6	RR Bridge	2.00	0.000005	8330	1300	0.22	37864	24.0	385000	2500	6.5	59462	0.8
12.8	188.4	5.8	USGS Gage 2117.2	2.20	0.000007	8330	1300	0.22	37864	38.7	385000	2500	6.5	59462	1.3
18.5	182.7	5.7	Johnson Cr-RB	3.36	0.000039	8330	1500	0.22	37864	38.0	385000	2500	6.5	59462	1.3
20.2	181.0	1.7	Tryon Cr-LB	3.71	0.000039	8310	1000	0.33	25182	7.6	385000	2500	6.5	59462	0.4
21.1	180.1	0.9	Oswego Lk-LB	3.89	0.000038	8310	550	0.44	18886	3.0	385000	2000	6.5	59462	0.2
24.8	176.4	3.7	Clackamas R -RB	4.65	0.000039	8310	900	0.44	18886	12.3	385000	2500	6.5	59462	0.8
25.4	175.8	0.6	Abernethy Cr-RB	4.77	0.000038	7610	400	0.90	8456	1.0	351000	2000	5.7	61598	0.2
26.5	174.7	1.1	Base of Falls	5.00	0.000040	7600	625	0.90	8444	1.8	351000	2000	5.7	61598	0.3
26.6	174.6	0.1	Willamette Falls	54.00	0.092803	7600	625	6.00	1267	0.0	351000	2000	9.7	36285	0.0
28.4	172.8	1.8	Tualatin R-LB	54.13	0.000014	7600	825	0.55	13818	4.8	351000	2000	5.6	62310	0.5
29.0	172.2	0.6	Beaver Cr	54.18	0.000016	7460	1000	0.52	14346	1.7	326000	2500	5.5	59787	0.2
35.7	165.5	6.7	Molalla R-RB	54.75	0.000016	7460	1000	0.52	14346	18.9	326000	2500	5.8	56538	1.7
37.6	163.6	1.9	Boeckman-LB	54.92	0.000017	7300	625	0.55	13273	5.1	305000	2500	5.6	54468	0.5
38.5	162.7	0.9	USGS Gage, 1980	55.02	0.000021	7300	600	0.55	13273	2.4	305000	2500	5.6	54468	0.2
39.8	161.4	1.3	Corral Cr-LB	55.20	0.000026	7300	600	0.66	11061	2.9	305000	2500	5.6	54468	0.3
45.1	156.1	5.3	Champoeg Cr-RB	56.28	0.000039	7300	650	0.66	11061	11.8	305000	2500	5.6	54468	1.4
47.4	153.8	2.3	Spring Br-LB	56.80	0.000043	7290	600	0.66	11045	5.1	305000	2500	5.6	54468	0.6
50.8	150.4	3.4	Chehalem C, lower Is	57.62	0.000046	7290	600	1.50	4860	3.3	305000	2500	5.6	54468	0.9
52.4	148.8	1.6	Upper Ash Is	58.20	0.000069	7290	525	1.50	4860	1.6	305000	2500	5.6	54468	0.4
54.9	146.3	2.5	Yamhill R-LB	60.00	0.000136	7290	600	1.50	4860	2.4	305000	2500	5.6	54468	0.7
60.0	141.2	5.1		68.00	0.000297	7170	550	4.55	1576	1.6	285000	2000	8.4	34020	0.9
64.9	136.3	4.9	Low Lambert Sl	76.40	0.000325	7170	500	7.90	908	0.9	285000	2000	8.4	34020	0.9
70.9	130.3	6.0	Up Lmbert Sl-Grnd Is	89.50	0.000414	7170	600	7.90	908	1.1	285000	2000	8.4	34020	1.1
73.5	127.7	2.6	Spring Valley Cr-LB	95.30	0.000422	7170	650	4.50	1593	0.8	285000	2000	8.4	34020	0.5
79.6	121.6	6.1	Glenn Cr-LB	102.00	0.000208	7160	800	3.10	2310	2.9	285000	2000	8.4	34020	1.1
83.6	117.6	4.0	Mill Cr-RB	110.60	0.000407	7160	700	3.10	2310	1.9	285000	2000	8.4	34020	0.7
84.1	117.1	0.5	USGS Gage, 1910	111.40	0.000303	7060	800	2.60	2715	0.3	283000	2000	8.4	33856	0.1
86.0	115.2	1.9	Pettijohn Cr-RB	113.20	0.000179	7060	600	2.60	2715	1.1	283000	2000	8.4	33856	0.3
88.1	113.1	2.1	Rickreall Cr-LB	115.30	0.000189	7060	550	2.60	2715	1.2	283000	2000	8.4	33856	0.4
95.3	105.9	7.2	Ash Cr-LB	128.00	0.000334	7050	600	2.90	2431	3.6	281000	2000	8.3	33690	1.3
101.3	99.9	6.0	Bashaw Cr-RB	140.20	0.000385	7050	600	2.90	2431	3.0	281000	2000	8.3	33690	1.1
101.5	99.7	0.2	Sydney Ditch-RB	140.60	0.000400	7050	600	2.90	2431	0.1	281000	2000	8.3	33690	0.0
107.5	93.7	6.0	Luckiamute R-LB	154.00	0.000422	7050	600	2.90	2431	3.0	281000	2000	8.3	33690	1.1
108.0	93.2	0.5	L Santiam R -RB	155.30	0.000492	7010	500	3.15	2225	0.2	279000	2000	8.3	33525	0.1
109.0	92.2	1.0	Santiam R-RB	157.40	0.000398	7010	400	2.40	2921	0.6	279000	2000	8.3	33525	0.2
115.5	85.7	6.5	Fourth Lake-RB	169.20	0.000344	5160	450	1.65	3127	5.8	168000	2000	7.6	21970	1.2
117.9	83.3	2.4	Cox & Periwinkle Crs	172.70	0.000276	5160	375	1.65	3127	2.1	168000	2000	7.6	21970	0.5
119.3	81.9	1.4	USGS Gage, 1740	174.70	0.000271	5160	500	1.65	3127	1.2	168000	2000	7.6	21970	0.3

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Willamette River from Albany (RM 119.5) to mouth—Continued

River Mile	DAFLOW Parameter Values					Diffusion Coefficient	
	Area			Width			
	A1	A2	A0	W1	W2	Low	High
1.2	12.00	0.60	45000	164.7	0.237	472371	8785033
3.4	12.00	0.60	45000	459.2	0.145	474320	12574447
7.0	11.34	0.60	34000	282.7	0.169	608987	14725496
12.8	11.34	0.60	34000	282.7	0.169	490573	11862206
18.5	11.34	0.60	34000	447.4	0.134	72040	1992072
20.2	11.34	0.60	34000	113.6	0.241	106558	1958724
21.1	11.34	0.60	34000	27.0	0.334	199440	2566107
24.8	11.34	0.60	34000	83.8	0.263	118673	2004884
25.4	10.35	0.66	14300	10.1	0.412	251130	2389379
26.5	10.35	0.66	14300	43.6	0.298	153533	2262960
26.6	10.35	0.60	14300	43.6	0.298	66	966
28.4	11.60	0.66	9300	108.5	0.227	336738	6515477
29.0	11.60	0.66	9300	119.8	0.238	236333	4203091
35.7	9.60	0.67	9100	119.8	0.238	231496	4117063
37.6	9.60	0.67	9100	23.9	0.367	344629	3659568
38.5	9.60	0.67	9100	20.8	0.378	289080	2946224
39.8	9.60	0.67	9100	20.8	0.378	231978	2364254
45.1	9.60	0.67	9100	27.1	0.357	145501	1603813
47.4	9.60	0.67	9100	20.8	0.378	141875	1447180
50.8	9.60	0.67	9100	20.8	0.378	132998	1356636
52.4	9.60	0.67	9100	13.3	0.413	101126	905164
54.9	9.60	0.67	9100	20.8	0.378	44550	454429
60.0	5.86	0.69	0	25.0	0.348	21940	242103
64.9	5.86	0.69	0	18.1	0.374	22084	221436
70.9	5.86	0.69	0	33.5	0.325	14449	173539
73.5	5.86	0.69	0	44.1	0.303	13054	170014
79.6	5.86	0.69	0	89.3	0.247	21512	344692
83.6	5.86	0.69	0	56.3	0.284	12560	175603
84.1	5.86	0.69	0	88.8	0.248	14561	233690
86.0	5.86	0.69	0	33.7	0.325	32790	396051
88.1	5.86	0.69	0	25.0	0.349	33888	374617
95.3	5.86	0.69	0	33.4	0.326	17586	210824
101.3	5.86	0.69	0	33.4	0.326	15256	182887
101.5	5.86	0.69	0	33.4	0.326	15256	182887
107.5	5.86	0.69	0	33.4	0.326	13937	167072
108.0	5.86	0.69	0	17.9	0.376	14236	141810
109.0	5.86	0.69	0	8.3	0.437	22031	175299
115.5	5.40	0.69	200	10.0	0.445	16675	115239
117.9	5.40	0.69	200	5.1	0.502	24910	141146
119.3	5.40	0.69	200	14.3	0.416	19071	145806

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Willamette River from Jasper (RM 201.2) to Albany (RM 119.5)

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
119.5	81.7	0.2	Calapooia R-RB	175.20	0.000473	5160	450	2.55	2024	0.1	168000	2000	7.6	21970	0.0
121.6	79.6	2.1	Low L Willamette R-R	180.00	0.000433	5130	400	3.50	1466	0.9	166000	2000	7.6	21791	0.4
122.7	78.5	1.1	Bowers Sl-LB	182.20	0.000379	5110	350	3.50	1460	0.5	166000	2000	7.6	21791	0.2
124.3	76.9	1.6	Up L Willamette R-RB	184.50	0.000272	5090	300	3.05	1669	0.8	166000	2000	8.7	19075	0.3
127.2	74.0	2.9	Dead R	186.50	0.000131	5060	350	2.60	1946	1.6	166000	2000	8.7	19075	0.5
130.8	70.4	3.6	Dixon Cr	190.80	0.000226	5030	400	2.60	1935	2.0	166000	2000	8.7	19075	0.6
132.1	69.1	1.3	Marys R.-Mill Race	193.40	0.000379	5000	400	2.60	1923	0.7	166000	2000	8.7	19075	0.2
132.6	68.6	0.5	Low East Ch-RB	194.60	0.000455	4960	500	2.60	1908	0.3	161000	1800	8.6	18682	0.1
134.0	67.2	1.4	Low Booneville Ch-LB	200.00	0.000731	4940	300	3.00	1647	0.7	161000	1800	10.9	14762	0.2
136.1	65.1	2.1	Up East Ch - RB	208.00	0.000722	4920	400	3.00	1640	1.0	161000	1800	10.9	14762	0.3
140.2	61.0	4.1	Up Middle Ch-LB	221.00	0.000601	4890	300	3.00	1630	2.0	161000	1800	10.9	14762	0.6
143.5	57.7	3.3	Up Hoacum Is	230.14	0.000525	4860	450	3.20	1519	1.5	161000	1800	8.6	18682	0.6
144.5	56.7	1.0	Up Albany Ch-LB	234.20	0.000769	4860	350	3.20	1519	0.5	161000	1800	8.6	18682	0.2
145.9	55.3	1.4	Long Tom R-LB	238.80	0.000622	4830	300	3.20	1509	0.6	161000	1800	8.6	18682	0.2
147.4	53.8	1.5	Unnamed Sl-RB	243.00	0.000530	4780	350	3.20	1494	0.7	155000	1600	10.8	14402	0.2
149.0	52.2	1.6	Up Old Long Tom Sl	248.00	0.000592	4750	300	3.20	1484	0.7	155000	1600	10.8	14402	0.2
154.1	47.1	5.1	Ingram Sl-LB	263.50	0.000576	4720	350	3.20	1475	2.3	155000	1600	10.8	14402	0.7
156.6	44.6	2.5	Morgan Isle Sl-LB	271.50	0.000606	4690	350	2.90	1617	1.3	155000	1600	10.8	14402	0.3
157.8	43.4	1.2	Low unnamed Sl	277.00	0.000868	4690	300	2.90	1617	0.6	155000	1600	10.8	14402	0.2
160.6	40.6	2.8	Up unnamed Sl-LB	291.20	0.000960	4660	450	2.90	1607	1.4	155000	1600	10.8	14402	0.4
161.2	40.0	0.6	USGS Gage, 1660	293.00	0.000568	4640	350	2.80	1657	0.3	155000	1600	10.6	14686	0.1
165.0	36.2	3.8		310.00	0.000847	4630	350	2.80	1654	2.0	155000	1600	10.6	14686	0.5
171.8	29.4	6.8	McKenzie R-RB	340.00	0.000836	4630	500	2.80	1654	3.6	155000	1600	10.6	14686	0.9
174.8	26.4	3.0	McKenzie R Alt Ch	358.00	0.001136	3000	450	2.20	1364	2.0	155000	1600	10.6	14686	0.4
177.8	23.4	3.0	Dedrick Sl-RB	376.50	0.001168	2030	450	1.91	1063	2.3	65000	1000	8.2	7928	0.5
184.2	17.0	6.4	“Q” St Floodway-RB	416.00	0.001169	2030	400	1.47	1381	6.4	65000	1000	8.2	7928	1.1
187.0	14.2	2.8	Coast F Willamette-L	436.00	0.001353	2030	350	1.47	1381	2.8	65000	1000	10.4	6280	0.4
187.9	13.3	0.9	Slough-LB	444.00	0.001684	1760	300	2.05	859	0.6	39000	700	8.6	4528	0.2
188.7	12.5	0.8	Slough and drains -L	450.00	0.001420	1760	300	2.65	664	0.4	39000	700	8.6	4528	0.1
189.4	11.8	0.7	Drain (RB)	456.00	0.001623	1760	120	2.65	664	0.4	39000	700	8.6	4528	0.1
191.4	9.8	2.0	Sloughs and drains-L	480.00	0.002273	1760	150	2.65	664	1.1	39000	700	8.6	4528	0.3
194.8	6.4	3.4	Wallace Cr-RB	515.00	0.001950	1760	225	2.65	664	1.9	39000	700	8.6	4528	0.6
195.0	6.2	0.2	USGS Gage, 1520	519.00	0.003788	1760	215	2.65	664	0.1	39000	700	8.6	4528	0.0
197.2	4.0	2.2	Rattlesn. & Hills Cr	540.00	0.001808	1760	300	2.65	664	1.2	39000	700	8.6	4528	0.4
198.3	2.9	1.1	Fall Cr and dr-RB	555.00	0.002583	1760	250	2.65	664	0.6	39000	700	8.6	4528	0.2
200.6	0.6	2.3	Lost Cr and Sl-LB	595.00	0.003294	1760	275	2.65	664	1.3	35000	700	8.3	4225	0.4
201.2	0.0	0.6	USGS Gage,1500	604.00	0.002841	1760	200	2.65	664	0.3	35000	700	8.3	4225	0.1

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Willamette River from from Jasper (RM 201.2) to Albany (RM 119.5)—Continued

River Mile	DAFLOW Parameter Values Area A1	A2	A0	Width W1	W2	Diffusion Coefficient Low	High
119.5	5.40	0.69	200	10.0	0.445	12109	83681
121.6	5.40	0.69	200	6.5	0.482	14813	89705
122.7	5.40	0.69	200	4.1	0.522	19272	101745
124.3	5.38	0.68	0	2.3	0.569	31160	139915
127.3	5.38	0.68	0	4.1	0.522	55342	293550
130.8	5.38	0.68	0	6.6	0.482	27794	170039
132.1	5.38	0.68	0	6.6	0.482	16500	101259
132.6	5.38	0.68	0	17.8	0.392	10912	90532
134.0	5.33	0.66	200	3.1	0.539	11271	56167
136.1	5.33	0.66	200	8.5	0.453	8524	57447
140.2	5.33	0.66	200	3.1	0.539	13572	67953
143.5	5.38	0.68	0	13.1	0.417	10294	79226
144.5	5.38	0.68	0	5.3	0.493	9029	53258
145.9	5.38	0.68	0	3.1	0.539	12936	65140
147.4	5.33	0.66	200	7.1	0.460	12877	84274
149.0	5.33	0.66	200	4.1	0.507	13376	74568
154.1	5.33	0.66	200	7.0	0.463	11714	76387
156.6	5.33	0.66	200	7.5	0.455	11055	74388
157.8	5.33	0.66	200	4.3	0.501	9005	51586
160.6	5.33	0.66	200	18.2	0.380	5391	47343
161.2	5.20	0.66	830	7.5	0.455	11666	78961
165.0	5.20	0.66	830	7.5	0.455	7806	52898
171.8	5.20	0.66	830	26.5	0.348	5541	54669
174.8	5.20	0.66	830	21.5	0.380	2933	33849
177.8	5.28	0.66	0	62.1	0.260	1931	25110
184.2	5.28	0.66	0	42.3	0.295	2171	25000
187.0	5.22	0.64	0	26.7	0.338	2144	21269
187.9	5.22	0.64	0	29.8	0.309	1742	14823
188.7	5.22	0.64	0	29.8	0.309	2065	17568
189.4	5.22	0.64	0	1.0	0.642	4517	13696
191.4	5.22	0.64	0	2.3	0.561	2581	10059
194.8	5.22	0.64	0	10.3	0.413	2006	12365
195.0	5.22	0.64	0	8.6	0.430	1081	6318
197.2	5.22	0.64	0	29.8	0.309	1623	13803
198.3	5.22	0.64	0	15.1	0.376	1363	9421
200.6	5.22	0.64	0	19.4	0.355	972	6684
201.2	5.22	0.64	0	5.7	0.475	1549	7443

APPENDIX 1. STREAM GEOMETRY FOR MAIN STEM AND MAJOR TRIBUTARIES OF THE WILLAMETTE RIVER, OREGON, AT SELECTED INTERVALS—CONTINUED

Yamhill River from Willamina (RM 56.8) to mouth of the Yamhill River

River Mile	Sta.	Reach Length (mi)	Location	Elev (ft)	Slope (ft/ft)	Low Flow Disch. (ft^3/s)	Low Flow Width (ft)	Low Flow Vel. (ft/s)	Low Flow Area (ft^2)	Low Flow Time (hrs)	High Flow Disch. (ft^3/s)	High Flow Width (ft)	High Flow Vel. (ft/s)	High Flow Area (ft^2)	High Flow Time (hrs)
0.0	56.8		Mouth	60.00											
4.9	51.9	4.9	Palmer Creek RB	62.00	0.000077	65	120	0.35	186	20.5	74500	686	3.8	19387	1.9
7.9	48.9	3.0	Henry Creek LB	66.00	0.000253	63	100	0.35	182	12.7	72000	680	3.8	18955	1.2
8.9	47.9	1.0	Haun Creek LB	68.50	0.000473	63	100	0.35	182	4.2	71000	677	3.8	18781	0.4
11.2	45.6	2.3	Conf. N. Yamhill R.	73.00	0.000371	63	100	0.35	182	9.7	70000	675	3.8	18606	0.9
16.8	40.0	5.6	Cozine Cr-LB	78.00	0.000169	47	100	0.46	102	17.7	46500	277	4.8	9630	1.7
22.5	34.3	5.7		87.00	0.000299	46	90	0.46	100	18.2	45500	276	4.8	9492	1.7
27.9	28.9	5.4	Gage 14194000	99.00	0.000421	46	80	0.46	100	17.2	44500	275	4.8	9354	1.7
29.4	27.4	1.5	Salt Creek RB	100.00	0.000126	46	80	0.55	84	4.0	43500	268	6.9	6350	0.3
35.9	20.9	6.5	Deer Creek LB	117.00	0.000495	46	120	0.55	84	17.4	42000	266	6.8	6205	1.4
41.4	15.4	5.5	Unnamed Creek RB	132.00	0.000517	46	120	0.55	84	14.7	40000	265	6.7	6009	1.2
46.4	10.4	5.0	Chandler Creek RB	158.00	0.000985	46	200	0.46	100	16.0	40000	265	4.6	8719	1.6
51.6	5.2	5.2	Rock Creek LB	183.00	0.000911	45	150	0.46	99	16.7	39000	264	4.5	8574	1.7
52.3	4.5	0.7	Mill Creek RB	190.00	0.001894	44	90	0.54	82	1.9	37000	262	6.5	5708	0.2
54.0	2.8	1.7	Willamina Creek LB	202.00	0.001337	40	90	0.51	78	4.8	29000	253	6.0	4863	0.4
54.5	2.3	0.5	Unnamed Creek RB	219.00	0.006439	25	90	0.47	53	1.5	20000	136	10.5	1899	0.1
56.8	0.0	2.3	Gage 14192500	235.00	0.001318	23	110	0.45	51	7.5	19000	136	10.3	1837	0.3

River Mile	DAFLOW Parameter Values: Area A1	Area A2	A0	Width W1	Width W2	Diffusion Coefficient Low	Diffusion Coefficient High
4.9	10.20	0.66	700	32.0	0.260	4438	814734
7.9	10.20	0.66	700	32.0	0.260	1327	243188
8.9	9.20	0.66	450	31.5	0.260	719	130402
11.2	8.20	0.66	90	31.0	0.260	934	167544
16.8	8.20	0.66	90	31.0	0.260	1647	271254
22.5	14.00	0.66	0	40.0	0.180	965	275896
27.9	9.50	0.66	0	40.0	0.180	686	192492
29.4	9.00	0.66	0	60.0	0.140	1776	643642
35.9	5.50	0.66	15	60.0	0.140	453	159188
41.4	5.50	0.66	15	60.0	0.140	434	146385
46.4	8.00	0.66	0	60.0	0.140	228	76775
51.6	8.00	0.66	0	60.0	0.140	242	81252
52.3	5.50	0.66	15	60.0	0.140	114	37334
54.0	5.50	0.66	15	60.0	0.140	149	42893
54.5	2.71	0.66	30	45.9	0.110	30	11382
56.8	2.71	0.66	30	45.9	0.110	135	53148

APPENDIX 2. ARC MACRO LANGUAGE (AML) PROGRAM USED TO CONVERT HYDROLOGIC RESPONSE UNIT (HRU) COVERAGE AND OTHER SPATIAL COVERAGE INFORMATION TO PRECIPITATION-RUNOFF MODELING SYSTEM (PRMS) PARAMETER VALUES

```
/*----------------------------- GIS.AML -----------------------------------*\
/*                                                                          *\
/* Command name: GIS.AML                                                    *\
/* Language: AML version 6.1 -  ARC MACRO LANGUAGE                          *\
/*                                                                          *\
/*           By: James M. Wilkinson                                         *\
/*               USGS-WRD, Portland, OR                                     *\
/*               (503) 251-3466                                             *\
/*               EDOC: JMWILK                                               *\
/*               internet: jmwilk@dorprx.wr.usgs.gov                        *\
/*                                                                          *\
/*::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::*\
/*                                                                          *\
/* Purpose: Input interface for PRMS. Creates ‘card’ files (c36, c37, c38)  *\
/*          from ARC/INFO coverages and related tables.                     *\
/*                                                                          *\
/*::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::*\
/*                                                                          *\
/* Usage: GIS <basin> {subbasin}                                            *\
/*                                                                          *\
/*::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::*\
/*                                                                          *\
/* Arguments:                                                               *\
/*                                                                          *\
/*   Variable name, Type, Definition, Description                           *\
/*   ------------------------------------------------------------           *\
/*   basin          UNIX  character   basin directory name                  *\
/*   subbasin       UNIX  character   subbasin directory name               *\
/*                                                                          *\
/*::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::*\
/*                                                                          *\
/* Required programs, coverages, and files:                                 *\
/*                                                                          *\
/*  Programs: none                                                          *\
/*                                                                          *\
/*  Coverages: basin/subbasin hru, basin lattice                            *\
/*                                                                          *\
/*  Info files:                                                             *\
/*                                                                          *\
/*  Ascii files: geosoils.tab, landuse1.tab, landuse2.tab, mis1.tab,        *\
/*               mis2.tab                                                   *\
/*                                                                          *\
/*  Other files:                                                            *\
/*                                                                          *\
/*::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::*\
/*                                                                          *\
/* History:                                                                 *\
/*  Author,        Site,                  Date,   Event                     *\
/*                                                                          *\
/*  Jim Wilkinson, USGS-WRD, Portland, OR 09JUN93 original coding           *\
```

```
/*                                                                          *\
/* Usage Notes:                                                             *\
/*                                                                          *\
/*  This program has only been tested when run from the current directory.  *\
/*  Use another directory at your own risk.  This program also deletes      *\
/*  existing files with the same name.                                      *\
/*                                                                          *\
/*::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::*\
/*
/* Error trap the arguments:
/*
&args basin subbasin
&s hrupath /deqbasin/final/
&s tablepath /will_models/nevadaprogs/tables/
&s outpath /will_models/basins/
/*
&if [null %basin%] &then
 &do
 &type  Insufficient parameters specified.
 &s basin [response 'Enter the name of a basin directory or <cr> to quit']
 &if [null %basin%] &then &goto terminator
 &end
/*
&label basincheck
&if ^ [exists %hrupath%%basin% -directory] &then
 &do
 &type basin directory %hrupath%%basin% doesn't exist
 &s basin [response 'Enter the name of a basin directory or <cr> to quit']
 &if [null %basin%] &then &goto terminator
 &goto basincheck
 &end
/*
&s outpath [pathname %outpath%%basin%/]
&s latpath [pathname %hrupath%%basin%/]
&s hrupath [pathname %hrupath%%basin%/]
&s latname [substr %basin% 1 4]_lat
/*
&if [null %subbasin%] &then
 &do
 &s covname [substr %basin% 1 4]_hru
 &s outname [substr %basin% 1 20]
 &s infoname [translate [substr %basin% 1 4]]
 &if ^ [exists %hrupath%%covname% -cover] &then
  &do
  &type coverage %hrupath%%covname% doesn't exist
  &goto terminator
  &end
 &else &goto cleancheck
 &end
/*
&s covname %subbasin%
```

```
&s outname [substr %subbasin% 1 20]
&s infoname [translate [substr %covname% 1 4]]
/*
&label subcheck
&if [exists %hrupath%subbasins/%covname% -cover] and [exists %hrupath%calbasins/
%covname% -cover] &then
 &do
 &label question
 &type Do you want to use the gsbasin or subbasin?
 &s answer [response ‘1 = gsbasin; 2 = subbasin; <cr> = quit:  ‘]
 &if [null %answer%] &then &goto terminator
 &select %answer%
  &when 2
   &s hrupath [pathname %hrupath%subbasins/]
  &when 1
   &s hrupath [pathname %hrupath%calbasins/]
  &otherwise
   &do
   &type invalid answer
   &goto question
   &end
  &end
 &end
&else &if [exists %hrupath%subbasins/%covname% -cover] &then &s hrupath [pathname
%hrupath%subbasins/]
&else &if [exists %hrupath%calbasins/%covname% -cover] &then &s hrupath [pathname
%hrupath%calbasins/]
&else
 &do
 &type invalid subbasin name
 &s covname [response ‘Please enter the name of the subbasin: ‘]
 &if [null %covname%] &then &goto terminator
 &goto subcheck
 &end
/*
&label cleancheck
&if ^ [exists %latpath%%latname% -grid] &then
 &do
 &type lattice %latpath%%latname% doesn’t exist
 &goto terminator
 &end
/*
&if ^ [exists %hrupath%%covname% -clean] &then
 &do
 &type coverage %hrupath%%covname% needs to be cleaned first
 &goto terminator
 &end
&else &goto start
/*
&label terminator
 &type terminating program gis.aml
```

```
 &type get a grip
 &return
 &end
/*
/*
/*
&label start
/*
&messages &off
&type 1
/*
/* DELETE PREVIOUS FILES
/*
&if [exists elevstats -info] &then
 &s delete_status [delete elevstats -info]
&if [exists geosoils -info] &then
 &s delete_status [delete geosoils -info]
&if [exists landuse1 -info] &then
 &s delete_status [delete landuse1 -info]
&if [exists landuse2 -info] &then
 &s delete_status [delete landuse2 -info]
&if [exists misc1 -info] &then
 &s delete_status [delete misc1 -info]
&if [exists misc2 -info] &then
 &s delete_status [delete misc2 -info]
&if [exists slopestats -info] &then
 &s delete_status [delete slopestats -info]
&if [exists tempstats -info] &then
 &s delete_status [delete tempstats -info]
&if [exists %infoname%.stats -info] &then
 &s delete_status [delete %infoname%.stats -info]
&if [exists slopegrid -grid] &then
 kill slopegrid
/*
/* CALCULATE MEAN ELEVATIONS AND SLOPE USING GRID
/*
&type 2
grid
setcell %latpath%%latname%
slopegrid = slope(%latpath%%latname%, percentrise)
slopestats = zonalstats(polygrid(%hrupath%%covname%, hru), slopegrid, #, data)
elevstats = zonalstats(polygrid(%hrupath%%covname%, hru), %latpath%%latname%, #,
data)
quit
/*
/* SUM UP THE AREA FOR EACH HRU TYPE
/*
&type 3
statistics %hrupath%%covname%.pat tempstats hru
sum area
end
```

```
/*
/* ASSIGN GENERIC ASPECT FOR FLAT AREAS
/*
&type 4
&select %basin%
 &when albany
  &s degree 348
 &when aleugene
  &s degree 350
 &when calapooia
  &s degree 325
 &when cfwillamette
  &s degree 350
 &when clackamas
  &s degree 310
 &when longtom
  &s degree 15
 &when luckiamute
  &s degree 90
 &when marys
  &s degree 60
 &when mckenzie
  &s degree 265
 &when mill
  &s degree 275
 &when molalla
  &s degree 340
 &when nsantiam
  &s degree 270
 &when portland
  &s degree 335
 &when porsalem
  &s degree 40
 &when rickreal
  &s degree 85
 &when salem
  &s degree 348
 &when ssantiam
  &s degree 295
 &when tualatin
  &s degree 130
 &when yamhill
  &s degree 70
 &when mfwillamette
  &s degree 300
 &otherwise
  &s degree 270
&end
/*
/* COMPILE THE DATA INTO A SINGLE INFO FILE, EXTRACT DATA
/* FROM RELATED TABLES, AND OUTPUT C36, C37, AND C38 FILES
```

```
/*
&type 5
additem elevstats elevstats hru 4 4 i
additem slopestats slopestats hru 4 4 i
pullitems  tempstats %infoname%.stats
hru
end
additem %infoname%.stats %infoname%.stats acres 8 8 i
additem %infoname%.stats %infoname%.stats meanelev 6 6 i
additem %infoname%.stats %infoname%.stats slope 4 4 f 3
additem %infoname%.stats %infoname%.stats aspect 3 3 i
additem %infoname%.stats %infoname%.stats geo 4 4 i
additem %infoname%.stats %infoname%.stats lu 4 4 i
additem %infoname%.stats %infoname%.stats iru 2 2 i
&type 6
&workspace info
&data info
ARC
CA $NM = 1
SEL ELEVSTATS
CA HRU = VALUE
SORT HRU
SEL SLOPESTATS
CA HRU = VALUE
SORT HRU
SEL TEMPSTATS
RES HRU = 0
PURGE
Y
RED
2,SLASP,1,1,I
[unquote ‘’]
SORT HRU
SEL %infoname%.STATS
RES HRU = 0
PURGE
Y
SORT HRU
RED
1,L1,1,1,I
2,L2,1,1,I
3,G1,2,2,I
[unquote ‘’]
CA IRU $RECNO
CA GEO = G1
CA LU = L1 * 1000
RES LU = 4000
RES L2 GT 0 AND L2 LT 3
CA LU = LU + L2 * 100
ASE
RELATE TEMPSTATS HRU ORDERED
```

```
CA ACRES = $1SUM-AREA * .0002471
RES $1SLASP = 0
CA ASPECT = %degree%
ASE
RES $1SLASP = 3
CA ASPECT = %degree%
ASE
RES $1SLASP GE 6
CA ASPECT = ( $1SLASP - 6 ) * 90
ASE
RELATE SLOPESTATS HRU ORDERED
CA SLOPE = $1MEAN / 100
RELATE ELEVSTATS HRU ORDERED
CA MEANELEV = $1MEAN * 3.281
DEFINE GEOSOILS
REC,80,80,C
GEO,4,4,I
SEP,4,4,F,3
SMAV,4,4,F,2
SMAX,4,4,F,2
RECHR,4,4,F,2
REMX,4,4,F,2
ISOIL,1,1,I
[unquote ‘’]
RED
5,RGEO,4,4,I
15,RSEP,4,4,N,3
25,RSMAV,4,4,N,2
35,RSMAX,4,4,N,2
45,RRECHR,4,4,N,2
55,RREMX,4,4,N,2
65,RISOIL,1,1,I
[unquote ‘’]
ADD FROM %tablepath%geosoils.tab
RES RGEO LT 1 OR RGEO GT 100
PURGE
Y
CA GEO = RGEO
CA SEP = RSEP
CA SMAV = RSMAV
CA SMAX = RSMAX
CA RECHR = RRECHR
CA REMX = RREMX
CA ISOIL = RISOIL
DEFINE LANDUSE1
REC,80,80,C
LU,4,4,I
IMPERV,4,4,F,3
ICOV,1,1,I
COVDNS,4,4,F,2
COVDNW,4,4,F,2
```

```
SNST,4,4,F,2
RNSTS,4,4,F,2
RNSTW,4,4,F,2
[unquote ‘’]
RED
5,RLU,4,4,I
15,RIMPERV,4,4,N,3
25,RICOV,1,1,I
35,RCOVDNS,4,4,N,2
45,RCOVDNW,4,4,N,2
55,RSNST,4,4,N,2
65,RRNSTS,4,4,N,2
75,RRNSTW,4,4,N,2
[unquote ‘’]
ADD FROM %tablepath%landuse1.tab
RES RLU LT 1000 OR RLU GT 5000
PURGE
Y
CA LU = RLU
CA IMPERV = RIMPERV
CA ICOV = RICOV
CA COVDNS = RCOVDNS
CA COVDNW = RCOVDNW
CA SNST = RSNST
CA RNSTS = RRNSTS
CA RNSTW = RRNSTW
DEFINE LANDUSE2
REC,80,80,C
LU,4,4,I
ITST,1,1,I
ITND,2,2,I
TST,1,1,I
SCX,4,4,F,3
RETIP,4,4,F,3
SCN,4,5,F,4
SC1,4,4,F,2
[unquote ‘’]
RED
5,RLU,4,4,I
15,RITST,1,1,I
25,RITND,2,2,I
35,RTST,1,1,I
45,RSCX,4,4,N,3
55,RRETIP,4,4,N,3
65,RSCN,5,5,N,4
75,RSC1,4,4,N,2
[unquote ‘’]
ADD FROM %tablepath%landuse2.tab
RES RLU LT 1000 OR RLU GT 5000
PURGE
Y
```

APPENDIX 2. ARC MACRO LANGUAGE (AML) PROGRAM USED TO CONVERT HYDROLOGIC RESPONSE UNIT (HRU) COVERAGE AND OTHER SPATIAL COVERAGE INFORMATION TO PRECIPITATION-RUNOFF MODELING SYSTEM (PRMS) PARAMETER VALUES—CONTINUED

```
CA LU = RLU
CA ITST = RITST
CA ITND = RITND
CA TST = RTST
CA SCX = RSCX
CA RETIP = RRETIP
CA SCN = RSCN
CA SC1 = RSC1
DEFINE MISC1
REC,80,80,C
LU,4,4,I
KGW,1,1,I
KDS,1,1,I
KDC,1,1,I
TRNCF,4,4,F,2
AIMX,2,2,I
SRX,1,1,I
KRES,1,1,I
[unquote ‘’]
RED
5,RLU,4,4,I
15,RKGW,1,1,I
25,RKDS,1,1,I
35,RKDC,1,1,I
45,RTRNCF,4,4,N,2
55,RAIMX,2,2,I
65,RSRX,1,1,I
75,RKRES,1,1,I
[unquote ‘’]
ADD FROM %tablepath%mis1.tab
RES RLU LT 1000 OR RLU GT 5000
PURGE
Y
CA LU = RLU
CA KGW = RKGW
CA KDS = RKDS
CA KDC = RKDC
CA TRNCF = RTRNCF
CA AIMX = RAIMX
CA SRX = RSRX
CA KRES = RKRES
DEFINE MISC2
REC,80,80,C
LU,4,4,I
KTS,1,1,I
TXAJ,1,1,I
TNAJ,1,1,I
[unquote ‘’]
RED
5,RLU,4,4,I
15,RKTS,1,1,I
```

```
25,RTXAJ,1,1,I
35,RTNAJ,1,1,I
[unquote '']
ADD FROM %tablepath%mis2.tab
RES RLU LT 1000 OR RLU GT 5000
PURGE
Y
CA LU = RLU
CA KTS = RKTS
CA TXAJ = RTXAJ
CA TNAJ = RTNAJ
SEL %infoname%.STATS
RELATE 1 GEOSOILS GEO ORDERED
RELATE 2 LANDUSE1 LU ORDERED
RELATE 3 LANDUSE2 LU ORDERED
RELATE 4 MISC1 LU ORDERED
RELATE 5 MISC2 LU ORDERED
CA $COMMA-SWITCH = -1
OUTPUT %outpath%c36.%outname% I
PRINT
'$RECNO',11T,'IRU',16T,'IRD',23T,'SLP',31T,'ELV',36T,'ICOV',42T,'COVDNS',50T,'CO
VDNW',59T,'TRNCF',68T,'SNST',75T,'RNSTS',83T,'RNSTW',89T,'ITST',94T,'ITND',99T,'
ITSW',108T,'CTX',115T,'TXAJ',123T,'TNAJ'
PRINT
1T,$RECNO,10T,HRU,HRU,22T,SLOPE,28T,MEANELEV,39T,$2ICOV,44T,$2COVDNS,52T,$2COVDN
W,60T,$4TRNCF,68T,$2SNST,76T,$2RNSTS,84T,$2RNSTW,92T,$3ITST,96T,$3ITND,102T,'1
0.00',118T,$5TXAJ,126T,$5TNAJ
OUTPUT %outpath%c37.%outname% I
PRINT
'$RECNO',11T,'IRU',16T,'ISOIL',24T,'SMAX',32T,'SMAV',40T,'REMX',47T,'RECHR',57T,
'SRX',65T,'SCX',73T,'SCN',81T,'SC1',86T,'IMPERV',95T,'RETIP',105T,'SEP',109T,'KR
ES',114T,'KGW',118T,'KSTOR'
PRINT
1T,$RECNO,10T,HRU,18T,$1ISOIL,24T,$1SMAX,32T,$1SMAV,40T,$1REMX,47T,$1RECHR,58T,$
4SRX,64T,$3SCX,72T,$3SCN,80T,$3SC1,87T,$2IMPERV,95T,$3RETIP,104T,$1SEP,111T,$4KR
ES,115T,$4KGW,120T,'0'
OUTPUT %outpath%c38.%outname% I
PRINT
'$RECNO',11T,'IRU',15T,'KDS',22T,'DARU',29T,'UPCOR',37T,'DRCOR',45T,'DSCOR',55T,
'TST',61T,'KTS',67T,'KSP',73T,'KDC',80T,'AIMX',87T,'PKFAC',95T,'ASPECT'
PRINT 1T,$RECNO,10T,HRU,17T,$4KDS,19T,ACRES,30T,'1.00    1.00
1.00',57T,$3TST,63T,$5KTS,69T,'0',75T,$4KDC,82T,$4AIMX,88T,'0.00',98T,ASPECT
Q STOP
&end
&workspace ..
/*
/* CLEAN UP
/*
&type 7
&if [exists elevstats -info] &then
 &s delete_status [delete elevstats -info]
```

```
&if [exists geosoils -info] &then
 &s delete_status [delete geosoils -info]
&if [exists landuse1 -info] &then
 &s delete_status [delete landuse1 -info]
&if [exists landuse2 -info] &then
 &s delete_status [delete landuse2 -info]
&if [exists misc1 -info] &then
 &s delete_status [delete misc1 -info]
&if [exists misc2 -info] &then
 &s delete_status [delete misc2 -info]
&if [exists slopestats -info] &then
 &s delete_status [delete slopestats -info]
&if [exists tempstats -info] &then
 &s delete_status [delete tempstats -info]
&if [exists %infoname%.stats -info] &then
 &s delete_status [delete %infoname%.stats -info]
&if [exists slopegrid -grid] &then
 kill slopegrid
/*
/* FINISHED
/*
&type 8
&messages &on
&return &inform FINISHED!
```

APPENDIX 3. DEFINITIONS OF PARAMETERS USED IN THE PRECIPITATION-RUNOFF MODELING SYSTEM (PRMS)

Parameter	Description
AJMX	Adjustment proportion of rain in a rain-snow mix event, for months I = 1, 12
ARSA	Minimum snowfall, in water equivalent, needed to reset snow albedo during the the snowpack accumulation stage
ARSM	Minimum snowfall, in water equivalent, needed to reset snow albedo during the the snowpack melt stage
BST	Temperature below which precipitation is snow and above which it is rain (degrees Fahrenheit or Celsius)
CECN	Convection-condensation energy coefficient for months I = 1, 12 (cal / ^{o}C above zero)
COVDNS	Summer cover density for major vegetation for each hydrologic-response unit (decimal percent)
COVDNW	Winter cover density for major vegetation for each hydrologic-response unit (decimal percent)
CTS	Monthly evapotranspiration coefficients
CTW	Coefficient for computing snowpack sublimation from PET
DENI	Initial density of new-fallen snow (decimal fraction)
DENMX	Average maximum density of snowpack (decimal fraction)
DRCOR	Daily precipitation correction factor for rain for each hydrologic-response unit
DRN	Drainage factor for redistribution of saturated moisture storage as a fraction of KSAT—storm mode
DTM	Routing interval for overland flow or channel segment—storm mode (minutes)
EAIR	Emissivity of air on days without precipitation
ELVC	Elevation of hydrologic-response unit (feet above MSL)
EVV	Evaporation pan coefficient for months 1-12
FLGTH	Length of overland flow plane or channel segment feet—storm mode
FRN	Roughness parameter for overland flow plane or channel segment—storm mode
FWCAP	Free water holding capacity of snowpack (decimal fraction of snowpack water equivalent)
GSNK	Coefficient to compute seepage from each ground-water reservoir to a ground-water sink
GW	Storage in each ground-water reservoir (acre - inches)
HRU	Hydrologic-response unit
ICOV	Vegetation cover type for each hydrologic-response unit (0=bare, 1=grasses, 2=shrubs, 3=trees
IMPERV	Percent impervious area for each hydrologic-response unit (decimal percent)
IPET	Potential evapotranspiration method switch (0=Jensen-Haise, 1= Hamon, 2=use pan data)
IRU	Index for specific hydrologic response unit
ISOIL	Soil type for each hydrologic-response unit (1=sand, 2=loam, 3=clay)
ISSR1	Surface runoff method switch (0=linear, 1=nonlinear)

Parameter	Description
ISUN	Storm subsurface and ground-water routing switch (0=not done, 1=subsurface and ground-water included in storm mode computation)
ITND	Month that transpiration ends for each hydrologic-response unit
ITST	Month to begin checking for start of transpiration for each hydrologic-response unit
ITSW	Transpiration switch for each hydrologic-response unit (0=vegetation dormant, 1=vegetation transpiring)
KDC	Index of snow covered area depletion curve for HRU
KDS	Index of rain gage associated with each hydrologic-response unit
KGW	Index of ground-water reservoir receiving seepage from each hydrologic-response unit
KRES	Index of subsurface reservoir receiving seepage from each hydrologic-response unit
KRSP	Index of ground-water reservoir receiving seepage from each subsurface reservoir
KSAT	Hydraulic conductivity of transmission zone—storm mode
KTS	Index of temperature gage associated with each HRU
LBC	I.D. of overland flow plane providing lateral inflow to channel segment—storm mode
NCRSEG	Number of channel routing segments—storm mode
NDS	Number of rain gage data sets
NDX	Number of intervals to subdivide overland flow planes
NGW	Number of ground-water storage reservoirs
NIRU	Hydrologic-response unit associated with overland flow plane—storm mode
NOFSEG	Number of overland flow planes—storm mode
NRES	Number of subsurface storage reservoirs
NRU	Number of hydrologic response units
NS	Number of hydrograph segments in storm period—storm mode
NSP	Number of storm periods—storm mode
PARM1	Kinematic parameter alpha for plane or channel type = 4; or width of channel for channel type = 1 or 3—storm mode
PARS	Correction factor for computed solar radiation on summer day with precipitation (decimal fraction)
PARW	Correction factor for computed solar radiation on winter day with precipitation (decimal fraction)
PAT	Maximum air temperature, which when exceeded forces precipitation to be rain regardless of minimum air temperature, for months I = 1, 12
PCRID	Identification characters for overland flow planes, channel and reservoir segments and junctions—storm mode
PERV	Percent of pervious area on each hydrologic-response unit (decimal)
PSP	Combined effect of moisture deficit and capillary potential (inches)—storm mode
RBA	Index of overland flow segment to be used as input to channel segment—storm mode

Parameter	Description
RBC	Identification of overland flow plane providing lateral inflow to channel segment—storm mode
RCB	routing coefficient for each ground-water reservoir
RCF	Linear routing coefficient for each subsurface reservoir
RCP	Nonlinear routing coefficient for each subsurface reservoir
RDB	Coefficient used in sky cover - solar radiation relation
RDC	Y - intercept for relation between temperature (X) and 1) degree day (Y) or 2) sky cover (Y) when MRDC = 1 or 2
RDM	Slope for relation between temperature (X) and 1) degree day (Y) or 2) sky cover (Y) when MRDC = 1 or 2
RDMX	Maximum percent of potential solar radiation (decimal fraction)
RDP	Coefficient used in sky cover—solar radiation relation
RECHR	Storage in upper part of soil profile where losses occur as evaporation and transpiration (inches)
REMX	Maximum value of RECHR for each hydrologic-response unit (inches)
RES	Storage in each subsurface reservoir (acre - inches)
RESMX	Coefficient for routing water from each subsurface reservoir to ground-water reservoir
RETIP	Maximum retention storage on impervious area for each hydrologic-response unit (inches)
REXP	Coefficient for routing water from each subsurface reservoir to ground-water reservoir
RGF	Ratio of combined effects of moisture deficit and capillary potential at wetting front from wilting point to field capacity—storm mode
RMXA	Proportion of rain in rain / snow event above which snow albedo is not reset for snowpack accumulation stage
RMXM	Proportion of rain in rain / snow event above which snow albedo is not reset for snowpack melt stage
RNSTS	Interception storage capacity of unit area of vegetation for rain during summer period, for each hydrologic-response unit (inches)
RNSTW	Interception storage capacity of unit area of vegetation for rain (inches) during winter period, for each hydrologic-response unit
RSEP	Seepage rate from each subsurface reservoir to ground-water reservoir (inches per day)
RSTOR	Retention storage on impervious area for each hydrologic-response unit
RTB	Y - intercept of temperature range (TMAX(HRU) - TSOLX(MO)) - estimated solar radiation adjusted factor (PA) relation
RTC	Slope of temperature range (TMAX(HRU) - TSOLX(MO)) - estimated solar radiation adjusted factor (PA) relation
SCN	Minimum contributing area for surface runoff when ISSR1=0; coefficient in contributing area—soil moisture index relation when ISSR1=1

Parameter	Description
SCX	Maximum possible contributing area for surface runoff as proportion of each hydrologic-response unit
SC1	Coefficient in surface runoff contributing area—soil moisture index relation
SETCON	Snowpack settlement time constant
SEP	Seepage rate from soil moisture excess to each ground-water reservoir (inches per day)
SMAV	Daily available water in soil profile for each hydrologic-response unit (inches)
SMAX	Maximum available water holding capacity of soil profile for each hydrologic-response unit (inches)
SNST	Interception storage capacity of unit area of vegetation for snow, for each HRU (inches, water equivalent)
SRX	Maximum daily snowmelt infiltration capacity of soil profile at field capacity for each HRU (inches)
THRES	Minimum depth of flow for continuation of routing (feet)—storm mode
TLN	Lapse rate for minimum daily air temperature for months I = 1, 12
TLX	Lapse rate for maximum daily air temperature for months I = 1, 12
TNAJ	Adjustment for minimum air temperature for slope and aspect for each HRU (Degrees Celsius or Fahrenheit)
TRNCF	Transmission coefficient for shortwave radiation through vegetation canopy for each HRU
TSOLX	Maximum daily air temperature below which solar radiation adjustment factor (PA) equals RTB, for months I = 1, 12
TST	Accumulated daily maximum temperature value for month ITST at which transpiration begins for each HRU
TXAJ	Adjustment for maximum air temperature for slope and aspect for each HRU (Degrees Celsius or Fahrenheit)
TYPE	Type of overland flow plane or channel routing segment—storm mode
UPCOR	Storm precipitation correction factor for each hydrologic-response unit
UP1	Upstream inflow segment for channel routing segment—storm mode
UP2	Upstream inflow segment for channel routing segment—storm mode
UP3	Upstream inflow segment for channel routing segment—storm mode

APPENDIX 4. MEASUREMENTS USED TO DEFINE GAINS AND LOSSES IN THE MAIN-STEM WILLAMETTE RIVER, SANTIAM RIVER, MCKENZIE RIVER, AND PUDDING RIVER, OREGON

WILLAMETTE RIVER SEEPAGE MEASUREMENTS (RM 195.0-55.0), August 17–28, 1992

LOCATION LAT	LOCATION LONG	RIVER MILE	MEASURED DISCHARGE	ROUTED DISCHARGE	DIFFER-ENCE	GAIN-LOSS	REMARKS
440001	1225427	195.0	2380.0	2384.0			Jasper stream-gaging station (14152000)
			0.0				Irrigation pumping (2.2 mi)
			0.0				Wallace Creek
440046	1225612	192.8	2120.0	2385.0	-265	-265	
			-32.7				Mill Race diversion
			0.7				Pudding Creek
			17.1				Mill Race return
			142.0				Coast Fork Willamette R. at mouth
			0.0				Irrigation pumping (5.8 mi)
440128	1230130	187.0	2300.0	2429.1	-129	136	Southern Blvd., Springfield
			13.4				Mill Race return
			-71.2				Alton Baker Park intake
			-1.5				UO Physical Plant
			-1.0				EWEB Power Plant
			65.0				Alton Baker Park return flow
			-6.7				Eugene Sand & Gravel
			-1.0				Sand & Gravel
			35.0				Eugene/Springfield STP
			-6.1				Whitney Island Channel
			1220.0				McKenzie River (EWEB diverting 300 cfs)
			-1.0				Irrigation pumping (12mi)
440643	1230239	175.0	3490.0	3614.0	-124	5	Below confluence with McKenzie River
			6.5				Return flow around Whitney Island
			1.0				Old McKenzie River channel
			14.1				Spring Creek
			-1.5				Irrigation pumping (5.4 mi)
441102	1230836	169.6	3810.0	3634.1	176	300	At Lanes Turn Road
			0.1				Marshall Slough
			1.9				Curtis Slough
			-1.0				Morse Bros. Gravel operations
			-9.5				Irrigation pumping (8.6 mi)

APPENDIX 4. MEASUREMENTS USED TO DEFINE GAINS AND LOSSES IN THE MAIN-STEM WILLAMETTE RIVER, SANTIAM RIVER, MCKENZIE RIVER, AND PUDDING RIVER, OREGON—CONTINUED

WILLAMETTE RIVER SEEPAGE MEASUREMENTS (RM 195.0-55.0)—August, 17-28, 1992—Continued

LOCATION LAT	LOCATION LONG	RIVER MILE	MEASURED DISCHARGE	ROUTED DISCHARGE	DIFFER-ENCE	GAIN-LOSS	REMARKS
441614	1231021	161.0	3770.0	3626.6	143	-33	Harrisburg stream gage (14166000)
			0.3				Harrisburg STP
			0.8				Slough
			0.8				Flat Creek
			-1.8				Irrigation pumping (11.2 mi)
442217	1231341	149.8	3640.0	3798.7	-159	-302	At Bundy Road
			-31.8				Long Tom diversion
			58.0				Long Tom return
			-3.0				James River Plant
			0.6				Unnamed slough
			-2.6				Albany Channel diversion
			-5.4				Irrigation pumping (8.1 mi)
442729	1231240	141.7	3580.0	3613.5	-33	125	At Peoria
			0.0				Clark Slough inflow
			-10.6				Middle Channel outflow
			2.4				Booneville Channel inflow
			-1.2				Irrigation pumping (7.3 mi)
443156	1231457	134.4	3700.0	3658.1	42	75	Above Willamette Park - Corvallis
			-12.7				Corvallis WTP
			24.8				East Channel
			-2.0				Evanrite
			6.5				Marys River
			11.3				Dixon Creek (Corvallis STP)
			0.2				Adair STP
			-5.0				Irrigation pumping (14.3 mi)
443825	1230718	120.1	4206.0	4058.2	148	106	At Highway 20 - Albany
			49.1				Calapooia River
			-0.7				Irrigation pumping (0.2 mi)
443825	1230718	119.3	4220.0	4106.4	114	-34	Albany stream-gaging station (14174000)
			0.1				Periwinkle Creek
			6.8				Albany STP
			-6.0				Willamette Ind., Telledyne Wah Chang
			4.3				Fourth Lake outlet
			-11.0				Irrigation pumping (10.9 mi)

APPENDIX 4. MEASUREMENTS USED TO DEFINE GAINS AND LOSSES IN THE MAIN-STEM WILLAMETTE RIVER, SANTIAM RIVER, MCKENZIE RIVER, AND PUDDING RIVER, OREGON—CONTINUED

WILLAMETTE RIVER SEEPAGE MEASUREMENTS (RM 195.0-55.0), August 17-28, 1992—Continued

LOCATION LAT	LOCATION LONG	RIVER MILE	MEASURED DISCHARGE	ROUTED DISCHARGE	DIFFER-ENCE	GAIN-LOSS	REMARKS
444453	1230823	108.4	4009.0	3922.8	86	-27	Above Santiam River confluence
			1504.0				Santiam River
			14.5				Luckiamute River
			11.8				Rock Creek
			10.0				Sydney Ditch inflow
			1.5				Independence/Monmouth STP
			-7.8				Irrigation pumping (14.2 mi)
443146	1230948	94.2	5524.0	5487.8	36	-50	Near Walker Road
			0.0				Ash Creek
			0.1				Rickreall Creek
			89.0				Mill Race (from Santiam River)
			-17.7				Irrigation pumping (10.2 mi)
445640	1230230	84.0	5680.0	5566.2	114	78	Salem stream-gaging station (14191000)
			49.3				Mill Creek
			41.0				Salem STP
			-0.5				Irrigation pumping (12.3 mi)
450526	1230239	71.7	5547.0	5643.0	-96	-210	At Wheatland Ferry
			-6.2				Irrigation pumping (10.4 mi)
451114	1230102	61.3	5547.0	5640.8	-94	2	At St. Paul
			-3.8				Irrigation pumping (6.3 mi)
451342	1225944	55.0	5358.0	5656.0	-298	-204	Above Yamhill River confluence

MCKENZIE RIVER SEEPAGE MEASUREMENTS (RM 47.0-7.0), August 17-28, 1992

LOCATION LAT	LOCATION LONG	RIVER MILE	MEASURED DISCHARGE	ROUTED DISCHARGE	DIFFER-ENCE	GAIN-LOSS	REMARKS
440730	1222810	47.0	1684.0	1684.0			Vida stream-gaging station (14162500)
			20.0				Gate Creek at Vida
			-300.0				EWEB filling reservoirs
			25.0				Mohawk River
			-86.0				Haden Bridge WTP
			-6.0				Diversions thru Springfield to Willamette
			-1.0				Lateral (Mill Slough)
440643	1230239	7.0	1220.0	1336.0	-116	-116	Below Armitage Park

SANTIAM RIVER SEEPAGE MEASUREMENTS (RM 28.5-0.0), September 1–3, 1992

NORTH SANTIAM RIVER

LOCATION LAT	LOCATION LONG	RIVER MILE	MEASURED DISCHARGE	ROUTED DISCHARGE	DIFFER-ENCE	GAIN-LOSS	REMARKS
444730	1224740	28.5	541.0	541.0			At Stayton bridge
			-154.0				Main Canal diversion
			13.5				Diversion inflow
444535	1225114	23.5	353.0	414.5	-61.5	-61.5	Above Bear Branch
			0.1				Bear Branch
			-40.0				Sydney Ditch diversion
444228	1225817	14.5	324.0	374.6	-50.6	10.9	At Greens Bridge
444113	1230018	11.7	332.0	374.6	-42.6	8.0	At mouth of North Santiam

SOUTH SANTIAM RIVER

LOCATION LAT	LOCATION LONG	RIVER MILE	MEASURED DISCHARGE	ROUTED DISCHARGE	DIFFER-ENCE	GAIN-LOSS	REMARKS
443802	1235523	7.7	1124.0	1124.0			At Sanderson Bridge
			12.4				Crabtree Creek
444032	1225742	3.3	1005.0	1131.4	-126.4	-126.4	Above Thomas Creek
			1.3				Thomas Creek
		0.0					At mouth of South Santiam

MAIN STEM SANTIAM RIVER

LOCATION LAT	LOCATION LONG	RIVER MILE	MEASURED DISCHARGE	ROUTED DISCHARGE	DIFFER-ENCE	GAIN-LOSS	REMARKS
444255	1230040	9.6	1480.0	1520.0	-40	129.0	Jefferson stream-gaging station (14189000)
444415	1230307	6.0	1382.0	1520.0	-138	-98.0	At I-5 Bridge
			1.8				Morgan Creek
444508	1230754	0.0	1504.0	1570.0	-66	72.0	At mouth of Santiam River

APPENDIX 4. MEASUREMENTS USED TO DEFINE GAINS AND LOSSES IN THE MAIN-STEM WILLAMETTE RIVER, SANTIAM RIVER, MCKENZIE RIVER, AND PUDDING RIVER, OREGON—CONTINUED

WILLAMETTE RIVER SEEPAGE MEASUREMENTS (NEWBERG POOL)(RM 55.0-28.0),November 10–12, 1992

LOCATION LAT	LOCATION LONG	RIVER MILE	MEASURED DISCHARGE	ROUTED DISCHARGE	DIFFER-ENCE	GAIN-LOSS	REMARKS
445640	1230230	84.0	14000	13000	1000		At Salem (14191000)
451348	1225944	55.0	15357	13935	1422	422	Above Yamhill River
		54.9	280				Yamhill River measurement
451615	1225817	51.5	15930	14215	1715	293	At Ash Island
451640	1225720	49.5	15980	14215	1765	50	Below Newberg Bridge
451542	1225421	46.5	15949	14215	1734	-31	At Champoeg Park
451547	1225038	43.0	15858	14215	1643	-91	At Butteville
451715	1224748	40.0	15820	14215	1605	-38	Upstream of I-5 Bridge
451803	1224428	37.0	15909	14215	1694	89	Above Molalla River
		35.7	578				Molalla River measurement
451800	1224130	34.5	16450	14793	1657	-37	Above Canby Ferry
451800	1223940	31.5	16386	14793	1593	-64	At New Era
		28.4	220				Tualatin River measurement
452227	1223825	28.0	16348	15013	1335	-258	At West Linn above falls

PUDDING RIVER SEEPAGE MEASUREMENTS (RM 49.2-8.0), March 2–3, 1993

LOCATION LAT	LOCATION LONG	RIVER MILE	MEASURED DISCHARGE	ROUTED DISCHARGE	DIFFER-ENCE	GAIN-LOSS	REMARKS
		49.5		108.0			
			138.0				Silver Creek in Silverton
			3.2				Brush Creek
			180.0				Abiqua Creek
450215	1225003	45.4	429.0	429.2	-0.2	-0.2	At Nusom Road bridge
			3.0				Two unnamed tributaries
			92.9				Little Pudding River off Rambler Dr.
			22.7				Zolner Creek on McKee Road
			3.0				Woodburn STP
			186.0				Butte Creek at Morriis Bridge
			3.0				Unnammed tributary
			188.0				Rock Creek on Meridian Road
451400	1224456	8.2	943.0	927.8	15.2	15.4	Aurora stream-gaging station (14202000)
			84.0				Mill Creek in Aurora
			2420.0				Molalla River in Canby

APPENDIX 4. MEASUREMENTS USED TO DEFINE GAINS AND LOSSES IN THE MAIN-STEM WILLAMETTE RIVER, SANTIAM RIVER, MCKENZIE RIVER, AND PUDDING RIVER, OREGON—CONTINUED

WILLAMETTE RIVER SEEPAGE MEASUREMENTS (RM 195.0-84.0),June 21–30, 1993

LOCATION LAT	LOCATION LONG	RIVER MILE	MEASURED DISCHARGE	ROUTED DISCHARGE	DIFFER-ENCE	GAIN-LOSS	REMARKS
440001	1225427	195.0	2416.0	2416.0	0.0		Jasper stream-gaging station (14152000)
			0.0				Irrigation pumping (2.2 mi)
			2.1				Wallace Creek
			-32.1				Mill Race diversion
			3.0				Pudding Creek
			19.6				Mill Race return
			715.0				Coast Fork Willamette R. at mouth
			0.0				Irrigation pumping (5.8 mi)
440128	1230130	187.0	2792.0	3124.0	-322	-332	Southern Blvd., Springfield
			32.6				Mill Race return
			-38.8				Alton Baker Park intake
			-1.5				UO Physical Plant
			-1.0				EWEB Power Plant
			47.0				Alton Baker Park return flow
			-6.7				Eugene Sand & Gravel
			-1.0				Sand & Gravel
			35.0				Eugene/Springfield STP
440610	1230608	177.5	2893.0	2956.0	-63	269	Above Confluence with McKenzie
			-6.1				Whitney Island Channel
			3909.0				McKenzie River
			0.0				Irrigation pumping (12 mi)
			6.5				Return flow around Whitney Island
			5.9				Old McKenzie River channel
			40.8				Spring Creek
			0.0				Irrigation pumping (5.4 mi)
441105	1230835	169.0	7168.0	6903.0	265	328	At Lanes Turn Road
			1.0				Marshall Slough
441233	1230932	166.5	6169.0	6904.0	-735	-1000	El Reo Lane
			28.9				Curtis Slough
			-1.0				Morse Bros. Gravel operations
			0.0				Irrigation pumping (8.6 mi)
441614	1231021	161.0	7087.0	6864.0	223	958	Harrisburg stream-gaging station (14166000)

APPENDIX 4. MEASUREMENTS USED TO DEFINE GAINS AND LOSSES IN THE MAIN-STEM WILLAMETTE RIVER, SANTIAM RIVER, MCKENZIE RIVER, AND PUDDING RIVER, OREGON—CONTINUED

WILLAMETTE RIVER SEEPAGE MEASUREMENTS (RM 195.0-84.0), June 21-30, 1993—Continued

LOCATION LAT	LOCATION LONG	RIVER MILE	MEASURED DISCHARGE	ROUTED DISCHARGE	DIFFER-ENCE	GAIN-LOSS	REMARKS
			0.3				Harrisburg STP
			2.5				Slough
			35.3				Flat Creek
			0.0				Irrigation pumping (11.2mi)
441951	1231345	155.0	6390.0	6892.0	-502	-725	McCartney Park
442217	1231341	149.8	7018.0	6912.0	106	608	At Bundy Road
			112.0				Long Tom diversion
			276.0				Long Tom return
			-3.0				James River Plant
442504	1231306	145.0	7215.0	7297.0	-82	-188	Below James River Plant
			8.2				Lake Creek
			-2.6				Albany Channel diversion
			0.0				Irrigation pumping (8.1 mi)
442729	1231240	141.7	6919.0	6700.0	219	301	At Peoria
			0.0				Clark Slough inflow
			-39.5				Middle Channel outflow
			74.0				Booneville Channel inflow
			0.0				Irrigation pumping (7.3 mi)
443156	1231457	134.4	6967.0	6734.0	232	13	Above Willamette Park - Corvallis
			-12.7				Corvallis WTP
			82.0				East Channel/Muddy Creek
			-2.0				Evanrite
			196.0				Marys River
			11.3				Dixon Creek (Corvallis STP)
443506	1231129	127.5	7254.0	6567.0	687	674	Near Half Moon Bend
			0.2				Adair STP
			6.1				Kiger Cutoff
			0.0				Little Willamette River
			0.0				Irrigation pumping (14.3 mi)
			302.0				Calapooia River
			0.0				Irrigation pumping (0.2 mi)
443825	1230718	119.3	7846.0	6915.0	931	244	Albany stream-gaging station (14174000)

APPENDIX 4. MEASUREMENTS USED TO DEFINE GAINS AND LOSSES IN THE MAIN-STEM WILLAMETTE RIVER, SANTIAM RIVER, MCKENZIE RIVER, AND PUDDING RIVER, OREGON—CONTINUED

WILLAMETTE RIVER SEEPAGE MEASUREMENTS (RM 195.0-84.0), June 21-30, 1993—Continued

LOCATION		RIVER	MEASURED	ROUTED	DIFFER-	GAIN-	REMARKS
LAT	LONG	MILE	DISCHARGE	DISCHARGE	ENCE	LOSS	
			3.2				Periwinkle Creek
			2.1				Cox Creek
			6.8				Albany STP
			-6.0				Willamette Ind., Telledyne Wah Chang
440442	1230658	114.0	7788.0	6760.0	1028	97	At Spring Hill
			9.1				Fourth Lake outlet
			-1.0				Irrigation pumping (10.9 mi)
444453	1230823	108.0	7516.0	6768.0	748	-280	Above Santiam River confluence
			2863.0				Santiam River
			234.0				Luckiamute River
444912	1230617	101.0	11563.0	9865.0	1698	950	Near Judson Landing
			19.2				Rock Creek
			6.4				Sydney Ditch inflow
			1.5				Independence/Monmouth STP
			-1.0				Irrigation pumping (14.2 mi)
			5.6				Ash Creek
445500	1230633	89.0	11670.0	9745.0	1925	75	At Hayden Island
			42.3				Rickreall Creek
			134.0				Mill Race (from Santiam River)
			-3.0				Irrigation pumping (10.2 mi)
445640	1230230	84.0	11798.0	9938.0	1860	-65	Salem stream-gaging station (14191000)

APPENDIX 4. MEASUREMENTS USED TO DEFINE GAINS AND LOSSES IN THE MAIN-STEM WILLAMETTE RIVER, SANTIAM RIVER, MCKENZIE RIVER, AND PUDDING RIVER, OREGON—CONTINUED

WILLAMETTE RIVER SEEPAGE MEASUREMENTS (RM 84.0-28.0), September 21—22, 1993

LOCATION LAT	LOCATION LONG	RIVER MILE	MEASURED DISCHARGE	ROUTED DISCHARGE	DIFFER-ENCE	GAIN-LOSS	REMARKS
445640	1230230	84.0	10470.0	8970.0	1500	-60	Salem stream-gaging station (14191000)
			45.9				Mill Creek
			41.0				Salem STP
			0.0				Irrigation pumping (12.3 mi)
450015	1230752	78.5	10345.0	9002.0	1343	-157	
			-24.0				Lambert Slough diversion
450526	1230239	71.7	10380.0	8923.0	1457	114	At Wheatland Ferry
			-1.0				Irrigation pumping (10.4 mi)
450934	1230408	65.0	10160.0	8867.0	1293	-164	Above Lambert Slough return
			24.0				Lambert Slough return
451114	1230102	61.3	10510.0	8891.0	1619	326	At St. Paul
			0.0				Irrigation pumping (6.3 mi)
451342	1225944	55.0	10660.0	8841.0	1819	200	Above Yamhill River confluence
			80.0				Yamhill River
451615	1225817	51.5	11160.0	9291.0	1869	50	Ash Island
			0.0				Chehalem Creek
			0.0				Coral Creek
			0.8				Spring Brook
451542	1225421	46.5	11000.0	9217.0	1783	-86	At Champoeg Park
			3.0				Champoeg Creek
451715	1224748	39.0	11470.0	9070.0	2400	617	Wilsonville gage (14198000)
			0.0				Newland Creek
			166.0				Molalla River
			0.0				Beaver Creek
451800	1223940	31.1	11090.0	9126.0	2296	-104	at New Era
			158.0				Tualatin River
452227	1223825	28.0	11530.0	9274.0	2256	-40	at West Linn

APPENDIX 5. EXAMPLE PRECIPITATION-RUNOFF MODELING SYSTEM INPUT FILE (basin_net.g1)—CLACKAMAS RIVER, OREGON, NETWORK (REFER TO PRECIPITATION-RUNOFF MODELING SYSTEM MANUAL BY LEAVESLEY, 1983)

```
01SIM/OPT      0    1    0    0    3    0   OR         0              0
02SIM/COMP          1    1    2    1    0
03TITL       CLACKAMAS NETWORK BASINS
04INIT1        2   29   17   01    1    0    2    0    1                166843.
05INIT2     1971   10   01 1978   09   30
06MFS-MFN     10    9
07PRINT-OP     1   10   09    4  001  366    0
08PLOT         0    0   12    6   12    6      120.       0.0
09DATATYPE     4    1    0    1    1    0    0    0    0    1    0
10PARM        60      9999899998                           45
11STAT         3         1    2                             6
12STAIDC
12STAIDC
12A         1710    0  416  316    0    0    0    0
13STAIDP DESTACADA
13A           16    0
13STAIDP DOREGON CITY
13A           33    0
13STAIDT DESTACADA              416  316
13STAIDT DOREGON CITY           433  333
14RD 1              0.00   0. 45.2
14RD 2              0.10   0. 45.2
14RD 3              0.20   0. 45.2
14RD 4              0.10  45. 45.2
14RD 5              0.20  45. 45.2
14RD 6              0.10  90. 45.2
14RD 7              0.20  90. 45.2
14RD 8              0.10 135. 45.2
14RD 9              0.20 135. 45.2
14RD10              0.10 180. 45.2
14RD11              0.20 180. 45.2
14RD12              0.10 225. 45.2
14RD13              0.20 225. 45.2
14RD14              0.10 270. 45.2
14RD15              0.20 270. 45.2
14RD16              0.10 315. 45.2
14RD17              0.20 315. 45.2
15RDM       -.13 -.13 -.10 -.08 -.08 -.07 -.07 -.07 -.08 -.08 -.13 -.13
16RDC       1.83 1.83 1.60 1.46 1.46 1.42 1.42 1.42 1.46 1.46 1.83 1.83
17RAD-COR    .44  .50  .40  .61   .8  1.0  1.0
17ATSOLX       1   60   50   50   50   55   60   70   70   60   50   50   50
18CLIM-PR    .05  .20  .80  .60    0    0    0              0    0
18ACSEL          2200        200
18BPCR        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
18BPCR        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
18BPCR        1.
18CPCS        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
18CPCS        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
18CPCS        1.
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APPENDIX 5. EXAMPLE PRECIPITATION-RUNOFF MODELING SYSTEM INPUT FILE (basin_net.g1)—CLACKAMAS RIVER, OREGON, NETWORK (REFER TO PRECIPITATION-RUNOFF MODELING SYSTEM MANUAL BY LEAVESLEY, 1983)—CONTINUED

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19CTS-CTW .007 .008 .008 .009 .009 .012 .013 .013 .012 .011 .01  .006    .5
20PAT       40.  40.  40.  40.  40.  40.  40.  40.  40.  40.  40.  40.
21AJMX      1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
22TLX       5.8  9.0  8.2  9.1 11.1 12.8 12.8 14.0 14.8 16.5  9.1  5.4
23TLN       4.9  4.9  6.6  7.4  9.5 11.5 11.9 12.8 11.5  7.4  4.9  4.9
24EVC       1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
25SNO-VAR    90  120 0.95  .05   .1  .60  0.1  32.
26CEN        5.   5.   5.   5.   5.   5.   5.   5.   5.   5.   5.   5.
27PKADJ        0    0    0    0    0    0    0    0    0    0    0    0
28RES       0.5
29GW       1.13
30KRSP        1
31RESMX-EX  .75 1.39
32RSEP     .029
33GSNK     .001
34RCB      .022
35RCF-RCP    0.0001   .145
36RU1    1 16 0.08  1145.    3 0.90 0.80 0.10 0.10 0.10 0.10 1121 0.00 0.00 0.00
37RU2    1    1 8.00 1.00 1.00 1.00 2.00 0.01.0010 0.20 0.01 0.00 0.15  1  1  0
38RU3    1  1 6674.0 1.00 1.23 1.23  0.0    1    0    150.00 0.00
36RU1    2 16 0.08   560.    3 0.90 0.80 0.10 0.10 0.10 0.10 1121 0.00 0.00 0.00
37RU2    2    2 7.00 1.00 1.00 1.00 2.00 0.01.0010 0.20 0.01 0.00 0.15  1  1  0
38RU3    2  1  935.0 1.00 1.00 1.00  0.0    1    0    150.00 0.00
36RU1    3 16 0.11  1836.    3 0.90 0.80 0.10 0.10 0.10 0.10 1121 0.00 0.00 0.00
37RU2    3    110.00 1.00 1.00 1.00 2.00 0.01.0010 0.20 0.01 0.00 0.15  1  1  0
38RU3    3  128641.0 1.00 1.48 1.48  0.0    1    0    150.00 0.00
36RU1    4  3 0.32  2736.    3 0.90 0.80 0.10 0.10 0.10 0.10 1121 0.00 0.00 0.00
37RU2    4    110.00 1.00 1.00 1.00 2.00 0.01.0010 0.20 0.01 0.00 0.15  1  1  0
38RU3    4  1 6983.0 1.00 1.65 1.65  0.0    1    0    150.00 0.00
36RU1    5  7 0.29  2880.    3 0.90 0.80 0.10 0.10 0.10 0.10 1121 0.00 0.00 0.00
37RU2    5    110.00 1.00 1.00 1.00 2.00 0.01.0010 0.20 0.01 0.00 0.15  1  1  0
38RU3    5  1 4872.0 1.00 1.63 1.63  0.0    1    0    150.00 0.00
36RU1    6 15 0.34  3538.    3 0.90 0.80 0.10 0.10 0.10 0.10 1121 0.00 0.00 0.00
37RU2    6    110.00 1.00 1.00 1.00 2.00 0.01.0010 0.20 0.01 0.00 0.15  1  1  0
38RU3    6  1 2126.0 1.00 1.56 1.56  0.0    1    0    150.00 0.00
36RU1    7  1 0.04   929.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2    7    1 8.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
38RU3    7  1 3445.0 1.00 1.05 1.05  0.0    1    0    150.00 0.00
36RU1    8  1 0.03   434.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2    8    2 7.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
38RU3    8  1 3628.0 1.00 0.94 0.94  0.0    1    0    150.00 0.00
36RU1    9  1 0.02   457.    1 0.50 0.40 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2    9    1 8.00 1.00 1.00 1.00 2.00 0.20.0010 0.20 0.25 0.10 0.15  1  1  0
38RU3    9  1  358.0 1.00 0.93 0.93  0.0    1    0    150.00 0.00
36RU1   10  1 0.05  1041.    3 0.90 0.80 0.10 0.10 0.10 0.10 1121 0.00 0.00 0.00
37RU2   10    1 8.00 1.00 1.00 1.00 2.00 0.01.0010 0.20 0.01 0.00 0.15  1  1  0
38RU3   10  1 5279.0 1.00 1.14 1.14  0.0    1    0    150.00 0.00
36RU1   11  1 0.03   900.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   11    1 8.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
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38RU3   11  1 9425.0 1.00 1.14 1.14  0.0    1    0    150.00 0.00
36RU1   12  1 0.03   615.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   12     2 7.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
38RU3   12  214157.0 1.00 1.27 1.27  0.0    2    0    150.00 0.00
36RU1   13 16 0.06   453.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   13     2 7.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
38RU3   13  2 2677.0 1.00 1.17 1.17  0.0    2    0    150.00 0.00
36RU1   14  1 0.04   337.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   14     1 8.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
38RU3   14  1 8309.0 1.00 0.93 0.93  0.0    1    0    150.00 0.00
36RU1   15 16 0.05   422.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   15     2 7.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
38RU3   15  1 2370.0 1.00 0.92 0.92  0.0    1    0    150.00 0.00
36RU1   16  1 0.04   455.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   16     2 7.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
38RU3   16  1 2517.0 1.00 1.00 1.00  0.0    1    0    150.00 0.00
36RU1   17 16 0.06  1055.    3 0.90 0.80 0.10 0.10 0.10 0.10 1121 0.00 0.00 0.00
37RU2   17     1 8.00 1.00 1.00 1.00 2.00 0.01.0010 0.20 0.01 0.00 0.15  1  1  0
38RU3   17  1 6776.0 1.00 1.04 1.04  0.0    1    0    150.00 0.00
36RU1   18 16 0.07   808.    3 0.90 0.80 0.10 0.10 0.10 0.10 1121 0.00 0.00 0.00
37RU2   18     2 7.00 1.00 1.00 1.00 2.00 0.01.0010 0.20 0.01 0.00 0.15  1  1  0
38RU3   18  2 7173.0 1.00 1.08 1.08  0.0    2    0    150.00 0.00
36RU1   19 17 0.15  2020.    3 0.90 0.80 0.10 0.10 0.10 0.10 1121 0.00 0.00 0.00
37RU2   19     110.00 1.00 1.00 1.00 2.00 0.01.0010 0.20 0.01 0.00 0.15  1  1  0
38RU3   19  112811.0 1.00 1.20 1.20  0.0    1    0    150.00 0.00
36RU1   20  1 0.03   952.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   20     1 8.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
38RU3   20  1 2304.0 1.00 0.96 0.96  0.0    1    0    150.00 0.00
36RU1   21  1 0.04   550.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   21     2 7.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
38RU3   21  217258.0 1.00 1.00 1.00  0.0    2    0    150.00 0.00
36RU1   22  1 0.04   242.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   22     1 8.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
38RU3   22  2 2374.0 1.00 1.00 1.00  0.0    2    0    150.00 0.00
36RU1   23  1 0.04   485.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   23     2 7.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
38RU3   23  2 2994.0 1.00 1.08 1.08  0.0    2    0    150.00 0.00
36RU1   24 16 0.06   515.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   24     2 7.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
38RU3   24  2 6016.0 1.00 1.05 1.05  0.0    2    0    150.00 0.00
36RU1   25  1 0.02   210.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   25     1 8.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
38RU3   25  2 2327.0 1.00 0.91 0.91  0.0    2    0    150.00 0.00
36RU1   26 16 0.08   415.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   26     2 7.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
38RU3   26  2 1051.0 1.00 0.95 0.95  0.0    2    0    150.00 0.00
36RU1   27  1 0.04   301.    1 0.40 0.30 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   27     2 7.00 1.00 1.00 1.00 2.00 0.10.0010 0.20 0.05 0.05 0.15  1  1  0
38RU3   27  2 1997.0 1.00 0.95 0.95  0.0    2    0    150.00 0.00
```

APPENDIX 5. EXAMPLE PRECIPITATION-RUNOFF MODELING SYSTEM INPUT FILE (basin_net.g1)—CLACKAMAS RIVER, OREGON, NETWORK (REFER TO PRECIPITATION-RUNOFF MODELING SYSTEM MANUAL BY LEAVESLEY, 1983)—CONTINUED

```
36RU1   28  1 0.00   197.    1 0.50 0.40 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   28    1 8.00 1.00 1.00 1.00 2.00 0.20.0010 0.20 0.25 0.10 0.15  1  1  0
38RU3   28  2  661.0 1.00 0.85 0.85  0.0    2    0    150.00 0.00
36RU1   29  1 0.00   199.    1 0.50 0.40 0.10 0.05 0.05 0.05 3111 0.00 0.00 0.00
37RU2   29    2 7.00 1.00 1.00 1.00 2.00 0.20.0010 0.20 0.25 0.10 0.15  1  1  0
38RU3   29  2  705.0 1.00 0.86 0.86  0.0    2    0    150.00 0.00
41          0.0  .05   .1  .18  .25   .3  .45   .8   .9  .95  1.0
DSNDV      1120 1002 1003 1004 1005 1006 1007 1008
SBSNS         6
DSNSB      1102    9    1    2    3    4    5    6    7    8    9
DSNSB      1104    4   10   11   12   13
DSNSB      1106    3   14   15   16
DSNSB      1108    5   17   18   19   20   21
DSNSB      1110    3   22   23   24
DSNSB      1112    5   25   26   27   28   29
```

APPENDIX 6. DIFFUSION ANALOGY FLOW MODEL INPUT FILES (FLOW.IN) FOR 11 NETWORK APPLICATIONS

Clackamas River Network (RM 23.1 to 4.8)

```
No. of Branches              1 *       7         2
/will_models/basins/wdmfile/will.wdm
Internal Junctions           0 *
Time Steps Modeled        2557   1971 10 01 00 00 00
Model Starts                 0 time steps after midnight.
Output Given Every           1 Time Steps in FLOW.OUT.
0=Metric,1=English           1 *
Time Step Size           24.00 Hours.
Peak Discharge          62000. *
Branch  1 has  9 xsects & routes 1.00 of flow at JNCT  1 To JNCT  2
Grd R Mile  IOUT  Disch        A1        A2        AO        DF         W1    W2
  1  0.000     0  2360.      3.60     0.640     320.0    0.290E+05   26.0 0.250
  2  6.400     0  2360.      4.30     0.660       0.0    0.326E+05   38.0 0.240
  3  11.00     0  2360.      4.30     0.660       0.0    0.326E+05   38.0 0.240
  4  11.10     0  2360.      6.20     0.660       0.0    0.307E+05   41.0 0.230
  5  15.10     0  2360.      6.20     0.660       0.0    0.307E+05   41.0 0.230
  6  16.70     0  2360.      5.90     0.640       0.0    0.740E+05   45.0 0.220
  7  18.30     0  2360.      5.90     0.640       0.0    0.512E+05   45.0 0.220
  8  23.10     0  2360.      4.70     0.640     180.0    0.122E+06   49.0 0.200
  9  24.00     0
Branch    001Grid 001DSN 1710
Branch    001Grid 002DSN 1102
Branch    001Grid 003DSN 1104
Branch    001Grid 004DSN 1106
Branch    001Grid 005DSN 1108
Branch    001Grid 006DSN 1110
Branch    001Grid 007DSN 1112
Branch    001Grid 002DSN 1150
Branch    001Grid 009DSN 1120
```

Johnson Creek Network (RM 10.2 to 0.7)

```
No. of Branches              1 *       4         2
/will_models/basins/wdmfile/will.wdm
Internal Junctions           0 *
Time Steps Modeled        1219 * 1989 05 01 00 00 00
Model Starts                 0 * time steps after midnight.
Output Given Every           1 * Time Steps in FLOW.OUT.
0=Metric,1=English           1 * English units
Time Step Size          24.000 Hours.
Peak Discharge           1000. *
Branch  1 has 11 xsects & routes 1.00 of flow at JNCT  1 To JNCT  2
Grd R Mile  IOUT  Disch        A1        A2        AO        DF         W1    W2
  1 0.0000E+00 0  2.300      4.10     0.600       6.0    0.432E+05   15.7 0.200
  2  1.000     1  2.300      4.00     0.600       4.0    0.190E+05   18.2 0.260
  3  2.600     0  2.300      3.00     0.620      28.0    0.472E+05   16.2 0.180
  4  3.200     0  2.300      3.00     0.620      13.0    0.233E+05   15.0 0.180
  5  4.000     0  2.300      2.20     0.620       4.0    0.141E+05   17.6 0.260
```

Johnson Creek Network (RM 10.2 to 0.7)—Continued

```
  6  4.700     0  2.300      2.20     0.620        9.0    0.589E+04   13.1 0.200
  7  7.300     0  2.300      3.00     0.640       17.0    0.503E+04    9.4 0.180
  8  8.900     0  2.300      1.90     0.640       26.0    0.486E+04   13.8 0.210
  9  9.500     0  2.300      1.90     0.640       12.0    0.681E+04   12.1 0.210
 10  10.20     0  2.300      1.90     0.640       12.0    0.681E+04   12.1 0.210
 11  11.00     1
Branch    001Grid 001DSN15730
Branch    001Grid 006DSN15002
Branch    001Grid 008DSN15741
Branch    001Grid 009DSN15004
Branch    001Grid 002DSN15006
Branch    001Grid 011DSN15050
```

McKenzie River Network (RM 47.7 to 0.0)

```
No. of Branches              7 *      13         3
/will_models/basins/wdmfile/will.wdm
Internal Junctions           4 *
Time Steps Modeled        2557 * 1971 10 01 00 00 00
Model Starts                 0 time steps after midnight.
Output Given Every           1 Time Steps in FLOW.OUT.
0=Metric,1=English           1 *
Time Step Size           24.00 Hours.
Peak Discharge          20000. *
Branch  1 has  8 xsects & routes 1.00 of flow at JNCT  1 To JNCT  2
Grd R Mile  IOUT  Disch        A1        A2        AO        DF          W1    W2
  1 0.0000     1 1000.0      3.32     0.640     285.0     0.196E+05  240.0 0.02
  2 0.8000     0 1000.0      3.32     0.640     285.0     0.414E+05  240.0 0.02
  3  3.400     0 1000.0      3.32     0.640     285.0     0.464E+05  240.0 0.02
  4  4.800     0 1000.0      3.32     0.640     285.0     0.517E+05  240.0 0.02
  5  6.300     0 1000.0      3.32     0.640     285.0     0.548E+05  240.0 0.02
  6  6.800     0 1000.0      2.80     0.640    1900.0     0.182E+06  160.0 0.06
  7  8.000     0 1000.0      2.80     0.640    1900.0     0.562E+06  200.0 0.06
  8  8.900     1
Branch  2 has  6 xsects & routes 0.60 of flow at JNCT  2 To JNCT  3
Grd R Mile  IOUT  Disch        A1        A2        AO        DF          W1    W2
  1  8.900     1  600.0      5.38     0.640       0.0     0.270E+04  220.0 0.06
  2  9.000     0  600.0      5.38     0.640       0.0     0.312E+05  240.0 0.06
  3 11.100     0  600.0      5.38     0.640       0.0     0.509E+05  240.0 0.06
  4 13.000     0  600.0      5.38     0.640       0.0     0.546E+05  240.0 0.06
  5 14.400     0  600.0      5.38     0.640       0.0     0.556E+05  240.0 0.06
  6 14.500     1
Branch  3 has  5 xsects & routes 1.00 of flow at JNCT  3 To JNCT  4
Grd R Mile  IOUT  Disch        A1        A2        AO        DF          W1    W2
  1 14.500     1 1000.0      5.38     0.640       0.0     0.477E+05  280.0 0.06
  2 15.700     0 1000.0      3.90     0.650     285.0     0.442E+05  240.0 0.08
  3 17.000     0 1000.0      3.90     0.650     285.0     0.530E+05  240.0 0.08
  4 17.600     0 1000.0      3.90     0.650     285.0     0.311E+05  270.0 0.09
  5 19.200     1
```

McKenzie River Network (RM 47.7 to 0.0)—Continued

```
Branch  4 has  4 xsects & routes 0.60 of flow at JNCT  4 To JNCT  5
Grd R Mile  IOUT  Disch         A1         A2         AO         DF        W1    W2
  1 19.200     1  600.0       5.38      0.640        0.0     0.247E+05  300.0 0.10
  2 21.100     0  600.0       5.38      0.640        0.0     0.267E+05  300.0 0.10
  3 26.900     0  600.0       3.90      0.660      285.0     0.277E+05   35.0 0.29
  4 27.000     1
Branch  5 has 16 xsects & routes 1.00 of flow at JNCT  5 To JNCT  6
Grd R Mile  IOUT  Disch         A1         A2         AO         DF        W1    W2
  1 27.000     1 1000.0       3.90      0.660      285.0     0.251E+05   35.0 0.29
  2 29.900     0 1000.0       3.90      0.660      285.0     0.256E+05   35.0 0.29
  3 31.100     0 1000.0       3.90      0.660      285.0     0.295E+05   35.0 0.29
  4 32.700     0 1000.0       3.90      0.660      285.0     0.300E+05   35.0 0.29
  5 34.000     0 1000.0       3.90      0.660      285.0     0.408E+05   35.0 0.29
  6 37.600     0 1000.0       3.90      0.660      285.0     0.398E+05   35.0 0.29
  7 40.200     0 1000.0       3.90      0.660      285.0     0.408E+05   35.0 0.29
  8 40.600     0 1000.0       4.54      0.660      200.0     0.431E+05   35.0 0.29
  9 41.300     0 1000.0       4.54      0.660      200.0     0.310E+05   35.0 0.29
 10 41.800     0 1000.0       4.54      0.660      200.0     0.351E+05   35.0 0.29
 11 43.500     0 1000.0       4.54      0.660      200.0     0.372E+05   35.0 0.29
 12 44.100     0 1000.0       4.54      0.660      200.0     0.413E+05   35.0 0.29
 13 44.900     0 1000.0       4.54      0.660      200.0     0.434E+05   35.0 0.29
 14 46.700     0 1000.0       4.54      0.660      200.0     0.522E+05   35.0 0.29
 15 47.700     0 1000.0       4.54      0.660      200.0     0.522E+05   35.0 0.29
 16 49.000     1
Branch  6 has  5 xsects & routes 0.40 of flow at JNCT  2 To JNCT  3
Grd R Mile  IOUT  Disch         A1         A2         AO         DF        W1    W2
  1 0.0000     1  400.0       5.00      0.660        0.0     0.168E+05   70.0 0.02
  2  2.000     0  400.0       5.00      0.660      180.0     0.273E+05   70.0 0.02
  3  3.700     0  400.0       5.00      0.660      180.0     0.374E+05   70.0 0.02
  4  4.900     0  400.0       1.00      0.660      180.0     0.162E+03   35.0 0.02
  5  5.000     1
Branch  7 has  4 xsects & routes 0.40 of flow at JNCT  4 To JNCT  5
Grd R Mile  IOUT  Disch         A1         A2         AO         DF        W1    W2
  1 0.0000     1  400.0       5.00      0.660      180.0     0.289E+04   70.0 0.10
  2  3.600     0  400.0       1.00      0.660        0.0     0.162E+03   25.0 0.02
  3  3.700     0  400.0       5.00      0.660      180.0     0.289E+04  100.0 0.06
  4  6.300     1
Branch    001Grid 001DSN 2710
Branch    001Grid 003DSN 2002
Branch    001Grid 005DSN 2004
Branch    002Grid 002DSN 2006
Branch    003Grid 002DSN 2010
Branch    004Grid 002DSN 2012
Branch    005Grid 002DSN 2016
Branch    005Grid 003DSN 2018
Branch    005Grid 005DSN   69
Branch    005Grid 007DSN 2020
Branch    005Grid 011DSN 2022
Branch    006Grid 002DSN 2008
Branch    007Grid 002DSN 2014
Branch    001Grid 002DSN 2024
Branch    001Grid 005DSN 2026
Branch    005Grid 016DSN 2050
```

Molalla River Network (RM 32.5 to 0.0)

```
No. of Branches              5 *      20         4
/will_models/basins/wdmfile/will.wdm
Internal Junctions           3 *
Time Steps Modeled        2557 * 1971 10 01 00 00 00
Model Starts                 0 time steps after midnight.
Output Given Every           1 Time Steps in FLOW.OUT.
0=Metric,1=English           1 *
Time Step Size          24.000 Hours.
Peak Discharge          11000. *
Branch  1 has  9 xsects & routes 1.00 of flow at JNCT  1 To JNCT  2
Grd R Mile  IOUT  Disch        A1        A2        AO        DF        W1    W2
  1 0.0000     0  228.0      3.00     0.660      60.0    0.445E+04   55.0 0.120
  2 0.2000     0  228.0      3.00     0.660      60.0    0.793E+04   55.0 0.120
  3  5.100     0  228.0      3.00     0.660      60.0    0.100E+05   55.0 0.120
  4  5.700     0  228.0      3.00     0.660      60.0    0.975E+04   55.0 0.120
  5  7.000     0  228.0      3.00     0.660       60.    0.179E+05   55.0 0.120
  6  8.200     0  228.0      2.52     0.660       20.    0.507E+05   80.0 0.100
  7  9.900     0  228.0      2.90     0.660        0.    0.279E+05   33.0 0.140
  8  13.40     0  228.0      3.40     0.660       40.    0.765E+04   41.0 0.180
  9  13.60     0
Branch  2 has  6 xsects & routes 1.00 of flow at JNCT  2 To JNCT  3
Grd R Mile  IOUT  Disch        A1        A2        AO        DF        W1    W2
  1  13.60     0  228.0      3.40     0.660       40.    0.245E+05   41.0 0.180
  2  17.80     0  228.0      3.40     0.660       40.    0.410E+05   41.0 0.180
  3  24.20     0  228.0      3.40     0.660       40.    0.320E+05   41.0 0.180
  4  26.20     0  228.0      4.00     0.640      120.    0.656E+05   45.0 0.180
  5  27.20     0  228.0      4.00     0.640      120.    0.883E+05   45.0 0.180
  6  31.4      0
Branch  3 has  4 xsects & routes 1.00 of flow at JNCT  3 To JNCT  4
Grd R Mile  IOUT  Disch        A1        A2        AO        DF        W1    W2
  1  31.40     0  228.0      4.00     0.640      120.    0.154E+05   45.0 0.180
  2  31.50     0  228.0      4.00     0.640      120.    0.154E+05   45.0 0.180
  3  32.20     0  228.0      4.00     0.640      120.    0.154E+05   45.0 0.180
  4  33.00     0
Branch  4 has 10 xsects & routes 1.00 of flow at JNCT  5 To JNCT  6
Grd R Mile  IOUT  Disch        A1        A2        AO        DF        W1    W2
  1 00.000     0  185.0      2.40     0.660       0.0    0.129E+06   20.0 0.180
  2 03.500     0  185.0      2.40     0.660       0.0    0.160E+06   18.0 0.200
  3 07.200     0  185.0      2.30     0.660     100.0    0.192E+06   16.0 0.220
  4 07.300     0  185.0      2.00     0.660     200.0    0.296E+06   12.0 0.260
  5 12.400     0  185.0      1.70     0.660     300.0    0.296E+06   12.0 0.260
  6 15.900     0  185.0      1.90     0.660     250.0    0.161E+06   12.0 0.260
  7 16.000     0  185.0      2.10     0.660     200.0    0.161E+06   12.0 0.260
  8 23.700     0  185.0      3.50     0.660     200.0    0.263E+06   18.0 0.240
  9 23.800     0  185.0      3.50     0.660     200.0    0.263E+06   18.0 0.240
 10 32.600     0
Branch  5 has  8 xsects & routes 1.00 of flow at JNCT  6 To JNCT  3
Grd R Mile  IOUT  Disch        A1        A2        A0        DF        W1    W2
  1 32.600     0  185.0      3.80     0.660     200.0    0.238E+06   24.0 0.200
  2 32.700     0  185.0      3.80     0.660     200.0    0.238E+06   24.0 0.200
```

Molalla River Network (RM 32.5 to 0.0)—Continued

```
  3 37.300     0  185.0      3.80     0.660     200.0     0.841E+06   30.0 0.160
  4 37.400     0  185.0      3.70     0.660     300.0     0.841E+06   30.0 0.160
  5 44.700     0  185.0      3.60     0.660     400.0     0.497E+06   37.0 0.120
  6 45.600     0  185.0      3.60     0.660     400.0     0.203E+06   42.0 0.110
  7 52.800     0  185.0      3.60     0.660     400.0     0.203E+06   42.0 0.110
  8 53.400     0
Branch    001Grid 001DSN   86
Branch    001Grid 003DSN 8102
Branch    001Grid 004DSN 8104
Branch    001Grid 007DSN 8106
Branch    002Grid 002DSN 8108
Branch    002Grid 003DSN 8110
Branch    002Grid 005DSN 8112
Branch    003Grid 002DSN 8114
Branch    004Grid 001DSN   87
Branch    004Grid 002DSN 8116
Branch    004Grid 003DSN 8118
Branch    004Grid 004DSN 8120
Branch    004Grid 006DSN 8122
Branch    004Grid 007DSN 8124
Branch    004Grid 008DSN 8126
Branch    004Grid 009DSN 8128
Branch    005Grid 002DSN   88
Branch    005Grid 003DSN 8132
Branch    005Grid 004DSN 8134
Branch    005Grid 006DSN 8136
Branch    002Grid 004DSN 8210
Branch    003Grid 004DSN 8200
Branch    004Grid 002DSN 8212
Branch    005Grid 002DSN 8130
```

Santiam River Network (RM 38.7 (north), RM 23.3 (south) to 0.0)

```
No. of Branches              3 *      13         1
/will_models/basins/wdmfile/will.wdm
Internal Junctions           1 *
Time Steps Modeled        2557 * 1971 10 01 00 00 00
Model Starts                 0 time steps after midnight.
Output Given Every        1096 Time Steps in FLOW.OUT.
0=Metric,1=English           1 *
Time Step Size          24.000 Hours.
Peak Discharge          30000. *
Branch  1 has 10 xsects & routes 1.00 of flow at JNCT  1 To JNCT  2
Grd R Mile  IOUT  Disch         A1        A2        AO        DF          W1    W2
  1 18.600     0 2850.0      3.00     0.660       0.0     0.189E+05   23.3 0.260
  2 20.900     0 2850.0      3.00     0.660       0.0     0.223E+05   23.3 0.260
  3 25.900     0 2850.0      3.00     0.660       0.0     0.220E+05   23.3 0.260
  4 26.700     0 2850.0      3.00     0.660       0.0     0.981E+04   23.3 0.260
  5 27.500     0 2850.0      3.00     0.660       0.0     0.859E+05   23.3 0.260
```

Santiam River Network (RM 38.7 (north), RM 23.3 (south) to 0.0)—Continued

```
  6 28.900     0 2850.0      3.00     0.660       0.0     0.272E+05   23.3 0.260
  7 34.400     0 2850.0      3.00     0.660       0.0     0.413E+05   23.3 0.260
  8 42.600     0 2850.0      3.00     0.660       0.0     0.413E+05   23.3 0.260
  9 45.400     0 2850.0      3.00     0.660       0.0     0.285E+05   23.3 0.260
 10 45.600     0
Branch  2 has 10 xsects & routes 1.00 of flow at JNCT  4 To JNCT  2
Grd R Mile  IOUT  Disch        A1        A2        AO        DF         W1    W2
  1 0.0000     0 2870.0      4.15     0.640     370.0     0.306E+05  150.0 0.100
  2  2.100     0 2870.0      4.15     0.640     370.0     0.229E+05  150.0 0.100
  3  2.500     0 2870.0      4.15     0.640     370.0     0.322E+05  150.0 0.100
  4  5.300     0 2870.0      3.00     0.640     570.0     0.164E+05   41.6 0.275
  5  8.100     0 2870.0      3.00     0.640     570.0     0.263E+05   41.6 0.275
  6 10.200     0 2870.0      3.00     0.640     570.0     0.197E+05   41.6 0.275
  7 19.000     0 2870.0      3.00     0.640     570.0     0.310E+05   41.6 0.275
  8 20.300     0 2870.0      3.96     0.640     270.0     0.390E+05   41.6 0.275
  9 20.700     0 2870.0      3.96     0.640     270.0     0.421E+05   41.6 0.275
 10 23.300     0
Branch  3 has  4 xsects & routes 1.00 of flow at JNCT  2 To JNCT  3
Grd R Mile  IOUT  Disch        A1        A2        AO        DF         W1    W2
  1 45.600     0 2850.0      2.80     0.660    1200.0     0.994E+05   49.0 0.260
  2 47.700     0 2850.0      2.80     0.660    1200.0     0.812E+05   49.0 0.260
  3 55.200     0 2850.0      2.80     0.660    1200.0     0.829E+05   49.0 0.260
  4 57.300     0
Branch    001Grid 001DSN 3720
Branch    001Grid 003DSN 3725
Branch    001Grid 004DSN 3110
Branch    001Grid 005DSN 3730
Branch    002Grid 001DSN 4720
Branch    002Grid 002DSN 4011
Branch    002Grid 003DSN 4725
Branch    002Grid 004DSN 4730
Branch    002Grid 005DSN 4015
Branch    002Grid 006DSN 4020
Branch    002Grid 007DSN 4025
Branch    002Grid 008DSN 4030
Branch    003Grid 003DSN 3115
Branch    003Grid 004DSN 3200
```

Tualatin River Network (RM 58.8 to 1.8)

```
No. of Branches              2 *      15          4
/will_models/basins/wdmfile/will.wdm
Internal Junctions           1 *
Time steps modeled        2557 * 1971 10 01 00 00 00
Model starts                 0 time steps after midnight
Output given every           1 time steps in FLOW.OUT
English units                1 *
Time step size             24. hours
Peak Discharge           1000.
```

Tualatin River Network (RM 58.8 to 1.8)—Continued

```
Branch  1 has 11 xsecs & routes  1.00 of flow at JNCT  1 to JNCT 2
Grd R Mile  IOUT  Discharge        A1        A2        A0               W1    W2
  1    5.1     0        170.      3.00     0.660     120.0     1085.  20.00 0.260
  2    7.3     0        180.      3.20     0.660     320.0     2019.  23.00 0.260
  3    8.6     0        175.      3.40     0.660     520.0     2901.  23.00 0.260
  4   12.4     0        165.      3.40     0.660     720.0     2511.  24.00 0.260
  5   16.4     0        160.      3.60     0.660     920.0     2876.  25.00 0.260
  6   19.1     0        180.      3.80     0.660    1120.0     5292.  27.00 0.260
  7   21.1     0        170.      3.80     0.660    1120.0     8583.  27.00 0.260
  8   25.8     0        160.      3.80     0.660    1120.0    16601.  27.50 0.260
  9   25.9     0        160.      3.80     0.660    1120.0    16601.  27.50 0.260
 10   28.2     0        155.      3.80     0.660    1120.0    22811.  27.50 0.260
 11   30.6     0
Branch  2 has 12 xsecs & routes  1.00 of flow at JNCT  2 to JNCT 3
Grd R Mile  IOUT  Discharge        A1        A2        A0               W1    W2
  1   30.6     0        937.      3.80     0.660    1120.0    27128.  27.7  0.26
  2   32.9     0        937.      3.80     0.660    1120.0    29591.  31.5  0.26
  3   33.0     0        937.      3.80     0.660    1600.0    67899.  35.3  0.26
  4   35.7     0        937.      2.00     1.000    1600.0  1830000.  39.1  0.26
  5   48.5     0        937.      2.00     1.000    2440.0  1830000.  42.9  0.26
  6   48.6     0        937.      2.00     1.000    2440.0  1830000.  42.9  0.26
  7   54.3     0        937.      2.20     1.000    2440.0  1200000.  46.8  0.26
  8   57.2     0        937.      2.20     1.000    1800.0   900000.  50.0  0.13
  9   57.3     0        937.      2.20     1.000    1800.0   900000.  50.0  0.13
 10   60.5     0        937.      4.00     0.660     340.0      291.  64.0  0.13
 11   62.1     0        937.      3.70     0.660     340.0      189.  64.0  0.13
 12   63.9
Branch    001Grid 001DSN13702
Branch    001Grid 003DSN   90
Branch    001Grid 004DSN13004
Branch    001Grid 006DSN13006
Branch    001Grid 008DSN13008
Branch    001Grid 009DSN13010
Branch    001Grid 010DSN13012
Branch    002Grid 002DSN13014
Branch    002Grid 003DSN13016
Branch    002Grid 004DSN13018
Branch    002Grid 005DSN13020
Branch    002Grid 006DSN13022
Branch    002Grid 007DSN13024
Branch    002Grid 008DSN13715
Branch    002Grid 009DSN13026
Branch    001Grid 003DSN13054
Branch    002Grid 001DSN13056
Branch    001Grid 002DSN13052
Branch    002Grid 012DSN13050
```

APPENDIX 6. DIFFUSION ANALOGY FLOW MODEL INPUT FILES (FLOW.IN) FOR 11 NETWORK APPLICATIONS—CONTINUED

Yamhill River Network (RM 27.9 to 0.0)

```
No. of Branches               1 *       6         2
/will_models/basins/wdmfile/will.wdm
Internal Junctions            1 *
Time Steps Modeled         2557 * 1971 10 01 00 00 00
Model Starts                  0 time steps after midnight.
Output Given Every         1096 Time Steps in FLOW.OUT.
0=Metric,1=English            1 *
Time Step Size           24.000 Hours.
Peak Discharge           11000. *
Branch  1 has 10 xsects & routes 1.00 of flow at JNCT  1 To JNCT  2
Grd R Mile  IOUT  Disch        A1        A2        AO        DF         W1    W2
  1 28.900     0  119.0      9.50     0.660       0.0     0.192E+06   40.0 0.180
  2 34.300     0  119.0     14.00     0.660       0.0     0.276E+06   40.0 0.180
  3 40.000     0  119.0      8.20     0.660       0.0     0.271E+06   31.0 0.260
  4 45.600     0  119.0      8.20     0.660       0.0     0.168E+06   31.0 0.260
  5 47.900     0  119.0      9.20     0.660       0.0     0.130E+06   31.5 0.260
  6 48.900     0  119.0     10.20     0.660       0.0     0.243E+06   32.0 0.260
  7 51.900     0  119.0     10.20     0.660       0.0     0.815E+06   32.0 0.260
  8 52.000     0  119.0     10.20     0.660       0.0     0.815E+06   32.0 0.260
  9 56.800     0  119.0     11.80     0.660       0.0     0.815E+06   37.1 0.260
 10 57.000     0
Branch    001Grid 001DSN10710
Branch    001Grid 003DSN10002
Branch    001Grid 004DSN10004
Branch    001Grid 005DSN10006
Branch    001Grid 007DSN10008
Branch    001Grid 008DSN10010
Branch    001Grid 002DSN10020
Branch    001Grid 009DSN10050
```

Willamette River Network (Albany to Salem RM 119.3 to 84.1)

```
No. of Branches               3 *      11         2
/will_models/basins/wdmfile/will.wdm
Internal Junctions            1 *
Time Steps Modeled         2557 * 1971 10 01 00 00 00
Model Starts                  0 time steps after midnight.
Output Given Every            1 Time Steps in FLOW.OUT.
0=Metric,1=English            1 *
Time Step Size           24.000 Hours.
Peak Discharge           19000. *
Branch  1 has  5 xsects & routes 1.00 of flow at JNCT  1 To JNCT  2
Grd R Mile  IOUT  Disch        A1        A2        AO        DF         W1    W2
  1 81.900     0 4730.0      5.40     0.690     200.0     0.146E+06   14.3 0.416
  2 83.300     0 4730.0      5.40     0.690     200.0     0.141E+06    5.1 0.502
  3 85.700     0 4730.0      5.40     0.690     200.0     0.115E+06   10.0 0.445
  4 85.800     0 4730.0      5.40     0.690     200.0     0.115E+06   10.0 0.445
  5 92.200     0
```

Willamette River Network (Albany to Salem RM 119.3 to 84.1)—Continued

```
Branch  2 has 10 xsects & routes 1.00 of flow at JNCT  2 To JNCT  3
Grd R Mile  IOUT  Disch        A1        A2        AO        DF        W1    W2
  1 92.200     0 4730.0      5.86     0.690       0.0    0.175E+06    8.3 0.437
  2 93.200     0 4730.0      5.86     0.690       0.0    0.142E+06   17.9 0.376
  3 93.700     0 4730.0      5.86     0.690       0.0    0.167E+06   33.4 0.326
  4 99.900     0 4730.0      5.86     0.690       0.0    0.183E+06   33.4 0.326
  5 105.90     0 4730.0      5.86     0.690       0.0    0.211E+06   33.4 0.326
  6 113.10     0 4730.0      5.86     0.690       0.0    0.375E+06   25.0 0.349
  7 113.20     0 4730.0      5.86     0.690       0.0    0.375E+06   25.0 0.349
  8 115.20     0 4730.0      5.86     0.690       0.0    0.396E+06   33.7 0.325
  9 117.10     0 4730.0      5.86     0.690       0.0    0.234E+06   88.8 0.248
 10 117.60     1
Branch  3 has  4 xsects & routes 1.00 of flow at JNCT  4 To JNCT  2
Grd R Mile  IOUT  Disch        A1        A2        AO        DF        W1    W2
  1 47.700     0 2850.0      2.80     0.660    1200.0    0.812E+05   49.0 0.260
  2 55.200     1 2850.0      2.80     0.660    1200.0    0.829E+05   49.0 0.260
  3 57.300     0 2850.0      2.80     0.660    1200.0    0.829E+05   49.0 0.260
  4 58.000     0
Branch    001Grid 001DSN  710
Branch    001Grid 002DSN20100
Branch    001Grid 003DSN20102
Branch    001Grid 004DSN20104
Branch    003Grid 001DSN 3710
Branch    003Grid 002DSN 3102
Branch    002Grid 003DSN20106
Branch    002Grid 004DSN20108
Branch    002Grid 005DSN20110
Branch    002Grid 006DSN20112
Branch    002Grid 007DSN20114
Branch    003Grid 002DSN20202
Branch    002Grid 010DSN20200
```

Willamette River Network (Harrisburg to Albany RM 161.0 to 119.3)

```
No. of Branches              3 *      10         2
/will_models/basins/wdmfile/will.wdm
Internal Junctions           1 *
Time Steps Modeled        2557 * 1971 10 01 00 00 00
Model Starts                 0 time steps after midnight.
Output Given Every           1 Time Steps in FLOW.OUT.
0=Metric,1=English           1 *
Time Step Size           24.00 Hours.
Peak Discharge          10000. *
Branch  1 has  8 xsects & routes 1.00 of flow at JNCT  1 To JNCT  2
Grd R Mile  IOUT  Disch        A1        A2        AO        DF        W1    W2
  1 40.000     0 3730.0      5.20     0.660     830.0    0.790E+05    7.5 0.455
  2 40.600     0 3730.0      5.33     0.660     200.0    0.473E+05   18.2 0.380
  3 43.400     0 3730.0      5.33     0.660     200.0    0.516E+05    4.3 0.501
  4 44.600     0 3730.0      5.33     0.660     200.0    0.744E+05    7.5 0.455
  5 47.100     0 3730.0      5.33     0.660     200.0    0.764E+05    7.0 0.463
```

Willamette River Network (Harrisburg to Albany RM 161.0 to 119.3)—Continued

```
  6 52.200     0 3730.0      5.33     0.660     200.0     0.746E+05    4.1 0.507
  7 53.800     0 3730.0      5.33     0.660     200.0     0.843E+05    7.1 0.460
  8 55.300     0
Branch  2 has 15 xsects & routes 1.00 of flow at JNCT  2 To JNCT  3
Grd R Mile  IOUT  Disch        A1        A2        AO        DF          W1    W2
  1 55.300     0 3760.0      5.38     0.680       0.0     0.651E+05    3.1 0.539
  2 56.700     0 3760.0      5.38     0.680       0.0     0.533E+05    5.3 0.493
  3 57.700     0 3760.0      5.38     0.680       0.0     0.792E+05   13.1 0.417
  4 61.000     0 3760.0      5.33     0.660     200.0     0.680E+05    3.1 0.539
  5 65.100     0 3760.0      5.33     0.660     200.0     0.574E+05    8.5 0.453
  6 67.200     0 3760.0      5.33     0.660     200.0     0.562E+05    3.1 0.539
  7 68.600     0 3760.0      5.38     0.680       0.0     0.905E+05   17.8 0.392
  8 69.100     0 3760.0      5.38     0.680       0.0     0.101E+06    6.6 0.482
  9 70.400     0 3760.0      5.38     0.680       0.0     0.170E+06    6.6 0.482
 10 74.000     0 3760.0      5.38     0.680       0.0     0.294E+06    4.1 0.522
 11 76.900     0 3760.0      5.38     0.680       0.0     0.140E+06    2.3 0.569
 12 78.500     0 3760.0      5.40     0.690     200.0     0.102E+06    4.1 0.522
 13 79.600     0 3760.0      5.40     0.690     200.0     0.897E+05    6.5 0.482
 14 81.700     0 3760.0      5.40     0.690     200.0     0.837E+05   10.0 0.445
 15 81.900     1
Branch  3 has  6 xsects & routes 1.00 of flow at JNCT  4 To JNCT  2
Grd R Mile  IOUT  Disch        A1        A2        A0        DF         W1   W2
  1  18.70     0   88.0      2.00     0.660     600.0     0.679E+05   22.0 0.22
  2  19.20     1   88.0      2.50     0.660     500.0     0.442E+05   20.0 0.24
  3  19.70     0   88.0      3.00     0.660     400.0     0.357E+05   18.0 0.26
  4  21.90     0   88.0      3.80     0.660     300.0     0.274E+05   20.0 0.26
  5  22.50     0   88.0      3.80     0.660     300.0     0.274E+05   20.0 0.26
  6  25.50     0
Branch    001Grid 001DSN18710
Branch    001Grid 005DSN20116
Branch    002Grid 003DSN20118
Branch    002Grid 005DSN20120
Branch    002Grid 007DSN20122
Branch    002Grid 008DSN20124
Branch    002Grid 011DSN20126
Branch    002Grid 014DSN20128
Branch    003Grid 001DSN 6710
Branch    003Grid 002DSN 6002
Branch    003Grid 002DSN20204
Branch    002Grid 015DSN20400
```

Willamette River (Jasper to Harrisburg-RM 195.0 to 161.0)

```
No. of Branches              4 *       8         1
/will_models/basins/wdmfile/will.wdm
Internal Junctions           2 *
Time Steps Modeled        2557 * 1971 10 01 00 00 00
Model Starts                 0 time steps after midnight.
Output Given Every            1 Time Steps in FLOW.OUT.
0=Metric,1=English           1 *
Time Step Size          24.000 Hours.
Peak Discharge          90000. *
```

Willamette River (Jasper to Harrisburg-RM 195.0 to 161.0)—Continued

```
Branch  1 has 6 xsects & routes 1.00 of flow at JNCT  1 To JNCT  2
Grd R Mile  IOUT  Disch        A1        A2        AO         DF         W1    W2
  1  6.200     0 4730.0      5.22     0.640       0.0     0.632E+04    8.6 0.430
  2  6.400     0 4730.0      5.22     0.640       0.0     0.124E+05   10.3 0.413
  3  9.800     0 4730.0      5.22     0.640       0.0     0.101E+05    2.3 0.561
  4 11.800     0 4730.0      5.22     0.640       0.0     0.137E+05    1.0 0.642
  5 12.500     0 4730.0      5.22     0.640       0.0     0.176E+05   29.8 0.309
  6 14.200     0
Branch  2 has 4 xsects & routes 1.00 of flow at JNCT  2 to JNCT  3
Grd R Mile  IOUT  Disch        A1        A2        A0         DF         W1    W2
  1 14.200     0 4730.0      5.22     0.640       0.0     0.213E+05   26.7 0.338
  2 17.000     0 4730.0      5.28     0.660       0.0     0.250E+05   42.3 0.295
  3 23.400     0 4730.0      5.28     0.660       0.0     0.251E+05   62.1 0.260
  4 26.400     0
Branch  3 has  5 xsects & routes 1.00 of flow at JNCT  3 To JNCT  4
Grd R Mile  IOUT  Disch        A1        A2        AO         DF         W1    W2
  1 26.400     0 5630.0      5.20     0.660     830.0     0.338E+05   21.5 0.380
  2 26.500     0 5630.0      5.20     0.660     830.0     0.338E+05   21.5 0.380
  3 29.400     0 4730.0      5.20     0.660     830.0     0.547E+05   26.5 0.348
  4 36.200     0 4730.0      5.20     0.660     830.0     0.529E+05    7.5 0.455
  5 40.000     0
Branch  4 has  3 xsects & routes 1.00 of flow at JNCT  5 To JNCT  2
Grd R Mile  IOUT  Disch        A1        A2        AO         DF         W1    W2
  1  23.00     0  900.0      5.00     0.620      150.     0.560E+05   21.0 0.244
  2  25.10     0  900.0      5.00     0.620      150.     0.480E+05   21.0 0.244
  3  29.40     0
Branch    001Grid 001DSN11710
Branch    001Grid 004DSN11002
Branch    002Grid 003DSN11003
Branch    003Grid 002DSN 2050
Branch    003Grid 003DSN11004
Branch    003Grid 004DSN11006
Branch    004Grid 001DSN12710
Branch    004Grid 002DSN12002
Branch    003Grid 005DSN20800
```

Willamette River (Salem to Willamette Falls: RM 84.1 to 26.6)

```
No. of Branches              2 *      12         1
/will_models/basins/wdmfile/will.wdm
Internal Junctions           1 *
Time Steps Modeled        2557 * 1971 10 01 00 00 00
Model Starts                 0 time steps after midnight.
Output Given Every           1 Time Steps in FLOW.OUT.
0=Metric,1=English           1 *
Time Step Size          24.000 Hours.
Peak Discharge          19000. *
Branch  1 has  9 xsects & routes 1.00 of flow at JNCT  1 To JNCT  2
Grd R Mile  IOUT  Disch        A1        A2        AO         DF         W1    W2
  1 117.10     0 4730.0      5.86     0.690       0.0     0.234E+06   88.8 0.248
```

APPENDIX 6. DIFFUSION ANALOGY FLOW MODEL INPUT FILES (FLOW.IN) FOR 11 NETWORK APPLICATIONS—CONTINUED

Willamette River (Salem to Willamette Falls: RM 84.1 to 26.6)—Continued

```
  2 117.60     0 4730.0      5.86     0.690      0.0     0.176E+06   56.3 0.284
  3 117.70     0 4730.0      5.86     0.690      0.0     0.176E+06   56.3 0.284
  4 121.60     0 4730.0      5.86     0.690      0.0     0.345E+06   89.3 0.247
  5 127.70     0 4730.0      5.86     0.690      0.0     0.170E+06   44.1 0.303
  6 130.30     0 4730.0      5.86     0.690      0.0     0.174E+06   33.5 0.325
  7 136.30     0 4730.0      5.86     0.690      0.0     0.221E+06   18.1 0.374
  8 141.20     0 4730.0      5.86     0.690      0.0     0.242E+06   25.0 0.348
  9 146.30     0
Branch  2 has 13 xsects & routes 1.00 of flow at JNCT  2 To JNCT  3
Grd R Mile  IOUT  Disch        A1        A2        AO        DF          W1    W2
  1 146.30     0 4730.0      9.60     0.670    9100.0     0.454E+06   20.8 0.378
  2 146.40     0 4730.0      9.60     0.670    9100.0     0.454E+06   20.8 0.378
  3 148.80     0 4730.0      9.60     0.670    9100.0     0.905E+06   13.3 0.413
  4 150.40     0 4730.0      9.60     0.670    9100.0     0.136E+07   20.8 0.378
  5 153.80     0 4730.0      9.60     0.670    9100.0     0.145E+07   20.8 0.378
  6 156.10     0 4730.0      9.60     0.670    9100.0     0.160E+07   27.1 0.357
  7 161.40     0 4730.0      9.60     0.670    9100.0     0.236E+07   20.8 0.378
  8 162.70     0 4730.0      9.60     0.670    9100.0     0.295E+07   20.8 0.378
  9 163.60     0 4730.0      9.60     0.670    9100.0     0.366E+07   23.9 0.367
 10 165.50     0 4730.0      9.60     0.670    9100.0     0.412E+07  119.8 0.238
 11 172.20     0 4730.0     11.60     0.660    9300.0     0.420E+07  119.8 0.238
 12 172.80     0 4730.0     11.60     0.660    9300.0     0.652E+07  108.5 0.227
 13 174.60     0
Branch    001Grid 001DSN17710
Branch    001Grid 002DSN20130
Branch    001Grid 003DSN14702
Branch    001Grid 004DSN20134
Branch    001Grid 007DSN20136
Branch    001Grid 008DSN20138
Branch    002Grid 002DSN10050
Branch    002Grid 004DSN10012
Branch    002Grid 007DSN10014
Branch    002Grid 010DSN 8020
Branch    002Grid 011DSN10016
Branch    002Grid 012DSN13720
Branch    002Grid 008DSN20600
```

APPENDIX 7. PROGRAMMING STEPS TO INPUT NEW DATA INTO A WATER DATA MANAGEMENT (WDM) FILE

1. Skip to step 2 if you do not need to create a new WDM file.
   Execute ANNIE
   Select file
   Select build
   Key in *newname.wdm*
   Exit ANNIE

2. Input data must meet the following specifications:
   Flat file, data in single column (free format), continuous data (9999 for missing data), all data of the same time increment

3. Create a file: *fltwdm.inp*

   Example:

```
fltwdm.inp
UPDATE      willamette.wdm
ortmx               2     1997 04 1  0  0  0   TMIN4    1900 6    1    4    1     SALEM AIRPORT
MIN. TEMP (sod357500)
```

4. Execute program fltwdm

fltwdm is a program designed to transfer data from a flat file into a specific WDM file in a space corresponding to a given data set number (DSN).

The file *flwwdm.inp* contains general information for one flat file to be utilized by the program, including the WDM file name to write to, the flat file name, the DSN, the starting date, and attribute settings for the data set. Following is the format required for this input file.

The file *flwwdm.inp* contains:

Record	Field	Start Column	Variable	Format	Description
1	1	1	-	A80	file title
2	1	1	KEY	A6	'CREATE' or 'UPDATE' WDM file
2	2	13	WDNAME	A64	WDM file name
3	1	1	FLATFL	A12	flat file name
3	3	23	DSN	I6	data set number

The file *flwwdm.inp* contains:

Record	Field	Start Column	Variable	Format	Description
3	4	29	STRDAT(1)	I5	starting year (e.g. 1985)
3	5	34	STRDAT(2)	I3	starting month
3	6	37	STRDAT(3)	I3	starting day
3	7	40	STRDAT(4)	I3	starting hour
3	8	43	STRDAT(5)	I3	starting minute
3	9	46	SRTDAT(6)	I3	starting second
3	5	50	TSTYPE	A4	type of data set (e.g. 'PREC',' FLOW',etc.)
3	6	54	TCODE	I5	time units code (e.g. 2 = min, 3 = hrs, etc.)
3	7	59	TSBYR	I5	starting year for data (default=1900)
3	8	64	TGROUP	I5	group pointers (e.g. 3 = hrs, 4 = dys,etc.)
3	9	69	TSSTEP	I5	time step (in TCODE units)
3	10	74	TSFORM	I5	form of data (1=mean over the timestep)
3	11	79	VBTIME	I5	time-step option for the data set (e.g. 1 = same)
3	12	85	STANAM	A48	short name or description of the data set

5. Repeat steps 2-4 for all data sets.

APPENDIX 8. PROGRAMMING STEPS TO DEFINE PRECIPITATION-RUNOFF MODELING SYSTEM PARAMETERS

1. Move to basin or subbasin directory and find *c36.**, *c37.**, and *c38.** files

2. Identify the rain gage(s) to be used, and use the associated annual precipitation value (from PRISM map) to determine the ratio's UPCOR, DRCOR, and DSCOR. Do not use the precipitation adjustment prompted for the first time through the program. This adjustment will be used later when calibrating for water balance.

3. Execute the program **g1maker**

   This program takes user specified input and the *c36.**, *c37.**, and *c38.** files to make a **.g1* file for PRMS.

4. Use the example file in Appendix E as a template for assembling your file for use in PRMS; use the PRMS manual by Leavesley (1983).

   Each HRU has to have it's unique drainage area, precipitation and temperature station(s) and station elevations, solar radiation planes, etc. (refer to manual).

   The *.g1 file defines the HRU identified to the applicable time-series data in the WDM file. Card groups 42-45 are used to designate HRU clusters that act as subbasin input. These card groups reflect a modification to the PRMS program not covered in the manual but included with this appendix.

5. All WDM file numbers must be identified in the WDM file before PRMS is run. Execute ANNIE and select build. Identify all input and output files expected for use.

   An example PRMS file can be found in Appendix 5.

PRMS Modification:

Several minor changes have been made to input card groups 1 and 4. The major program change is the manner in which the time-series data is accessed. Time-series data is read from a WDM file. WDM files are created using ANNIE. PRMS outputs time-series data to PLTGEN files. These files are documented in Johanson and others (1981), and Lumb and others (1989)

MASTER CONTROL FILE:

RCRD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION
1				FILE CONTROL RECORD--Min of 3, Max of 7 File names may be entered in any order.
	1-3	A3	CODES	Identifier for file type, see below for required values
	11-74	A64	NAME	Name of file. May be any name that is valid on the computer system being used. May include the complete path name if necessary. The length of the file name may be restricted on some machines.

CODES	Required	Description
***	opt	Comment record
WDM	yes	WDM file containing observed data. Simulated data may be output to this file.
CG1	yes	Card group 1, parameter and variable initialization
CG2	opt	Card group 2, storm period selection
CG3	opt	Card group 3, infiltration/ upland erosion parameters
CG4	OPT	Card group 4, flow & sediment routing specifications
CG5	opt	Card group 5, precipitation form adjustment
CG6	opt	Card group 6, snowpack adjustment
CG7	opt	Card groups 7 and 8, optimizations and sensitivity
OUT	yes	Model output (print) file.
QDY	opt	output predicted daily flow (unit 20)
QUN	opt	output predicted unit flow (unit 21)
PLT	opt	output daily plots (unit42)
HRU	opt	print hru (unit 43)

Example:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

WDM       cane.wdm
CG1       test03.g1
CG2       test03.g2
CG3       test03.g3
CG4       test03.g4
OUT       test03.out

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

```
  GROUP CARD COLUMNS FORMAT VARIABLE  DEFINITION
  ----- ---- ------- ------ --------  ----------------------------------


    1     1      35     I1    IDOUT   Store predicted daily mean data
                                        0 = no storage
                                        1 = store predicted and observed
                                            daily mean streamflow values
                                            as sequential direct access
                                            data file by water year on
                                            unit 20.
                                        2 = same as 1, format is standard
                                            WATSTORE daily-values record.
                                        3 = store obsv precip and disch,
                                            computed reservoir values,
                                            predicted discharge in wdm

                 40     I1    IUOUT   Store unit values data
                                        0 = no storage
                                        1 = store predicted streamflow
                                            on unit 19 as sequential
                                            direct-access data file by
                                            storm. Format is standard
                                            WATSTORE unit-values record.
                                        2 = store in wdm file

                 70    I1    PROB     Extended Streamflow Prediction (ESP)
                                      0 - do not run
                                      1 - run ESP
```

GROUP	CARD	COLUMNS	FORMAT	VARIABLE	DEFINITION
	2	40	I1	ILPS	Lapse rates 0 - use monthly lapse rates 1 - compute daily lapse rates
	4	41-45	I5	NTS	number of temperature stations
		46-50	I5	NPLW	number of snow pillow stations
		51-55	I5	NDC	number of snow covered area depletion curves
		71-80	F10.0	DAT	Total basin drainage area, in acres
	7	30	I1	IPOP2	Individual HRU values print switch 0 = no print 1 = annual summary 2 = 1 plus monthly summary 3 = 2 + daily summary 4 = write HRUs or combinations of HRUs (subbasins) to wdm file record types SBSNS and DSNSB required.
	12a	11-50	8I5	DSNC(I)	WDM data set number for data types 1 thru 8. Card follows card 12.
	13a	11-15	I5	DSNP	WDM data set number for data type 9 for each rain gage data set.
		16-20	I5	DSNP	WDM data set number for data type 10 for each rain gage data set. There will be a set of cards 13 and 13a for each rain gage data set.
	13b	11-26	A16	STAIDT(i)	Station ID for temperature station i
		31-40	2I5	DSNT(j,i)	ANNIE WDM data-set number for maximum(j=1) and minimum(j=2) air temperature data for station i One record 13b for each temperature sta.
	13c	11-26	A16	STAIDS(i)	Station ID for snow pillow station i
		31-35	I5	DSNS(i)	ANNIE WDM data-set number for snow pillow data for station i

GROUP	CARD	COLUMNS	FORMAT	VARIABLE	DEFINITION
					One record 13b for each snow pillow station
	17	36-40	F5.2	RTB	Y-intercept of temperature range (TMAX(HRU) - TSOLX(MO)) - estimated solar radiation adjusted factor (PA) relation
		41-45	F5.2	RTC	Slope of temperature range estimated solar radiation adjustment factor (PA) relation
	17a	11-15	I5	ITSOL	HRU used to computed daily temperature range (TMAX(HRU) - TSOLX(MO)) used in computation of solar radiation adjustment factor (PA)
		16-75	12F5.0	TSOLX	Maximum daily air temperature below which solar radiation adjustment factor (PA) equals RTB, for months Jan-Dec
	18	11-15	F5.2	ARSA	Minimum snowfall, in water equivalent, needed to reset snow albedo during snowpack accumulation stage
		16-20	F5.2	ARSM	Minimum snowfall, in water equivalent, needed to reset snow albedo during the snowpack melt stage
	18a	11-60	5F10.0	CSEL(i)	elevation of climate stations, in feet i = 1, nts
	18b	11-80	14F5.2	PCR(j)	override value for DRCOR for period MPCS to MPCN, j = 1, nru
	18c	11-80	14F5.2	PCS(j)	override value for DSCOR for period MPCS to MPCN, j = 1, NRU
	38	41-45	I5	KTS	index of temperature station to use
		46-50	I5	KSP	index of snow pillow station to use
		51-55	I5	KDC	index of snow covered area depletion curve to use
		56-60	I5	AIMX	maximum threshold snowpack water equivalent (AI) below which the snowcovered area depletion curve is applied

GROUP	CARD	COLUMNS	FORMAT	VARIABLE	DEFINITION
		61-65	F5.2	PKFAC	snowpack water equivalent adjustment factor snow pillow KSP
	41	11-75	11F5.2	SCA(j,k)	Areal extent of snow cover as decimal fraction, for each 0.1 increment of the ration of areal water equivalent to the threshold water equivalent (AI) j=1,NDC, k=1,11 for 0.0 to 1.0 in increments of 0.1 one record 41 for each areal depletion curve
	42	1-5	“DSNDV”		record identifier
		11-50	8I5	DSNDV	data set numbers for daily output. required when IDOUT = 3 data written to wdm dsn for non-zero entries (1) simulated flow (2) precipitation (3) potential evaporation (4) actual evapotranspiration (5) available soil moisture (6) ground water contribution (7) subsurface contribution (8) surface contribution
	43	1-5	“SBSNS”		record identifier
		11-15	I5	NSB	number of subbasins to be written to the wdm file (max of 50)
	44	1-5	“DSNSB”		record identifier
		11-15	I5	DSNSB(n)	output data set number for this subbasin
		16-20	I5	NHRUSB(n)	number of HRUs in this subbasin (max of 50)
		21-80	12I5	KHRUSB(k,n)	index numbers of the HRUs contained in this subbasin (first 12)
	45	1-5	“DSNSB”		record identifier
		21-80	12I5	KHRUSB(k,n)	index numbers of HRU’s contained in this subbasin (12th and greater)

one record 44 (and 45 if needed) for each subbasin

GROUP	CARD	COLUMNS	FORMAT	VARIABLE	DEFINITION
4	2	35	I1	PRTIN	Print switch 0 = no 1 = print rainfall excess 2 = plot rainfall excess 3 = save in wdm file
		37	I1	PRTOUT	Print outflow switch 0 = no 1 = print outflow 2 = plot outflow 3 = save outflow in wdm file
	4	35	I1	PRTIN	Print inflow switch 0 = no 1 = print inflow to segment 2 = plot inflow to segment 3 = save inflow in wdm file
		37	I1	PRTOUT	Print outflow switch 0 = no 1 = print outflow from segment 2 = plot outflow from segment 3 = save outflow in wdf file
4	5	11-50	10I5	DSNQ	data set numbers for segment discharge entered in same order as flow planes and channels. Required if IUOUT>=2 PRTIN or PRTOUT must be =3
4	6	11-50	10I5	DSNS	data set numbers for sediment discharge entered in same order as flow planes and channels. Required if IUOUT>=2 PRTIN or PRTOUT must be =3

APPENDIX 9. PROGRAMMING STEPS TO RUN A MODEL NETWORK IN DIFFUSION ANALOGY FLOW

1. Build a *FLOW.IN* file as described in Jobson (1989) and show in examples in Appendix F.

2. Run **wdaflo**

Modifications have been made to **daflow** to accomodate WDM files.
wdaflo is the **daflow** model modified to read/write time series data to/from a WDM file.
Changes to the FLOW.IN file are as follows:

Data Set 1 - General information

Rec 2 - add field 2 - variable IBCCNT - format (2X,I8) - number of input boundary conditions from WDM file
add field 3 - variable OBCCNT - format (2X,I8) - number of output boundary conditions to WDM file

Rec 2A - new record (include only if IBCCNT+OBCCNT>0) - variable WDNAME - format (A64) - name of WDM file

Rec 4 - add fields 2-7 - variable CURDAT - format (2X,I5,5I3) - date run starts on
Data Set 3 - Boundary condition

(eliminate entirely if IBCCNT > 0)
Data Set 4 - WDM data set numbers

(repeat Rec 1 IBCCNT times)
Rec 1 - field 1 - variable IBCBRA(I) - format (10X,I3) - Branch number for input boundary condition
- field 2 - variable IBCGRD(I) - format (5X,I3) - Grid number for input boundary condition
- field 3 - variable IBCDSN(I) - format (3X,I5) - Data set number containing input boundary values
(repeat Rec 2 OBCCNT times)

Rec 2 - field 1 - variable OBCBRA(I) - format (10X,I3) - Branch number for output values
- field 2 - variable OBCGRD(I) - format (5X,I3) - Grid number for output values
- field 3 - variable OBCDSN(I) - format (3X,I5) - Data set number to write output values to

****** CONVERSION NOTE: A utility program called DAFWDM has been written, it reads a FLOW.IN file and its own input specification file DAFWDM.IN and writes the input boundary conditions from the FLOW.IN file to a WDM file.

APPENDIX 10. DIRECTORY TREE AND DESCRIPTION OF DIRECTORY CONTENTS FOR DIRECTORIES USED IN MODELING

```
Climate
        maxtemp
        mintemp
        precipitation

F77progs

Flowdata
        daily
        peak
        wdmdata

awkprogs
        awk_prog

basins
      calapooia
            up_calapooia
      cfwillamette
            mosby
            mouth_cfw
            row
            up_cfwill
      clackamas
            up_clack
      longtom
            lo_amazon
      luckiamute
            up_lucki
      marys
            marys
      mckenzie
            blue
            clear
            gate
            lookout
            mcken_b1g3
            mohawk
            sf_mckenzie
            smith
      mfwillamette
            hills
            mouth_mfw
            nf_mfwillam
            salmon
            salt
            up_fall
            up_mfwillam
            waldo_lk
            winberry

basins (cont.)
      mill
      molalla
            butte
            mill
            silver
            up_molalla
      nsantiam
            breitenbush
            little_nsan
            lo_nsantiam
            nsantiam
            santiam

      porsalem
            will_b1g3
            will_b1g6
            will_b1g7
            will_b2g10
            will_b2g3
            will_b2g7
      portland
            john_b1g6
            john_b1g9
            up_johnson
      pudding
      rickreall
            up_rick
      salem
      ssantiam
            crabtree
            hamilton
            lo_crabtree
            lo_ssantiam
            lo_thomas
            m_santiam
            one_horse
            quartzville
            up_crabtree
            up_ssantiam
            up_thomas
            wiley
      tualatin
            gales
            up_tualatin
      wdmfile
       pudd.wdm
       will.wdm
            READ.ME-dir
            fltwdm-dir
      yamhill
            lo_yamhill
            n_yamhill
            nf_yamhill
            palmer
            s_yamhill
            willamina
            yam_b1g3
            yam_b1g5

geom

networks
      johnson
      mckenzie
      molalla
      pudding
      santiam
      stats
      tualatin
      will.alb-sal
      will.har-alb
      will.jas-har
      will.sal-willfalls
      yamhill

report
      schematicdiagrams

seep

slides

stats
      sediment

text
      fact
      figures
      tables
transfer

weather

wilk

work
      molalla
      santiam
      wilson
```

APPENDIX 10. DIRECTORY TREE AND DESCRIPTION OF DIRECTORY CONTENTS FOR DIRECTORIES USED IN MODELING—CONTINUED

/will_models/Climate/climatelist.README

This directory contains data obtained from the State Climatologist and modified for use in importing to wdm files. There are three directories: maxtemp, mintemp, and precipitation.[c = complete, md = missing data, nf = not found, id = state identification number]

Station		id	period of record (water year)	record status precip	min temp	max temp
1	Aurora	350343	50-69	-	-	-
2	BeavertonSSW	350595	73-78	md	md	md
3	Bellfountain	350673	50-51	-	-	-
4	Blackbutte	350781	48-65	-	-	-
5	BonnevilleDam	350897	72-78	c	c	c
6	Cascadia	351433	72-78	md	md	md
7	Clatskanie	351643	72-78	c	md	md
8	CorvallisOSU	351862	72-78	c	c	c
9	CorvallisWater	351877	72-78	c	md	md
10	CottageGrove1S	351897	72-78	c	c	c
11	CottageGroveDam	351902	72-78	c	c	c
12	Dallas	352112	72-78	c	md	md
13	Dilley	352325	72-78	c	nf	nf
14	DorenaDam	352374	72-78	c	md	md
15	EagleCreek	352493	74-78	c	nf	nf
16	Estacada	352693	72-78	md	md	md
17	EugeneWSOAP	352709	72-78	c	c	c
18	FernRidgeDam	352867	72-78	c	c	c
19	ForestGrove	352997	72-78	c	c	c
20	FosterDam	353047	72-78	c	c	c
21	Glenwood	353318	49-51	-	-	-
22	Gresham	353521	50-51	-	-	-
23	HaskinsDam	353705	72-78	c	nf	nf
24	Headworks	353770	72-78	c	c	c
25	Hillsboro	353908	72-78	c	md	md
26	Holley	353971	72-78	c	nf	nf
27	Lacomb	354606	74-78	c	md	md
28	Leaburg1SW	354811	72-78	c	c	c
29	LookoutPointDam	355050	72-78	c	md	md
30	McMinnville	355384	72-78	md	md	md
31	N.WillametteExpStn	356151	72-78	md	md	md
32	Noti	356173	72-78	c	c	c
33	OregonCity	356334	72-78	c	md	md
34	PortlandKGW-TV	356749	74-78	md	md	md
35	PortlandWSOAP	356751	72-78	c	c	c
36	Rex	357127	72-78	c	nf	nf
37	St.Helens	357466	77-78	c	c	c
38	SalemWSOAP	357500	72-78	c	c	c
39	ScottsMills	357631	72-78	c	c	md
40	SilverCreekFalls	357809	72-78	md	md	md
41	Silverton	357823	72-78	c	c	c
42	Stayton	358095	72-78	c	c	c
43	Troutdale	358634	72-78	md	md	md
44	Waterloo	359083	72-78	c	nf	nf
45	Belknap Springs	0652	72-78	md	md	md
46	Detroit Dam	2292	72-78	c	c	c
47	Government Camp	3908	72-78	c	md	md
48	Marion Forks	5221	72-78	c	md	md
49	McKenzie Bridge	5362	72-78	md	md	md
50	Oakridge	6213	72-78	c	c	c
51	Santiam Pass	7559	72-78	c	md	md
52	Three Lynx	8466	72-78	c	md	md

```
/will_models/F77progs/README

This directory contains several FORTRAN programs used to manipulate files
for use in specific model programs.

anniestats.f
      Program to summary statistics for MHMS output, Statvar.dat is
      used as input data file.

dafinput.f
      Program used to create either BC or OBS files for DAFLOW model

flwplot.f
      Program that plots simulated and observed data from DAFLOW

g1maker.f
      Program used to make PRMS files using the c36, c37, and c38 files
      output from Jim Wilkinson's AML program.  This program outputs two
      files: one for the card 14 group and the other for the 36-38 cards.

mhmscards.f
      Program used to format three files used to describe hru's in MHMS.
      Based on the FCARDS program in PRIME.

mhmsdata1.f
      Program merges an ADAPS flat file of flow and a single OSU climate
      file into an MHMS data file.

mhmsdata2.f
      Program merges an ADAPS flat file of flow with two OSU climate
      files into an MHMS data file.

mhmsdata3.f
      Program merges an ADAPS flat file of flow with three OSU climate
      files into an MHMS data file.

mhmsheader
      Header information template

missingdata.f
      Program identifies missing values in climate files.

*****************************************************************************
*/will_models/Flowdata/README

This directory contains data obtained from the ADAPS files and has been
modified for use in importing to wdm files.  There are three directories:
daily, peak, and wdmdata.
******************************************************************************

/will_models/awkprogs

awk_prog
      Program to generate smaller time increment data from daily data
      using the BLTM.FLW file.  Any timestep can be generated starting
      from a given first day.  Needed for use with BLTM model.

waterbalheader
      Program to create header file for water balance.

waterbalscript
      Program to print out monthly data from PRINT.OUT files.
```

```
/will_models/basins/README

For each basin or subbasin there can be the following files:

14
      Solar radiation data, card group 14 for PRMS model (see PRMS manual)

36
      General HRU data (see PRMS manual)

c36.*
      Specific card group 36 data for PRMS from AML program

c37.*
      Specific card group 37 data for PRMS from AML program

c38.*
      Specific card group 38 data for PRMS from AML program

g1cardfile
      Other card information needed for PRMS

manager
      UNIX program language to set desired input/output file names

*.g1
      Complete PRMS file for * basin model

*.g7
      Dates and input files used in simulation


The wdmfile is the binary water data management file that contains all
input data and simulated data. See separate README files for directory.
/will_models/basins/wdmfile/READ.ME-dir/wdm.directory
```

Directory for will.wdm

Data set number	Sections
Observed daily data	
1 - 52	Precipitation data
53 - 100	Headwater flow data
101 - 300	Additional observed data
301 - 400	Minimum temperature data
401 - 500	Maximum temperature data
Subbasins:	
501 - 1000	Albany
1001 - 2000	Clackamas
2001 - 3000	McKenzie
3001 - 4000	North Santiam
4001 - 5000	South Santiam
5001 - 6000	Calapooia
6001 - 7000	Long Tom
7001 - 8000	Marys
8001 - 9000	Molalla
9001 - 10000	Rickreall
10001 - 11000	Yamhill
11001 - 12000	Middle Fork
12001 - 13000	Coast Fork
13001 - 14000	Tualatin
14001 - 15000	Mill
15001 - 16000	Portland
16001 - 17000	Portland-Salem
17001 - 18000	Salem-Albany
18001 - 19000	Albany-Eugene
19001 - 20000	Luckiamute

Subbasin breakdown:

< = ##700	Simulated flows
##701 - ##800	Observed flow data
##801 - ##900	Observed precipitation data
##901 - ##950	Observed minimum temperature
##951 - #1000	Observed maximum temperature

Observed precipitation:

DSN	TYPE	WY	FILENAME	LOCATION
1	PREC	50-69	no file	Aurora
2	PREC	73-78	sod350595pf	BeavertonSSW
3	PREC	50-51	no file	Bellfountain
4	PREC	48-65	no file	Blackbutte
5	PREC	72-78	sod350897pf	BonnevilleDam
6	PREC	72-78	sod351433pe	Cascadia
7	PREC	72-78	sod351643pf	Clatskanie
8	PREC	72-78	sod351862pf	CorvallisOSU
9	PREC	72-78	sod351877pf	CorvallisWater
10	PREC	72-78	sod351897pf	CottageGrove1S
11	PREC	72-78	sod351902pf	CottageGroveDam
12	PREC	72-78	sod352112pf	Dallas
13	PREC	72-78	sod352325pf	Dilley
14	PREC	72-78	sod352374pf	DorenaDam
15	PREC	74-78	sod352493pf	EagleCreek
16	PREC	72-78	sod352693pe	Estacada

Directory for will.wdm (cont.)

17	PREC	72-78	sod352709pf	EugeneWSOAP
18	PREC	72-78	sod352867pf	FernRidgeDam
19	PREC	72-78	sod352997pf	ForestGrove
20	PREC	72-78	sod353047pf	FosterDam
21	PREC	49-51	no file	Glenwood
22	PREC	50-51	no file	Gresham
23	PREC	72-78	sod353705pf	HaskinsDam
24	PREC	72-78	sod353770pf	Headworks
25	PREC	72-78	sod353908pf	Hillsboro
26	PREC	72-78	sod353971pf	Holley
27	PREC	74-78	sod354606pf	Lacomb
28	PREC	72-78	sod354811pf	Leaburg1SW
29	PREC	72-78	sod355050pf	LookoutPointDam
30	PREC	72-78	sod355384pe	McMinnville
31	PREC	72-78	sod356151pe	N.WillametteExpStn
32	PREC	72-78	sod356173pf	Noti
33	PREC	72-78	sod356334pf	OregonCity
34	PREC	74-78	sod356749pe	PortlandKGW-TV
35	PREC	72-78	sod356751pf	PortlandWSOAP
36	PREC	72-78	sod357127pf	Rex
37	PREC	77-78	no file	St.Helens
38	PREC	72-78	sod357500pf	SalemWSOAP
39	PREC	72-78	sod357631pf	ScottsMills
40	PREC	72-78	sod357809pe	SilverCreekFalls
41	PREC	72-78	sod357823pf	Silverton
42	PREC	72-78	sod358095pf	Stayton
43	PREC	72-78	sod358634pe	Troutdale
44	PREC	72-78	sod359083pf	Waterloo
45	PREC	72-78	cnv0652pe	Belknap Springs
46	PREC	72-78	cnv2292pf	Detroit Dam
47	PREC	72-78	cnv3908pf	Government Camp
48	PREC	72-78	cnv5221pf	Marion Forks
49	PREC	72-78	cnv5362pe	McKenzie Bridge
50	PREC	72-78	cnv6213pf	Oakridge
51	PREC	72-78	cnv7559pf	Santiam Pass
52	PREC	72-78	cnv8466pf	Three Lynx
15833	PREC	89-92	sod356334	Oregon City

Observed headwater flow:

53	FLOW	72-78	gs14144800	Middle Fork Willamette @Oakridge
54	FLOW	72-78	gs14144900	Hills creek @ Oakridge
55	FLOW	72-78	gs14146500	Salmon creek @ Oakridge
56	FLOW	72-78	gs14147000	Waldo Lake @ Oakridge
57	FLOW	72-78	gs14147500	Nf of mf Willamette @ Oakridge
58	FLOW	72-78	gs14150300	Fall creek @ Lowell
59	FLOW	72-78	gs14150800	Winberry creek @ Lowell
60	FLOW	72-78	gs14152500	Cf Willamette @ London
61	FLOW	72-78	gs14154500	Row river above Pitcher creek
62	FLOW	72-78	gs14156500	Mosby creek @ Cottage grove
63	FLOW	72-78	gs14158500	McKenzie @ Clear lake
64	FLOW	72-78	gs14158790	Smith river @ Belknap spring
65	FLOW	72-78	gs14159200	Sf Mckenzie @ Rainbow
66	FLOW	72-78	gs14161100	Blue river @ Blue river
67	FLOW	72-78	gs14161500	Lookout creek @ Blue river
68	FLOW	72-78	gs14163000	Gate creek at Vida
69	FLOW	72-78	gs14165000	Mohawk river @ Springfield
70	FLOW	72-75	gs14169300	Amazon creek @ Eugene
71	FLOW	72-78	gs14171000	Marys river at Philomath

APPENDIX 10. DIRECTORY TREE AND DESCRIPTION OF DIRECTORY CONTENTS FOR DIRECTORIES USED IN MODELING—CONTINUED

Directory for will.wdm (cont.)

72	FLOW	72-78	gs14172000	Calapooia at Holley
73	FLOW	72-78	gs14178000	N. Santiam @ Detroit
74	FLOW	72-78	gs14179000	Breitenbush river @ Detroit
75	FLOW	72-78	gs14182500	L. North Santiam @ Mehama
76	FLOW	72-78	gs14185000	S. Santiam river @ Cascadia
77	FLOW	72-78	gs14185800	M. Santiam river @ Cascadia
78	FLOW	72-78	gs14185900	Quartzville creek @ Cascadia
79	FLOW	72-73	gs14187000	Wiley creek @ Foster
80	FLOW	72-78	gs14188800	Thomas creek @ Scio
81	FLOW	72-78	gs14189500	Luckiamute river @ Hoskins
82	FLOW	72-78	gs14190700	Rickreall creek @ Dallas
83	FLOW	72-78	gs14192500	S. yamhill @ Willamina
84	FLOW	72-78	gs14193000	Willamina creek @ willamina
85	FLOW	72-78	gs14194300	N. yamhill river @ Fairdale
86	FLOW	72-78	gs14198500	Molalla river @ Wilhoit
87	FLOW	72-78	gs14200300	Silver creek @ Silverton
88	FLOW	72-78	gs14201500	Butte creek @ monitor
89	FLOW	73-76	gs14202500	Tualatin @ Gaston
90	FLOW	72-78	gs14204500	Gales creek @ Forest Grove
91	FLOW	65-70	gs14208000	Clackamas @ Big Bottom
92	FLOW	72-78	gs14211500	Johnson creek @ Sycamore

Observed minimum temperature:

DSN	TYPE	WY	FILENAME	LOCATION
301	TMIN	50-69	no file	Aurora
302	TMIN	73-78	sod350595nf	BeavertonSSW
303	TMIN	50-51	no file	Bellfountain
304	TMIN	48-65	no file	Blackbutte
305	TMIN	72-78	sod350897nf	BonnevilleDam
306	TMIN	72-78	sod351433ne	Cascadia
307	TMIN	72-78	sod351643nf	Clatskanie
308	TMIN	72-78	sod351862nf	CorvallisOSU
309	TMIN	72-78	sod351877ne	CorvallisWater
310	TMIN	72-78	sod351897nf	CottageGrove1S
311	TMIN	72-78	sod351902nf	CottageGroveDam
312	TMIN	72-78	sod352112ne	Dallas
313	TMIN	72-78	no file	Dilley
314	TMIN	72-78	sod352374ne	DorenaDam
315	TMIN	74-78	sod352493nf	EagleCreek
316	TMIN	72-78	sod352693ne	Estacada
317	TMIN	72-78	sod352709nf	EugeneWSOAP
318	TMIN	72-78	sod352867nf	FernRidgeDam
319	TMIN	72-78	sod352997nf	ForestGrove
320	TMIN	72-78	sod353047nf	FosterDam
321	TMIN	49-51	no file	Glenwood
322	TMIN	50-51	no file	Gresham
323	TMIN	72-78	no file	HaskinsDam
324	TMIN	72-78	sod353770nf	Headworks
325	TMIN	72-78	sod353908nf	Hillsboro
326	TMIN	72-78	no file	Holley
327	TMIN	74-78	sod354606ne	Lacomb
328	TMIN	72-78	sod354811nf	Leaburg1SW
329	TMIN	72-78	sod355050ne	LookoutPointDam
330	TMIN	72-78	sod355384ne	McMinnville
331	TMIN	72-78	sod356151ne	N.WillametteExpStn
332	TMIN	72-78	sod356173nf	Noti
333	TMIN	72-78	sod356334ne	OregonCity
334	TMIN	74-78	sod356749ne	PortlandKGW-TV

Directory for will.wdm (cont.)

335	TMIN	72-78	sod356751nf	PortlandWSOAP
336	TMIN	72-78	no file	Rex
337	TMIN	77-78	no file	St.Helens
338	TMIN	72-78	sod357500nf	SalemWSOAP
339	TMIN	72-78	sod357631ne	ScottsMills
340	TMIN	72-78	sod357809ne	SilverCreekFalls
341	TMIN	72-78	sod357823nf	Silverton
342	TMIN	72-78	sod358095nf	Stayton
343	TMIN	72-78	sod358634ne	Troutdale
344	TMIN	72-78	no file	Waterloo
345	TMIN	72-78	cnv0652ne	Belknap Springs
346	TMIN	72-78	cnv2292nf	Detroit Dam
347	TMIN	72-78	cnv3908ne	Government Camp
348	TMIN	72-78	cnv5221ne	Marion Forks
349	TMIN	72-78	cnv5362ne	McKenzie Bridge
350	TMIN	72-78	cnv6213nf	Oakridge
351	TMIN	72-78	cnv7559ne	Santiam Pass
352	TMIN	72-78	cnv8466ne	Three Lynx
15933	TMIN	89-92	sod356334	Oregon City

Observed maximum temperature:

DSN	TYPE	WY	FILENAME	LOCATION
401	TMAX	50-69	no file	Aurora
402	TMAX	73-78	sod350595xf	BeavertonSSW
403	TMAX	50-51	no file	Bellfountain
404	TMAX	48-65	no file	Blackbutte
405	TMAX	72-78	sod350897xf	BonnevilleDam
406	TMAX	72-78	sod351433xe	Cascadia
407	TMAX	72-78	sod351643xf	Clatskanie
408	TMAX	72-78	sod351862xf	CorvallisOSU
409	TMAX	72-78	sod351877xe	CorvallisWater
410	TMAX	72-78	sod351897xf	CottageGrove1S
411	TMAX	72-78	sod351902xf	CottageGroveDam
412	TMAX	72-78	sod352112xe	Dallas
413	TMAX	72-78	no file	Dilley
414	TMAX	72-78	sod352374xe	DorenaDam
415	TMAX	74-78	sod352493xf	EagleCreek
416	TMAX	72-78	sod352693xe	Estacada
417	TMAX	72-78	sod352709xf	EugeneWSOAP
418	TMAX	72-78	sod352867xf	FernRidgeDam
419	TMAX	72-78	sod352997xf	ForestGrove
420	TMAX	72-78	sod353047xf	FosterDam
421	TMAX	49-51	no file	Glenwood
422	TMAX	50-51	no file	Gresham
423	TMAX	72-78	no file	HaskinsDam
424	TMAX	72-78	sod353770xf	Headworks
425	TMAX	72-78	sod353908xf	Hillsboro
426	TMAX	72-78	no file	Holley
427	TMAX	74-78	sod354606xe	Lacomb
428	TMAX	72-78	sod354811xf	Leaburg1SW
429	TMAX	72-78	sod355050xe	LookoutPointDam
430	TMAX	72-78	sod355384xe	McMinnville
431	TMAX	72-78	sod356151xe	N.WillametteExpStn
432	TMAX	72-78	sod356173xf	Noti
433	TMAX	72-78	sod356334xe	OregonCity
434	TMAX	74-78	sod356749xe	PortlandKGW-TV
435	TMAX	72-78	sod356751xf	PortlandWSOAP
436	TMAX	72-78	no file	Rex

Directory for will.wdm (cont.)

437	TMAX	77-78	no file	St.Helens
438	TMAX	72-78	sod357500xf	SalemWSOAP
439	TMAX	72-78	sod357631xe	ScottsMills
440	TMAX	72-78	sod357809xe	SilverCreekFalls
441	TMAX	72-78	sod357823xf	Silverton
442	TMAX	72-78	sod358095xf	Stayton
443	TMAX	72-78	sod358634xe	Troutdale
444	TMAX	72-78	no file	Waterloo
445	TMAX	72-78	cnv0652xe	Belknap Springs
446	TMAX	72-78	cnv2292xf	Detroit Dam
447	TMAX	72-78	cnv3908xe	Government Camp
448	TMAX	72-78	cnv5221xe	Marion Forks
449	TMAX	72-78	cnv5362xe	McKenzie Bridge
450	TMAX	72-78	cnv6213xf	Oakridge
451	TMAX	72-78	cnv7559xe	Santiam Pass
452	TMAX	72-78	cnv8466xe	Three Lynx
15984	TMAX	89-92	sod356334	Oregon City

Observed flow stations at downstream reaches

DSN	TYPE	WY	FILE	LOCATION
710	FLOW	72-78	gs14174000	Willamette @ Albany
1710	FLOW	72-78	gs14210000	Clackamas @ Estacada
1715	FLOW	72-78	gs14211000	Clackamas @ Clackamas
2710	FLOW	72-78	gs14162500	McKenzie @ Vida
2720	FLOW	72	gs14165500	McKenzie @ Coburg
3710	FLOW	72-78	gs14189000	Santiam @ Jefferson
3720	FLOW	72-78	gs14183000	N.Santiam @ Mehama
3725	FLOW	72-78		Salem wp (45 cfs with.)
3730	FLOW	72-78		Salem ditch (10 cfs with.)
4720	FLOW	72-78	gs14187500	S. Santiam @ Waterloo
4725	FLOW	72-78		Lebanon ditch (30 cfs)
4730	FLOW	72-78		Albany ditch (40 cfs)
6710	FLOW	72-78	gs14170000	Long Tom @ Monroe
8706	FLOW	72-78	gs14200000	Molalla @ Canby
10710	FLOW	72-78	gs14194000	S. Yamhill @ Whiteson
11710	FLOW	72-78	gs14152000	M.F. Willamette @ Jasper
12710	FLOW	72-78	gs14157500	C.F. Willamette @ Goshen
13702	FLOW	72-78	gs14203500	Tualatin @ Dilley
13710	FLOW	72-78	gs14207000	Lake Oswego Diversion
13715	FLOW	72-78		Lake Oswego Diversion (constant)
13720	FLOW	72-78	gs14207500	Tualatin @ West Linn
14702	FLOW	72-78		Santiam diversion return
15720	FLOW	90-92	gs14211550	Johnson Cr. @ Milwaukie
15730	FLOW	90-92	gs14211500	Johnson Cr. @ Sycamore
15740	FLOW	72-92		Crystal Springs (15 cfs constant)
16710	FLOW	72	gs14180000	Willamette @ Wilsonville
17710	FLOW	72-78	gs14191000	Willamette @ Salem
18710	FLOW	72-78	gs14166000	Willamette @ Harrisburg

Directory for will.wdm (cont.)

Network applications:

Clackamas River network

DSN	TYPE	WY	FILE	LOCATION
1710	FLOW			estacada flow (14210000)
1150	FLOW			simulated estacada flow
1102	FLOW			eagle basins
1104	FLOW			deep basin
1106	FLOW			clack_b1g3 basin
1108	FLOW			clear basin
1110	FLOW			rock basin
1112	FLOW			clack_b1g6 basin
1120	FLOW			simulated basin sum

Molalla River network

DSN	TYPE	WY	FILE	LOCATION
86	FLOW			wilhoit flow (14198500)
8210	FLOW			simulated wilhoit flow
8102	FLOW			mol_b1g4
8104	FLOW			nf_molalla basin
8106	FLOW			mol_b1g7
8108	FLOW			mol_b2g2
8110	FLOW			milk basin
8112	FLOW			gribble basin
8114	FLOW			mol_b3g1 basin
87	FLOW			silver flow (14200300)
8212	FLOW			simulated silver flow
8116	FLOW			up_pudding basin
8118	FLOW			mi_pudding basin
8120	FLOW			abiqua basins
8122	FLOW			little_pud basins
8124	FLOW			pud_b4g5 basin
8126	FLOW			zollner basin
8128	FLOW			pud_b4g6 basin
8130	FLOW			butte basin
8132	FLOW			rock basin
8134	FLOW			pud_b5g3 basin
8136	FLOW			mill basin
8138	FLOW			mol_b5g4 basin
8200	FLOW			simulated basin sum

Willamette River (albany to salem) network

DSN	TYPE	WY	FILE	LOCATION
710	FLOW			albany flow (14174000)
20100	FLOW			periwinkle basin
20102	FLOW			fourth_lk basin
20104	FLOW			will_b1g3 basin
3710	FLOW			jefferson flow (14189000)
20202	FLOW			simulated jefferson flow
3102	FLOW			san_b3g2 basin
20106	FLOW			luckiamute basins
20108	FLOW			will_b2g4 basin
20110	FLOW			ash_creek basin
20112	FLOW			rickreall basins
20114	FLOW			will_b2g6 basin
20200	FLOW			simulated basin sum

APPENDIX 10. DIRECTORY TREE AND DESCRIPTION OF DIRECTORY CONTENTS FOR DIRECTORIES USED IN MODELING—CONTINUED

Directory for will.wdm (cont.)

Willamette River (harrisburg to albany) network

DSN	TYPE	WY	FILE	LOCATION
18710	FLOW			harrisburg flow (14166000)
20116	FLOW			ingram basin
6710	FLOW			longtom @ monroe flow (14170000)
20204	FLOW			simulated monroe flow
6002	FLOW			mouth_long basin
20118	FLOW			lake basin
20120	FLOW			will_b2g5 basin
20122	FLOW			muddy basins
20124	FLOW			marys basins
20126	FLOW			will_b2g11 basin
20128	FLOW			calapooia basins
20400	FLOW			simulated basin sum

Willamette River (salem to willamette falls) network

DSN	TYPE	WY	FILE	LOCATION
17710	FLOW			salem flow (14191000)
20130	FLOW			mill basins
14702	FLOW			santiam diversion return flow
20134	FLOW			will_b1g3 basin
20136	FLOW			will_b1g6 basin
20138	FLOW			will_b1g7 basin
10710	FLOW			whiteson flow (14194000)
10002	FLOW			yam_b1g3 basin
10004	FLOW			nf_yamhill basins
10006	FLOW			yam_b1g5 basin
10008	FLOW			lo_yamhill basin
10010	FLOW			palmer basin
10012	FLOW			will_b2g3 basin
10014	FLOW			will_b2g7 basin
8200	FLOW			molalla river simulated flow
10016	FLOW			will_b2g10_swf basin
13720	FLOW			tualatin flow (14207500)
20600	FLOW			simulated basin sum

Willamette river (jasper to harrisburg) network

DSN	TYPE	WY	FILE	LOCATION
11710	FLOW			jasper flow (14152000)
11002	FLOW			mouth_mfw basin
11003	FLOW			will_b2g3 basin
2050	FLOW			mckenzie river simulated flow
11004	FLOW			will_b3g2 basin
11006	FLOW			will_b3g3 basin
12710	FLOW			goshen flow (14157500)
12004	FLOW			simulated goshen flow
12002	FLOW			mouth_cfw basin
20800	FLOW			simulated basin sum

Tualatin river network

DSN	TYPE	WY	FILE	LOCATION
13702	FLOW			tualatin @ dilley flow (14203500)
13052	FLOW			simulated dilley flow

Directory for will.wdm (cont.)

90	FLOW			gales creek flow (14204500)
13054	FLOW			simulated gales flow
13004	FLOW			tual_b1g4 basin
13006	FLOW			dairy basins
13008	FLOW			tual_b1g8 basin
13010	FLOW			rock_cr basin
13012	FLOW			butternut basin
13056	FLOW			simulated farmington flow
13014	FLOW			christensen basin
13016	FLOW			tual_b2g2 basin
13018	FLOW			mcfee basin
13020	FLOW			chicken basin
13022	FLOW			tual_b2g4 basin
13024	FLOW			fanno basin
13710	FLOW			oswego diversion flow (14207000)
13026	FLOW			tual_b2g6 basin
13050	FLOW			simulated basin sum

Johnson creek network

DSN	TYPE	WY	FILE	LOCATION
15710	FLOW	72-78		sycamore flow (14211500)
15730	FLOW	90-92		sycamore flow (14211500)
15006	FLOW			simulated sycamore flow
15002	FLOW			john_b1g6 basin
15004	FLOW			john_b1g9 basin
15050	FLOW			simulated basin sum
15833	FLOW	90-92		Oregon City precipitation
15933	FLOW	90-92		Oregon City minimum temperature
15984	FLOW	90-92		Oregon City maximum temperature

Mckenzie river network

DSN	TYPE	WY	FILE	LOCATION
2710	FLOW			vida flow (14162500)
2024	FLOW			simulated vida flow
2002	FLOW			mcken_b1g3 basin
2004	FLOW			gate basin
2026	FLOW			simulated gate flow
2006	FLOW			mcken_b2g1 basin
2008	FLOW			mcken_b6g1 basin
2010	FLOW			mcken_b3g1 basin
2012	FLOW			mcken_b4g1 basin
2014	FLOW			mcken_b7g1 basin
2016	FLOW			camp basin
2018	FLOW			mcken_b5g3 basin
69	FLOW			mohawk flow (14165000)
2020	FLOW			mcken_b5g7 basin
2022	FLOW			mcken_b5g11 basin
2050	FLOW			simulated basin sum

Yamhill river network

DSN	TYPE	WY	FILE	LOCATION
10710	FLOW			whiteson flow (14194000)
10002	FLOW			yam_b1g3 basin
10004	FLOW			nf_yamhill basins
10006	FLOW			yam_b1g5 basin

Directory for will.wdm (cont.)

10008	FLOW			lo_yamhill basin
10010	FLOW			palmer basin
10050	FLOW			simulated basin flow

Santiam river network

DSN	TYPE	WY	FILE	LOCATION
3110	FLOW			lo_nsantiam
3115	FLOW			nsantiam
4010	FLOW			hamilton
4015	FLOW			onehorse
4020	FLOW			lo_ssantiam
4025	FLOW			crabtree
4030	FLOW			thomas
3710	FLOW	72-78	gs14189000	Santiam @ Jefferson
3720	FLOW	72-78	gs14183000	N.Santiam @ Mehama
3725	FLOW	72-78		Salem wp (45 cfs with.)
3730	FLOW	72-78		Salem ditch (10 cfs with.)
4720	FLOW	72-78	gs14187500	S. Santiam @ Waterloo
4725	FLOW	72-78		Lebanon ditch (30 cfs)
4730	FLOW	72-78		Albany ditch (40 cfs)

/will_models/basins/wdmfile/READ.ME-dir/network.directory

Clackamas River network

subbasin or flow	node	DSN	climate-DSN	# of HRUs
estacada flow (14210000)	b1g1	1710	-	-
eagle basins	b1g2	1102	16	9
deep basin	b1g3	1104	33,16	4
clack_b1g3 basin	b1g3	1106	16	3
clear basin	b1g4	1108	16,33	5
rock basin	b1g5	1110	33	3
clack_b1g6 basin	b1g6	1112	33	5
simulated basin sum	b1g8	1120	-	

Molalla River network

subbasin or flow	node	DSN	climate-DSN	# of HRUs
wilhoit flow (14198500)	b1g1	86	-	-
mol_b1g4	b1g3	8102	39,16	4
nf_molalla basin	b1g4	8104	39,16	5
mol_b1g7	b1g7	8106	39	6
mol_b2g2	b2g2	8108	39	5
milk basin	b2g3	8110	31,16	10
gribble basin	b2g5	8112	31	3
mol_b3g1 basin	b3g1	8114	31	3
silver flow (14200300)	b4g1	87	-	-
up_pudding basin	b4g2	8116	41,40	6
mi_pudding basin	b4g3	8118	41	6
abiqua basins	b4g3	8120	41,40	12
little_pud basins	b4g5	8122	41	5
pud_b4g5 basin	b4g5	8124	41	3
zollner basin	b4g6	8126	41	4
pud_b4g6 basin	b4g6	8128	41	4
butte basin	b5g1	88	39,41	12
rock basin	b5g2	8132	39,31	8
pud_b5g3 basin	b5g2	8134	31	3
mill basin	b5g4	8136	31,41	5
simulated basin sum	b3g3	8200	-	

Willamette River (albany to salem) network

subbasin or flow	node	DSN	climate-DSN	# of HRUs
albany flow (14174000)	b1g1	710	-	-
periwinkle basin	b1g2	20100	8	2
fourth_lk basin	b1g3	20102	8,44	4
will_b1g3 basin	b1g3	20104	8	9
jefferson flow (14189000)	b3g1	3710	-	-
san_b3g2 basin	b3g2	3102	8	5
luckiamute basins	b2g3	20106	12,8	10
will_b2g4 basin	b2g4	20108	38	7
ash_creek basin	b2g5	20110	12	9
rickreall basins	b2g6	20112	12	12
will_b2g6 basin	b2g6	20114	38	7
simulated basin sum	b2g9	20200	-	

/will_models/basins/wdmfile/READ.ME-dir/network.directory (cont.)

Willamette River (harrisburg to albany) network

subbasin or flow	node	DSN	climate-DSN	# of HRUs
harrisburg flow (14166000)	b1g1	18710	-	-
ingram basin	b1g5	20116	17	2
longtom flow (14170000)	b3g1	6710	-	-
mouth_long basin	b3g4	6002	17	2
lake basin	b2g3	20118	17,26	2
will_b2g5 basin	b2g5	20120	8	4
muddy basins	b2g7	20122	8,26	8
marys basins	b2g8	20124	9	19
will_b2g11 basin	b2g11	20126	8	11
calapooia basins	b2g14	20128	26,8	20
simulated basin sum	b2g15	20400		

Willamette River (salem to willamette falls) network

subbasin or flow	node	DSN	climate-DSN	# of HRUs
salem flow (14191000)	b1g1	17710	-	-
mill basins	b1g2	20130	38,42	17
santiam diversion return flow (40 cfs constant)	b1g2	14702	-	-
will_b1g3 basin	b1g3	20134	38	5
will_b1g6 basin	b1g6	20136	38	3
will_b1g7 basin	b1g7	20138	36	3
yamhill river simulated flow	b2g1	10050	-	-
will_b2g3 basin	b2g3	10012	36	8
will_b2g7 basin	b2g6	10014	31,36	5
molalla river simulated flow	b2g9	8200	-	-
will_b2g10_swf basin	b2g10	10016	31,33	9
tualatin flow (14207500)	b2g11	13720	-	-
simulated basin sum	b2g12	20600	-	-

Willamette river (jasper to harrisburg) network

subbasin or flow	node	DSN	climate-DSN	# of HRUs
jasper flow (14152000)	b1g1	11710	-	-
mouth_mfw basin	b1g4	11002	29	4
will_b2g3 basin	b2g3	11003	18	3
mckenzie river simulated flow	b3g1	2050	-	-
will_b3g2 basin	b3g2	11004	18	3
will_b3g3 basin	b3g3	11006	18	2
goshen flow (14157500)	b4g1	12710	-	-
mouth_cfw basin	b4g2	12002	29	6
simulated basin sum	b3g4	20800	-	-

/will_models/basins/wdmfile/READ.ME-dir/network.directory (cont.)

Tualatin river network

subbasin or flow	node	DSN	climate-DSN	# of HRUs
dilley flow (14203500)	b1g1	13702	-	-
gales flow (14204500)	b1g3	90	-	-
tual_b1g4 basin	b1g4	13004	13	6
dairy basins	b1g6	13006	19	10
tual_b1g8 basin	b1g8	13008	25	8
rock_cr basin	b1g8	13010	25	6
butternut basin	b1g9	13012	25	3
christensen basin	b2g2	13014	25	4
tual_b2g2 basin	b2g2	13016	25	6
mcfee basin	b2g3	13018	25	4
chicken basin	b2g4	13020	36	3
tual_b2g4 basin	b2g4	13022	36	10
fanno basin	b2g5	13024	36	8
oswego diversion flow (14207000)	b2g6	13710	(- flow)	-
tual_b2g6 basin	b2g6	13026	31	9
simulated basin sum	b2g9	13050	-	-

Johnson creek network

subbasin or flow	node	DSN	climate-DSN	# of HRUs
sycamore flow (14211500)	b1g1	92	-	
john_b1g6 basin	b1g6	15002	34	3
john_b1g9 basin	b1g9	15004	34	4
simulated basin sum	b1g11	15050	-	-

Mckenzie river network

subbasin or flow	node	DSN	climate-DSN	# of HRUs
vida flow (14162500)	b1g1	2710	-	-
mcken_b1g3 basin	b1g3	2002	28	6
gate basin	b1g5	2004	28	6
mcken_b2g1 basin	b2g1	2006	28	3
mcken_b6g1 basin	b6g1	2008	28	2
mcken_b3g1 basin	b3g1	2010	28	3
mcken_b4g1 basin	b4g1	2012	28	4
mcken_b7g1 basin	b7g1	2014	28	5
camp basin	b5g1	2016	28	3
mcken_b5g3 basin	b5g3	2018	28	6
mohawk flow (14165000)	b5g5	69	-	-
mcken_b5g7 basin	b5g7	2020	28	5
mcken_b5g11 basin	b5g11	2022	28	4
simulated basin sum	b5g16	2050	-	-

/will_models/basins/wdmfile/READ.ME-dir/network.directory (cont.)

Yamhill river network

subbasin or flow	node	DSN	climate-DSN	# of HRUs
whiteson flow (14194000)	b1g1	10710	-	-
yam_b1g3 basin	b1g3	10002	30	7
nf_yamhill basins	b1g4	10004	23,30	7
yam_b1g5 basin	b1g5	10006	30	6
lo_yamhill basin	b1g7	10008	30	2
palmer basin	b1g7	10010	30	3
simulated basin sum	b1g9	10050	-	-

Santiam river network

subbasin or flow	node	DSN	climate-DSN	# of HRUs
Mehama flow (14183000)	b1g1	3720	-	-
salem wp (45 cfs)	b1g3	3725	-	-
lo_nsantiam	b1g4	3110	42	8
salem ditch (200 cfs)	b1g5	3730	-	-
Waterloo flow (14187500)	b2g1	4720	-	-
hamilton	b2g2	4010	42, 44	6
lebanon ditch (30 cfs)	b2g3	4725	-	-
albany ditch (40 cfs)	b2g4	4730	-	-
onehorse	b2g5	4015	42, 44	6
lo_ssantiam	b2g6	4020	42, 44	6
crabtree	b2g7	4025	42, 44	15
thomas	b2g8	4030	42, 44	15
nsantiam	b3g3	3115	42	10

****

/will_models/geom/README

This directory contains geometry information from reaches of streams on the main stem of the Willamette Rive and major tributaries.

*.t
    Tactician spreadsheet files

*.data
    ASCII files from spreadsheet

*.prt
    Print files from spreadsheet

****

```
/will_models/networks/README

flow.*
      Initial FLOW.IN files created from geom data.


All river network directories contain the following files:

14cards
      Solar radiation data for PRMS.

36-38cards.*, and c36.*, c37.*,and  c38.*
      Type 36-38 card data for PRMS from AML program.

*.g1
      Complete input file for PRMS simulation to define flow at
      appropriate grid locations in DAFLOW.

FLOW.IN
      Input file for DAFLOW model (streamflow routing).


******************************************************************************
/will_models/report/README

This directory contains text, tables, and figures used in the study report
written primarily by John Risley and modified in this directory.  Refer to
README files in the text, figures, and tables directories for the files
used in this directory that were actually used in the final text.

******************************************************************************


/will_models/seep/README

This directory contains schedules, tactician spreadsheets, and g2 graphs
used in the seepage (gain-loss) investigations.

******************************************************************************


/will_models/networks/slides/README

*.cdr
      CoralDraw files that create slides for various presentations.
            gdansk is for the Polish-USA meeting
            pm if for a presentation to the Willamette Task Force
            slide is for a presentation to headquarters

******************************************************************************


/will_models/stats/sediment/README

This directory contains primarily g2 graphs and supporting files used in
the sediment transport study.  Some g2 files are used in the fact sheet
report and the first draft of the report is located here.
```

```
/will_models/text/README

This directory contains text, figures, and tables used in the final study
report and the fact sheet.  It has three subdirectories: fact, figures, and
tables.  The *.doc files are using the framemaker publisher.

******************************************************************************
/will_models/text/figures/README

      DIRECTORY LOCATION OF TEXT FIGURES

FIGURE
NUMBER

1.    Base map -- illustrations section
2.    fig2.doc in /will_models/text/figures
3.    fig3.doc in /will_models/text/figures
      sta.cgm and sta.aml in /will_models/work
4.    prec_line.gra and prec_line.aml in /willgis/precip
5.    fig5.doc in /will_models/text/figures
      basin.cgm and basin.aml in /will_models/work
6.    lu.ps and lufinplt.aml in /willdeq/willamette/hru/molalla
7.    slope.ps and slfinplt.aml in /willdeq/willamette/hru/molalla
8.    geo.ps and geoplot.aml in /gis_willam/deq/molalla
9.    soil.ps and soilplot.aml in /gis_willam/deq/molalla
10.   hru.ps and hrufinplt.aml in /willdeq/willamette/hru/molalla
11.   fig11.doc in /will_models/text/figures
      temp.cgm and temp.aml in /will_models/work
12.   fig12.doc in /will_models/text/figures
      cal.cgm, cal.ps, and cal.aml in /will_models/work
13.   butte.g2 and butte.dat in /will_models/report

14.   fig14.doc in /will_models/text/figures
      dye.ps, dye.aml, gain.ps, gain.aml in /will_models/work
      (Pudding River arcs missing on /gis_willam/deq/dyeyellow)
15.   gain.aug92.g2 and gain.june93.g2 in /will_models/seep
      aux. files: aug92.err, jun93.err, sep93.err
16.   cala_area.g2, cala.pts, and cala_cv.prt in /will_models/geom
17.   butte.sep.g2 and butte.sep.dat in /will_models/report
18.   johnson.schem in will_models/report/schematisdiagrams
      johnson.cgm and johnson.aml in /deqbasin/gis_work
19.   john.g2 and johnson.dat in /will_models/report
20.   clackamas.schem in will_models/report/schematisdiagrams
      clackamas.cgm and clakamas.aml in /deqbasin/gis_work
21.   clac.g2 and clack.dat in /will_models/report
22.   tualatin.schem in will_models/report/schematisdiagrams
      tualatin.cgm and tualatin.aml in /deqbasin/gis_work
23.   tual.g2 and tual.dat in /will_models/report
24.   molalla.schem in will_models/report/schematisdiagrams
      molalla.cgm and molalla.aml in /deqbasin/gis_work
25.   mol.g2 and mol.dat in /will_models/report
26.   yamhill.schem in will_models/report/schematisdiagrams
      yamhill.cgm and yamhill.aml in /deqbasin/gis_work
27.   yamhill.g2 and yamhill.dat in /will_models/report
28.   santiam.schem in will_models/report/schematisdiagrams
      johnson.cgm and johnson.aml in /deqbasin/gis_work
29.   santiam.g2 and santiam.data in /will_models/report
30.   mckenzie.schem in will_models/report/schematisdiagrams
      johnson.cgm and johnson.aml in /deqbasin/gis_work
31.   mcken.g2 and mcken.dat in /will_models/report
32.   will.jas-har.schem in will_models/report/schematisdiagrams
      aleugene.cgm and aleugene.aml in /deqbasin/gis_work
```

```
/will_models/text/figures/README (cont.)

FIGURE
NUMBER

33.   will.har.g2 and will.har.dat in /will_models/report
34.   will.har-alb.schem in will_models/report/schematisdiagrams
      aleugene.cgm and aleugene.aml in /deqbasin/gis_work
35.   will.alb.g2 and will.alb.dat in /will_models/report
36.   will.alb-sal.schem in will_models/report/schematisdiagrams
      alsalem.cgm and alsalem.aml in /deqbasin/gis_work
37.   will.sal.g2 and will.sal.dat in /will_models/report
38.   will.sal-falls.schem in will_models/report/schematisdiagrams
      porsalem.cgm and porsalem.aml in /deqbasin/gis_work
39.   will.wil.g2 and will.wil.dat in /will_models/report
40..46flowcharts.doc in /will_models/report
47.   upper.pudd.recov.g2, bound.45.5.adj, sim.40.7.adj, sim.35.8.adj,
      sim.31.5.adj, obs.40.7.recov, obs.35.8.recov, obs.31.5.recov, all
      in the /will_models/report/dye directory
48.   middle.pudd.recov.g2, bound.31.5, sim.27.0, sim.22.3, sim.17.6,
      obs.27.0.recov, obs.22.3.recov, obs.17.6.recov, all
      in the /will_models/report/dye directory
49.   lower.pudd.recov.g2, bound.17.6, sim.14.2, sim.12.1, sim.08.1,
      sim.05.4, obs.14.2.recov, obs.12.1.recov, obs.08.1.recov,
      obs.05.4.recov, all in the /will_models/report/dye directory
50.   tt.g2 and tt.dat in /will_models/report/dye


*******************************************************************************

/will_models/transfer/README

This directory contains names and locations for data that were retrieved from
ADAPS and from the State Climatologist files.  None of the original data are
left in this file but modified data are found in the Climate and Flowdata
directories.

*******************************************************************************

/will_models/weather/README

This directory contains methods for looking at the current weather situation.

*******************************************************************************

/will_models/wilk/README

This directory contains the AML and work files used to create a program
to create PRMS parameter values from ARC coverages.  The final working
program is called kengis.aml.

*******************************************************************************

/will_models/work/README

This is a scratch directory that contains some coverage plots and three
subdirectories where provisional flow routing with DAFLOW was done for the
seepage investigation.  The subdirectories are molalla, santiam, and wilson.

*******************************************************************************
```

APPENDIX 11. DIRECTORY TREES AND DESCRIPTION OF DIRECTORY CONTENTS FOR DIRECTORIES USED IN GEOGRAPHIC INFORMATION SYSTEM WORK

```
/gis_willam/deq

Coverages:
 subbasins (20 major Willamette Basins)
 willbound_utm (Willamette Basin boundary)
 will.basins (all 253 subbasins plus all calibration basins)
 will-hydro (1:100K density stream hydrography)
 r-gage.pnts (rain-gage point locations)
 flowcov (stream-gage point locations)
 hucs.utm (hydrologic unit code boundaries)
 prec_map (PRISM precipitation map (not a coverage) of Willamette Basin)

      Directories:
             al_eugene
             albany
             calapooia
             clackamas
             coast_f
             info
             keys
             longtom
             luckiamute
             marys
             mckenzie
             middle_f
             mill
             molalla
             n_santiam
             port_salem
             portland
             rickreall
             s_santiam
             salem
             tualatin
             willhucs.alb
             yamhill

All Directories have the following maps:
            #aspect (map of north, south, east, and west facing slopes
                  above 5% slope)
            #bound.tics (map of 7.5 min corner tics and basin boundary)
            #hydro (map of stream hydrology at 1:100K scale)
            #hygeo (map of surface geology and associated aquifer units)
            #hysoil (map of hydrologic soil classifications A-D)
            #lnduse (map of land use -- urban, agriculture, range, forest,
                  water, wetlands, and barren land)
            #relief (shaded relief map)
            #slope (map of slopes 0-5%, 5-30%, and >30%)
            #soil (map of soils by SCS classification)
```

APPENDIX 11. DIRECTORY TREES AND DESCRIPTION OF DIRECTORY CONTENTS FOR DIRECTORIES USED IN GEOGRAPHIC INFORMATION SYSTEM WORK—CONTINUED

```
/willdeq/willamette/hru

Files:
 critems.aml
 crpnts.aml
 digcov.aml
 editcov.aml
 orientation (file with average basin aspect orientation)

 Coverages:
 basins.utm (Oregon hydrologic unit basin boundary coverage)

      Directories:
       albany
       albany-eugene
       calapooia
       cfwillamette
       clackamas
       longtom
       luckiamute
       marys
       mckenzie
       mfwillamette
       mills
       molalla
       nsantiam
       portland
       portland-salem
       rickreall
       salem
       ssantiam
       tualatin
       will.tics
       yamhill

Each directory (*) contains the following coverages:
            *_basin (hru coverage)
            *.hru (basin boundary coverage)
            *.map (map of hru's and boundary)
            info (info file with attributes)
            sub.pnts (point coverage of gaging stations)
            subbasins (subbasin boundary coverage)
```

```
/deqbasin/final/DIR.TREE

Files:
 README (refer to this file to determine maps, coverages, and files in each
      basin directory)

 Coverages:
 prec_poly (precipitation coverage used to determine mean annual precip
            for each basin or subbasin)

      Directories:
            albany
            aleugene
            calapooia
            cfwillamette
            clackamas
            info
            longtom
            luckiamute
            marys
            mckenzie
            mfwillamette
            mill
            molalla
            nsantiam
            porsalem
            portland
            Rickreall
            salem
            ssantiam
            tualatin
            willamette
            yamhill

/deqbasin/final/README

 This directory was made to contain all of the necessary information to
run the AML created by Jim Wilkinson that produces the c36, c37, and c38
card files. Each basin directory is basically the same containing the
following:

 subbasins - a directory of originally chosen subbasins and subbasins
 setup for network calibration which include HRU values.

 calbasins - a directory of calibration basins that include HRU values
 and may or may not be the same as the original subbasins.
 (some calbasins are a combination of two or more subbasins)

 basin_hru - the original arc coverage of the basin which includes all
             of the HRU values for the entire basin.
```

basin_lat - an arc lattice coverage of the entire basin with elevation data. (note: basin_grid is a backup coverage with grids and lattices being identical)

network-basin_lat - a lattice coverage for a specific subbasin when the entire area was not contained in one basin. (Which just occurs in the porsalem and aleugene basins)

The individual subbasin and calbasin coverages were created by combining the basin_hru coverages and one of the basin_sub, _cal, or _net coverages in the gis_work directory. This was accomplished by using the basic steps which follow, and steps 2-5 can be used in the future if more changes are required.

1. The GIS Unit’s coverage basins.utm was CLIPPED by each basin outline to take advantage of any subbasins that may have already been digitized.

2. New arcs were delineated on 15 or 7 1/2 minute Drainage Area Maps and then the new arcs were digitized into the coverages. Each basin_sub was then CLEANED and BUILT to eliminate any small sliver polygons.

3. ADDITEM was used to give all subbasin polygons an attribute called “sub-id” which uniquely identifies each subbasin.

4. The SPLIT command was then used to “cookie-cut” the basin_hru coverage into the separate smaller subbasins. It was used with the following general format:

   ```
   SPLIT basin_hru basin_sub(or _cal, or _net) sub-id poly 10
   ```

5. The small (less than 5% usually) sliver polygons were then edited out of the new subbasin coverages, and these final subbasins were then CLEANED, BUILT and saved in the /deqbasin/final directory.

APPENDIX 12. DIRECTORY FOR *will.wdm* FILE

Data set number	Sections
Observed daily data	
1 - 52	Precipitation data
53 - 100	Headwater flow data
101 - 300	Additional observed data
301 - 400	Minimum temperature data
401 - 500	Maximum temperature data
Subbasins:	
501 - 1000	Albany
1001 - 2000	Clackamas
2001 - 3000	McKenzie
3001 - 4000	North Santiam
4001 - 5000	South Santiam
5001 - 6000	Calapooia
6001 - 7000	Long Tom
7001 - 8000	Marys
8001 - 9000	Molalla
9001 - 10000	Rickreall
10001 - 11000	Yamhill
11001 - 12000	Middle Fork
12001 - 13000	Coast Fork
13001 - 14000	Tualatin
14001 - 15000	Mill
15001 - 16000	Portland
16001 - 17000	Portland-Salem
17001 - 18000	Salem-Albany
18001 - 19000	Albany-Eugene
19001 - 20000	Luckiamute

Subbasin breakdown:

< = ##700 Simulated flows	
##701 - ##800	Observed flow data
##801 - ##900	Observed precipitation data
##901 - ##950	Observed minimum temperature
##951 - #1000	Observed maximum temperature

Observed precipitation:

DSN	TYPE	WY	FILENAME	LOCATION
1	PREC	50-69	no file	Aurora
2	PREC	73-78	sod350595pf	BeavertonSSW
3	PREC	50-51	no file	Bellfountain
4	PREC	48-65	no file	Blackbutte
5	PREC	72-78	sod350897pf	BonnevilleDam
6	PREC	72-78	sod351433pe	Cascadia
7	PREC	72-78	sod351643pf	Clatskanie
8	PREC	72-78	sod351862pf	CorvallisOSU
9	PREC	72-78	sod351877pf	CorvallisWater
10	PREC	72-78	sod351897pf	CottageGrove1S
11	PREC	72-78	sod351902pf	CottageGroveDam
12	PREC	72-78	sod352112pf	Dallas
13	PREC	72-78	sod352325pf	Dilley
14	PREC	72-78	sod352374pf	DorenaDam
15	PREC	74-78	sod352493pf	EagleCreek
16	PREC	72-78	sod352693pe	Estacada
17	PREC	72-78	sod352709pf	EugeneWSOAP
18	PREC	72-78	sod352867pf	FernRidgeDam
19	PREC	72-78	sod352997pf	ForestGrove
20	PREC	72-78	sod353047pf	FosterDam
21	PREC	49-51	no file	Glenwood
22	PREC	50-51	no file	Gresham
23	PREC	72-78	sod353705pf	HaskinsDam
24	PREC	72-78	sod353770pf	Headworks
25	PREC	72-78	sod353908pf	Hillsboro
26	PREC	72-78	sod353971pf	Holley
27	PREC	74-78	sod354606pf	Lacomb
28	PREC	72-78	sod354811pf	Leaburg1SW
29	PREC	72-78	sod355050pf	LookoutPointDam
30	PREC	72-78	sod355384pe	McMinnville
31	PREC	72-78	sod356151pe	N.WillametteExpStn
32	PREC	72-78	sod356173pf	Noti
33	PREC	72-78	sod356334pf	OregonCity
34	PREC	74-78	sod356749pe	PortlandKGW-TV
35	PREC	72-78	sod356751pf	PortlandWSOAP
36	PREC	72-78	sod357127pf	Rex
37	PREC	77-78	no file	St.Helens
38	PREC	72-78	sod357500pf	SalemWSOAP
39	PREC	72-78	sod357631pf	ScottsMills
40	PREC	72-78	sod357809pe	SilverCreekFalls

Observed precipitation (cont.):

DSN	TYPE	WY	FILENAME	LOCATION
41	PREC	72-78	sod357823pf	Silverton
42	PREC	72-78	sod358095pf	Stayton
43	PREC	72-78	sod358634pe	Troutdale
44	PREC	72-78	sod359083pf	Waterloo
45	PREC	72-78	cnv0652pe	Belknap Springs
46	PREC	72-78	cnv2292pf	Detroit Dam
47	PREC	72-78	cnv3908pf	Government Camp
48	PREC	72-78	cnv5221pf	Marion Forks
49	PREC	72-78	cnv5362pe	McKenzie Bridge
50	PREC	72-78	cnv6213pf	Oakridge
51	PREC	72-78	cnv7559pf	Santiam Pass
52	PREC	72-78	cnv8466pf	Three Lynx
15833	PREC	89-92	sod356334	Oregon City

Observed headwater flow:

DSN	TYPE	WY	FILENAME	LOCATION
53	FLOW	72-78	gs14144800	Middle Fork Willamette @Oakridge
54	FLOW	72-78	gs14144900	Hills creek @ Oakridge
55	FLOW	72-78	gs14146500	Salmon creek @ Oakridge
56	FLOW	72-78	gs14147000	Waldo Lake @ Oakridge
57	FLOW	72-78	gs14147500	Nf of mf Willamette @ Oakridge
58	FLOW	72-78	gs14150300	Fall creek @ Lowell
59	FLOW	72-78	gs14150800	Winberry creek @ Lowell
60	FLOW	72-78	gs14152500	Cf Willamette @ London
61	FLOW	72-78	gs14154500	Row river above Pitcher creek
62	FLOW	72-78	gs14156500	Mosby creek @ Cottage grove
63	FLOW	72-78	gs14158500	McKenzie @ Clear lake
64	FLOW	72-78	gs14158790	Smith river @ Belknap spring
65	FLOW	72-78	gs14159200	Sf Mckenzie @ Rainbow
66	FLOW	72-78	gs14161100	Blue river @ Blue river
67	FLOW	72-78	gs14161500	Lookout creek @ Blue river
68	FLOW	72-78	gs14163000	Gate creek at Vida
69	FLOW	72-78	gs14165000	Mohawk river @ Springfield
70	FLOW	72-75	gs14169300	Amazon creek @ Eugene
71	FLOW	72-78	gs14171000	Marys river at Philomath
72	FLOW	72-78	gs14172000	Calapooia at Holley
73	FLOW	72-78	gs14178000	N. Santiam @ Detroit
74	FLOW	72-78	gs14179000	Breitenbush river @ Detroit

75 FLOW 72-78 gs14182500 L. North Santiam @ Mehama
76 FLOW 72-78 gs14185000 S. Santiam river @ Cascadia
77 FLOW 72-78 gs14185800 M. Santiam river @ Cascadia
78 FLOW 72-78 gs14185900 Quartzville creek @ Cascadia
79 FLOW 72-73 gs14187000 Wiley creek @ Foster
80 FLOW 72-78 gs14188800 Thomas creek @ Scio
81 FLOW 72-78 gs14189500 Luckiamute river @ Hoskins
82 FLOW 72-78 gs14190700 Rickreall creek @ Dallas
83 FLOW 72-78 gs14192500 S. yamhill @ Willamina
84 FLOW 72-78 gs14193000 Willamina creek @ willamina
85 FLOW 72-78 gs14194300 N. yamhill river @ Fairdale
86 FLOW 72-78 gs14198500 Molalla river @ Wilhoit
87 FLOW 72-78 gs14200300 Silver creek @ Silverton
88 FLOW 72-78 gs14201500 Butte creek @ monitor
89 FLOW 73-76 gs14202500 Tulatin @ Gaston
90 FLOW 72-78 gs14204500 Gales creek @ Forest Grove
91 FLOW 65-70 gs14208000 Clackamas @ Big Bottom
92 FLOW 72-78 gs14211500 Johnson creek @ Sycamore

Observed minimum temperature:

DSN TYPE WY FILENAME LOCATION

301 TMIN 50-69 no file Aurora
302 TMIN 73-78 sod350595nf BeavertonSSW
303 TMIN 50-51 no file Bellfountain
304 TMIN 48-65 no file Blackbutte
305 TMIN 72-78 sod350897nf BonnevilleDam
306 TMIN 72-78 sod351433ne Cascadia
307 TMIN 72-78 sod351643nf Clatskanie
308 TMIN 72-78 sod351862nf CorvallisOSU
309 TMIN 72-78 sod351877ne CorvallisWater
310 TMIN 72-78 sod351897nf CottageGrove1S
311 TMIN 72-78 sod351902nf CottageGroveDam
312 TMIN 72-78 sod352112ne Dallas
313 TMIN 72-78 no file Dilley
314 TMIN 72-78 sod352374ne DorenaDam
315 TMIN 74-78 sod352493nf EagleCreek
316 TMIN 72-78 sod352693ne Estacada
317 TMIN 72-78 sod352709nf EugeneWSOAP
318 TMIN 72-78 sod352867nf FernRidgeDam
319 TMIN 72-78 sod352997nf ForestGrove
320 TMIN 72-78 sod353047nf FosterDam
321 TMIN 49-51 no file Glenwood

322 TMIN 50-51 no file Gresham
323 TMIN 72-78 no file HaskinsDam
324 TMIN 72-78 sod353770nf Headworks
325 TMIN 72-78 sod353908nf Hillsboro
326 TMIN 72-78 no file Holley
327 TMIN 74-78 sod354606ne Lacomb
328 TMIN 72-78 sod354811nf Leaburg1SW
329 TMIN 72-78 sod355050ne LookoutPointDam
330 TMIN 72-78 sod355384ne McMinnville
331 TMIN 72-78 sod356151ne N.WillametteExpStn
332 TMIN 72-78 sod356173nf Noti
333 TMIN 72-78 sod356334ne OregonCity
334 TMIN 74-78 sod356749ne PortlandKGW-TV
335 TMIN 72-78 sod356751nf PortlandWSOAP
336 TMIN 72-78 no file Rex
337 TMIN 77-78 no file St.Helens
338 TMIN 72-78 sod357500nf SalemWSOAP
339 TMIN 72-78 sod357631ne ScottsMills
340 TMIN 72-78 sod357809ne SilverCreekFalls
341 TMIN 72-78 sod357823nf Silverton
342 TMIN 72-78 sod358095nf Stayton
343 TMIN 72-78 sod358634ne Troutdale
344 TMIN 72-78 no file Waterloo
345 TMIN 72-78 cnv0652ne Belknap Springs
346 TMIN 72-78 cnv2292nf Detroit Dam
347 TMIN 72-78 cnv3908ne Government Camp
348 TMIN 72-78 cnv5221ne Marion Forks
349 TMIN 72-78 cnv5362ne McKenzie Bridge
350 TMIN 72-78 cnv6213nf Oakridge
351 TMIN 72-78 cnv7559ne Santiam Pass
352 TMIN 72-78 cnv8466ne Three Lynx
15933 TMIN 89-92 sod356334 Oregon City

Observed maximum temperature:

DSN TYPE WY FILENAME LOCATION

401 TMAX 50-69 no file Aurora
402 TMAX 73-78 sod350595xf BeavertonSSW
403 TMAX 50-51 no file Bellfountain
404 TMAX 48-65 no file Blackbutte
405 TMAX 72-78 sod350897xf BonnevilleDam
406 TMAX 72-78 sod351433xe Cascadia
407 TMAX 72-78 sod351643xf Clatskanie

408 TMAX 72-78 sod351862xf CorvallisOSU
409 TMAX 72-78 sod351877xe CorvallisWater
410 TMAX 72-78 sod351897xf CottageGrove1S
411 TMAX 72-78 sod351902xf CottageGroveDam
412 TMAX 72-78 sod352112xe Dallas
413 TMAX 72-78 no file Dilley
414 TMAX 72-78 sod352374xe DorenaDam
415 TMAX 74-78 sod352493xf EagleCreek
416 TMAX 72-78 sod352693xe Estacada
417 TMAX 72-78 sod352709xf EugeneWSOAP
418 TMAX 72-78 sod352867xf FernRidgeDam
419 TMAX 72-78 sod352997xf ForestGrove
420 TMAX 72-78 sod353047xf FosterDam
421 TMAX 49-51 no file Glenwood
422 TMAX 50-51 no file Gresham
423 TMAX 72-78 no file HaskinsDam
424 TMAX 72-78 sod353770xf Headworks
425 TMAX 72-78 sod353908xf Hillsboro
426 TMAX 72-78 no file Holley
427 TMAX 74-78 sod354606xe Lacomb
428 TMAX 72-78 sod354811xf Leaburg1SW
429 TMAX 72-78 sod355050xe LookoutPointDam
430 TMAX 72-78 sod355384xe McMinnville
431 TMAX 72-78 sod356151xe N.WillametteExpStn
432 TMAX 72-78 sod356173xf Noti
433 TMAX 72-78 sod356334xe OregonCity
434 TMAX 74-78 sod356749xe PortlandKGW-TV
435 TMAX 72-78 sod356751xf PortlandWSOAP
436 TMAX 72-78 no file Rex
437 TMAX 77-78 no file St.Helens
438 TMAX 72-78 sod357500xf SalemWSOAP
439 TMAX 72-78 sod357631xe ScottsMills
440 TMAX 72-78 sod357809xe SilverCreekFalls
441 TMAX 72-78 sod357823xf Silverton
442 TMAX 72-78 sod358095xf Stayton
443 TMAX 72-78 sod358634xe Troutdale
444 TMAX 72-78 no file Waterloo
445 TMAX 72-78 cnv0652xe Belknap Springs
446 TMAX 72-78 cnv2292xf Detroit Dam
447 TMAX 72-78 cnv3908xe Government Camp
448 TMAX 72-78 cnv5221xe Marion Forks
449 TMAX 72-78 cnv5362xe McKenzie Bridge
450 TMAX 72-78 cnv6213xf Oakridge
451 TMAX 72-78 cnv7559xe Santiam Pass

452 TMAX 72-78 cnv8466xe Three Lynx
15984 TMAX 89-92 sod356334 Oregon City

Observed flow stations at downstream reaches

DSN TYPE WY FILE LOCATION

710 FLOW 72-78 gs14174000 Willamette @ Albany
1710 FLOW 72-78 gs14210000 Clackamas @ Estacada
1715 FLOW 72-78 gs14211000 Clackamas @ Clackamas
2710 FLOW 72-78 gs14162500 McKenzie @ Vida
2720 FLOW 72 gs14165500 McKenzie @ Coburg
3710 FLOW 72-78 gs14189000 Santiam @ Jefferson
3720 FLOW 72-78 gs14183000 N.Santiam @ Mehama
3725 FLOW 72-78 Salem wp (45 cfs with.)
3730 FLOW 72-78 Salem ditch (10 cfs with.)
4720 FLOW 72-78 gs14187500 S. Santiam @ Waterloo
4725 FLOW 72-78 Lebanon ditch (30 cfs)
4730 FLOW 72-78 Albany ditch (40 cfs)
6710 FLOW 72-78 gs14170000 Long Tom @ Monroe
8706 FLOW 72-78 gs14200000 Molalla @ Canby
10710 FLOW 72-78 gs14194000 S. Yamhill @ Whiteson
11710 FLOW 72-78 gs14152000 M.F. Willamette @ Jasper
12710 FLOW 72-78 gs14157500 C.F. Willamette @ Goshen
13702 FLOW 72-78 gs14203500 Tualatin @ Dilley
13710 FLOW 72-78 gs14207000 Lake Oswego Diversion
13715 FLOW 72-78 Lake Oswego Diversion (constant)
13720 FLOW 72-78 gs14207500 Tualatin @ West Linn
14702 FLOW 72-78 Santiam diversion return
15720 FLOW 90-92 gs14211550 Johnson Cr. @ Milwaukie
15730 FLOW 90-92 gs14211500 Johnson Cr. @ Sycamore
15740 FLOW 72-92 Crystal Springs (15 cfs constant)
16710 FLOW 72 gs14180000 Willamette @ Wilsonville
17710 FLOW 72-78 gs14191000 Willamette @ Salem
18710 FLOW 72-78 gs14166000 Willamette @ Harrisburg

Network applications:

Clackamas River network
DSN TYPE WY FILE LOCATION

1710 FLOW estacada flow (14210000)
1150 FLOW simulated estacada flow

1102 FLOW eagle basins
1104 FLOW deep basin
1106 FLOW clack_b1g3 basin
1108 FLOW clear basin
1110 FLOW rock basin
1112 FLOW clack_b1g6 basin
1120 FLOW simulated basin sum

Molalla River network
DSN TYPE WY FILE LOCATION

86 FLOW wilhoit flow (14198500)
8210 FLOW simulated wilhoit flow
8102 FLOW mol_b1g4
8104 FLOW nf_molalla basin
8106 FLOW mol_b1g7
8108 FLOW mol_b2g2
8110 FLOW milk basin
8112 FLOW cribble basin
8114 FLOW mol_b3g1 basin
87 FLOW silver flow (14200300)
8212 FLOW simulated silver flow
8116 FLOW up_pudding basin
8118 FLOW mi_pudding basin
8120 FLOW abiqua basins
8122 FLOW little_pud basins
8124 FLOW pud_b4g5 basin
8126 FLOW zollner basin
8128 FLOW pud_b4g6 basin
8130 FLOW butte basin
8132 FLOW rock basin
8134 FLOW pud_b5g3 basin
8136 FLOW mill basin
8138 FLOW mol_b5g4 basin
8200 FLOW simulated basin sum

Willamette River (albany to salem) network
DSN TYPE WY FILE LOCATION

710 FLOW albany flow (14174000)
20100 FLOW periwinkle basin
20102 FLOW fourth_lk basin

20104 FLOW will_b1g3 basin
3710 FLOW jefferson flow (14189000)
20202 FLOW simulated jefferson flow
3102 FLOW san_b3g2 basin
20106 FLOW luckiamute basins
20108 FLOW will_b2g4 basin
20110 FLOW ash_creek basin
20112 FLOW rickreal basins
20114 FLOW will_b2g6 basin
20200 FLOW simulated basin sum

Willamette River (harisburg to albany) network
DSN TYPE WY FILE LOCATION

18710 FLOW harisburg flow (14166000)
20116 FLOW ingram basin
6710 FLOW longtom @ monroe flow (14170000)
20204 FLOW simulated monroe flow
6002 FLOW mouth_long basin
20118 FLOW lake basin
20120 FLOW will_b2g5 basin
20122 FLOW muddy basins
20124 FLOW marys basins
20126 FLOW will_b2g11 basin
20128 FLOW calapooia basins
20400 FLOW simulated basin sum

Willamette River (salem to willamette falls) network
DSN TYPE WY FILE LOCATION

17710 FLOW salem flow (14191000)
20130 FLOW mill basins
14702 FLOW santiam diversion return flow
20134 FLOW will_b1g3 basin
20136 FLOW will_b1g6 basin
20138 FLOW will_b1g7 basin
10710 FLOW whiteson flow (14194000)
10002 FLOW yam_b1g3 basin
10004 FLOW nf_yamhill basins
10006 FLOW yam_b1g5 basin
10008 FLOW lo_yamhill basin
10010 FLOW palmer basin
10012 FLOW will_b2g3 basin

10014 FLOW will_b2g7 basin
8200 FLOW molalla river simulated flow
10016 FLOW will_b2g10_swf basin
13720 FLOW tualatin flow (14207500)
20600 FLOW simulated basin sum

Willamette river (jasper to harisburg) network
DSN TYPE WY FILE LOCATION

11710 FLOW jasper flow (14152000)
11002 FLOW mouth_mfw basin
11003 FLOW will_b2g3 basin
2050 FLOW mckenzie river simulated flow
11004 FLOW will_b3g2 basin
11006 FLOW will_b3g3 basin
12710 FLOW goshen flow (14157500)
12004 FLOW simulated goshen flow
12002 FLOW mouth_cfw basin
20800 FLOW simulated basin sum

Tualatin river network
DSN TYPE WY FILE LOCATION

13702 FLOW tualatin @ dilley flow (14203500)
13052 FLOW simulated dilley flow
90 FLOW gales creek flow (14204500)
13054 FLOW simulated gales flow
13004 FLOW tual_b1g4 basin
13006 FLOW dairy basins
13008 FLOW tual_b1g8 basin
13010 FLOW rock_cr basin
13012 FLOW butternut basin
13056 FLOW simulated farmington flow
13014 FLOW christensen basin
13016 FLOW tual_b2g2 basin
13018 FLOW mcfee basin
13020 FLOW chicken basin
13022 FLOW tual_b2g4 basin
13024 FLOW fanno basin
13710 FLOW oswego diversion flow (14207000)
13026 FLOW tual_b2g6 basin
13050 FLOW simulated basin sum

Johnson creek network
DSN TYPE WY FILE LOCATION

15710 FLOW 72-78 sycamore flow (14211500)
15730 FLOW 90-92 sycamore flow (14211500)
15006 FLOW simulated sycamore flow
15002 FLOW john_b1g6 basin
15004 FLOW john_b1g9 basin
15050 FLOW simulated basin sum
15833 FLOW 90-92 Oregon City precipitation
15933 FLOW 90-92 Oregon City minimum temperature
15984 FLOW 90-92 Oregon City maximum temperature

Mckenzie river network
DSN TYPE WY FILE LOCATION

2710 FLOW vida flow (14162500)
2024 FLOW simulated vida flow
2002 FLOW mcken_b1g3 basin
2004 FLOW gate basin
2026 FLOW simulated gate flow
2006 FLOW mcken_b2g1 basin
2008 FLOW mcken_b6g1 basin
2010 FLOW mcken_b3g1 basin
2012 FLOW mcken_b4g1 basin
2014 FLOW mcken_b7g1 basin
2016 FLOW camp basin
2018 FLOW mcken_b5g3 basin
69 FLOW mohawk flow (14165000)
2020 FLOW mcken_b5g7 basin
2022 FLOW mcken_b5g11 basin
2050 FLOW simulated basin sum

Yamhill river network
DSN TYPE WY FILE LOCATION

10710 FLOW whiteson flow (14194000)
10002 FLOW yam_b1g3 basin
10004 FLOW nf_yamhill basins
10006 FLOW yam_b1g5 basin
10008 FLOW lo_yamhill basin
10010 FLOW palmer basin
10050 FLOW simulated basin flow

Santiam river network
DSN TYPE WY FILE LOCATION

3110 FLOW lo_nsantiam
3115 FLOW nsantiam
4010 FLOW hamilton
4015 FLOW onehorse
4020 FLOW lo_ssantiam
4025 FLOW crabtree
4030 FLOW thomas

3710 FLOW 72-78 gs14189000 Santiam @ Jefferson
3720 FLOW 72-78 gs14183000 N.Santiam @ Mehama
3725 FLOW 72-78 Salem wp (45 cfs with.)
3730 FLOW 72-78 Salem ditch (10 cfs with.)
4720 FLOW 72-78 gs14187500 S. Santiam @ Waterloo
4725 FLOW 72-78 Lebannon ditch (30 cfs)
4730 FLOW 72-78 Albany ditch (40 cfs)

APPENDIX 13. PROGRAMMING STEPS FOR RUNNING THE SCENARIO GENERATOR

The scenario generator executable file is called: *willamsg*. The control file for the program, which must be in the same directory, is called: *willam.sta*

The user activates the scenario generator by typing: *willamsg*

After the main menu appears, arrow keys are used to move the cursor to different options. The F2 key is then used to activate any option.

The current layout for this study uses flow as the only item for display as a ‘scenario.’ However, the user can add new ‘scenarios’ such as different water-quality constituents by adding this data to the wdmfile and making modifications to the *willam.sta* file.

The flow sites for display may be selected either using ‘Map-basin’ or ‘Location’ submenus.

If the ‘Map-basin’ option is selected, a map of the Willamette Basin will appear. The user can select individual flow sites with the left mouse button. To go back to the menu window, it is necessary to click on ‘RETURN’ located on the bottom of the map window.

If the ‘Location’ option is used, the flow site is selected from a list.

After the flow site is selected, the user selects ‘Graph-produce’ submenu to view a hydrograph or flow duration plot. The period of record to be viewed is designated in this submenu under ‘Units- and time span of plot’. The ‘Axis-type and scale’ option allows the user to select an arithmetic or logarithmic scale axis.

The file ‘willamsg.sta’ contains the operation settings of the scenario generator. Details about this file are provided in the following page. The user can use two versions of the *willamsg.sta* file. In the wdmfile subdirectory there are the files: *calibration.sta* and *network.sta*. The *calibration.sta* file contains 40 flow locations, while the *network.sta* file contains only the outlet flow locations for 12 stream networks. The user can select either file by copying it.

cp *network.sta willamsg.sta* or, cp *calibration.sta willamsg.sta*

The Scenario Generator **.sta* file

The scenario generator **.sta* file is a file containing information about the current state of the scenario generator. This file is read when the scenario generator is initialized, and it is written just before returning to the operating system. The **.sta* file contains some general information necessary to the operation of the scenario generator as well as detailed information about the scenario mapping specifications, and plot specifications. This file is updated when leaving the scenario generator; thus any change in these specifications made during a scenario generator run will be “remembered” for subsequent runs. The **.sta* file is designed such that, after being set up for a particular scenario generator, the file should be transparent to the user.

The Scenario Generator **.sta* file (cont.)

The first record in the **.sta* file contains the name of the wdm data file associated with this scenario generator (FORMAT A64). This file name can be up to 64 characters in length in and should include the path to the **.wdm* file if the **.wdm* file does not reside in that directory.

Example:
/home/hass/ctwsg/bin/truckee.wdm

The second record contains two integer values (FORMAT 2I5). The first value represents the total number of scenarios, and the second value indicates which model this scenario generator will run under the “simulate” menu option (0-HSPF, 2-DAFLOW).

Example:
```
    4    0
```

Following the number of scenarios is a series of records containing information about each of the scenarios (FORMAT 4I5,I2,I3,1X,A10). Each of these records contains a scenario identification number, a flag indicating whether this scenario is currently active (1-active, 2-inactive), a series of integers specifying line color, line type, symbol type, and fill pattern, and a character string containing the corresponding scenario name.

Example:
```
    2    1    0    3 0  0 Scenario 1
```

The next line contains three integer values representing the mapping device (1-screen, 2-printer, 3-plotter), the map border specifications (1-USA, 2-latlng, 3-hydro region, 4-state, 5-local), and a map interaction flag (>0-allow user interaction) (FORMAT 3I5).

Example:
```
    1    2    2
```

The next record specifies minimum and maximum latitude and longitude values as well as a base longitude value (FORMAT 5F10.1). These values are used in setting the default boundaries on the map. The base longitude is used to specify the reference point of the map viewer, or in other words a location at which map north appears directly vertical on the map projection.

Example:
```
      38.5      40.5     119.0     120.5     119.0
```

The Scenario Generator **.sta* file (cont.)

The three integers on the next record indicate specific details of the map marker (FORMAT 3I5). The first integer is the map marker type (1-., 2-+, 3-*, 4-o, 5-x), the second is the marker select color, and the third is the marker unselect color.

Example:

```
    3    2    7
```

The single integer on the following record indicates the number of possible location points on the map (FORMAT 1I5).

Example:

```
   50
```

The next series of records contains information about each map location point (FORMAT 2I5,2F10.4,1X,A40). The first integer is a location identification number, followed by a location status flag (1-on, 2-off). The two real numbers are the latitude and longitude of that location. The character field contains the name of that location.

Example:

```
    1    2    39.052   120.120 GENERAL C NR MEEKS BAY
```

The single integer on the next record indicates the number of available constituents (FORMAT 1I5).

Example:

```
    4
```

After the number of constituents is a series of records indicating the constituent identification number and the constituent name (FORMAT I5,1X,A16).

Example:

```
    1 FLOW (CFS)
```

The single integer on the next record indicates the number of available time series data sets (FORMAT 1I5).

Example:

```
  120
```

The Scenario Generator **.sta* file (cont.)

After the number of data sets is a series of records containing a location identification number, a constituent identification number, a scenario number, and the corresponding time series data set number (FORMAT 4I5).

Example:

```
   10    1    1  111
```

The next record contains a series of five integers representing the time step, time units, transformation function, allowed quality flag, and axis type (1-arith, 2-log) (FORMAT 5I5).

Example:

```
    1    6    0    1    1
```

The next record is an array of five integers, one corresponding to each of five possible lines on a plot (FORMAT 5I5). The value represents the axis on which this line should be plotted (1-left y-axis, 2-right y-axis, 3-auxiliary axis).

Example:

```
    1    1    1    1    1
```

The two integers on the next line indicate data type for the values on the plot (1-mean, 2-point) (FORMAT 2I5).

Example:

```
    1    1
```

The next two records indicate the starting and ending dates and times for the plots, respectively, in the following order: year, month, day, hour, minute, second (FORMAT 6I5).

Example:

```
 1990   12   31   24    0    0
```

The following five records contain character strings representing the labels on each on the five plot curves (FORMAT A20). If less than five curves are to be plotted the unneeded labels can be left blank.

Example:

```
Scenario 1
```

The Scenario Generator **.sta* file (cont.)

The next three records contain labels for the left, right, and auxiliary axes, respectively (FORMAT A80).

Example:

FLOW (CFS)

The next three records contain a title for the current plot (FORMAT A80).

Example:

Scenario comparison plot for TRUCKEE R AT VISTA, NV

Finally, the following seven records contain the dimensions of graphics windows 1 through 7 (FORMAT 4F10.3). The dimensions are specified in the order left, top, right, and bottom, with each value representing the relative distance from the left side of the screen (for left and right dimensions) or from the top of the screen (for top and bottom dimensions)

Example:

0.000   0.000   0.500   0.500

APPENDIX 14. INPUT FILES FOR BRANCHED LAGRANGIAN TRANSPORT MODEL MODELING OF THE PUDDING RIVER, OREGON

The *FLOW.IN* file for DAFLOW modeling:

```
Pudding River Network (RM 53.4 to 0.0)
No. of Branches              3 *      12         1
/will_models/basins/wdmfile/pudd.wdm
Internal Junctions           2 *
Time Steps Modeled          15 * 1993 07 01 00 00 00
Model Starts                 0 time steps after midnight.
Output Given Every           1 Time Steps in FLOW.OUT.
0=Metric,1=English           1 *
Time Step Size          24.000 * Hours
Peak Discharge           1000. *
Branch  1 has  8 xsects & routes 1.00 of flow at JNCT  3 To JNCT  1
Grd R Mile  IOUT  Disch        A1        A2        AO        DF         W1    W2
  1 00.000     0   81.0      2.40     0.660       0.0     0.129E+05   20.0 0.180
  2 03.500     0   81.0      2.40     0.660       0.0     0.160E+05   18.0 0.200
  3 07.200     0  134.0      2.30     0.660      90.0     0.192E+05   16.0 0.220
  4 07.300     0  153.0      2.00     0.660     140.0     0.296E+05   12.0 0.260
  5 12.100     0  153.0      1.70     0.660     140.0     0.296E+05   12.0 0.260
  6 15.900     0  158.0      1.90     0.660     130.0     0.161E+05   12.0 0.260
  7 17.000     1  182.0      2.10     0.660     130.0     0.161E+05   12.0 0.260
  8 21.300     0
Branch  2 has  8 xsects & routes 1.00 of flow at JNCT  1 To JNCT  2
Grd R Mile  IOUT  Disch        A1        A2        AO        DF         W1    W2
  1 21.300     0  210.0      2.80     0.660     130.0     0.212E+05   15.0 0.250
  2 23.700     0  210.0      3.50     0.660     140.0     0.263E+05   18.0 0.240
  3 23.800     0  210.0      3.50     0.660     140.0     0.263E+05   18.0 0.240
  4 25.800     0  219.0      3.60     0.660     120.0     0.250E+05   20.0 0.220
  5 30.500     0  219.0      3.70     0.660     120.0     0.250E+05   20.0 0.220
  6 32.600     0  219.0      3.80     0.660     120.0     0.238E+05   24.0 0.200
  7 32.700     1  224.0      3.80     0.660     120.0     0.238E+05   24.0 0.200
  8 35.200     0
Branch  3 has 10 xsects & routes 1.00 of flow at JNCT  2 To JNCT  4
Grd R Mile  IOUT  Disch        A1        A2        A0        DF         W1    W2
  1 35.200     0  228.0      3.80     0.660     170.0     0.238E+05   24.0 0.200
  2 37.300     0  256.0      3.80     0.660     220.0     0.841E+05   30.0 0.160
  3 37.400     0  291.0      3.70     0.660     240.0     0.841E+05   30.0 0.160
  4 38.600     0  291.0      3.70     0.660     240.0     0.841E+05   30.0 0.160
  5 40.700     0  291.0      3.70     0.660     300.0     0.841E+05   30.0 0.160
  6 44.700     0  291.0      3.60     0.660     360.0     0.497E+05   37.0 0.120
  7 45.600     0  291.0      3.60     0.660     440.0     0.203E+05   42.0 0.110
  8 47.400     0  291.0      3.60     0.660     400.0     0.203E+05   42.0 0.110
  9 52.800     1  291.0      3.60     0.660     400.0     0.203E+05   42.0 0.110
 10 53.400     0
Branch    001Grid 001DSN 8213      silver cr.
Branch    001Grid 002DSN 8117      upper pudding
Branch    001Grid 003DSN 8119      middle pudding
Branch    001Grid 004DSN 8121      abiqua cr.
Branch    001Grid 006DSN 8123      little pudding
Branch    001Grid 007DSN 8125      pudding b4g5
Branch    002Grid 002DSN 8127      zolner cr.
```

FLOW.IN file for DAFLOW modeling—Continued

```
Branch    002Grid 003DSN 8129      pudding b4g6
Branch    002Grid 007DSN 8131      butte cr.
Branch    003Grid 002DSN 8133      rock cr.
Branch    003Grid 003DSN 8139      pudding b5g3
Branch    003Grid 007DSN 8137      mill cr.
Branch    003Grid 006DSN 1010      Aurora simulation
```

The *BLTM.IN* file for modeling the upper reach:

```
pudding - branch 1 - dye input at RM 45.5
HEADER 1         3      2    120      1      0      1      1      0      1
HEADER 2      0.50   0.10
LABEL            1    DYE       1
BRANCH   1       8   0.06       3      1      1
 GRID    1  0.000       0   0.00
 GRID    2  3.500       0   0.00
 GRID    3  7.200       0   0.00
 GRID    4  7.300       1   0.00
 GRID    5 12.100       1   0.00
 GRID    6 15.900       0   0.00
 GRID    7 17.000       1   0.00
 GRID    8 21.300       0
BRANCH   2       8   0.15       1      2      1
 GRID    1 21.300       1   0.00
 GRID    2 23.700       0   0.00
 GRID    3 23.800       0   0.00
 GRID    4 25.800       0   0.00
 GRID    5 30.500       0   0.00
 GRID    6 32.600       0   0.00
 GRID    7 32.700       0   0.00
 GRID    8 35.200       0
BRANCH   3      10   0.12       2      4      1
 GRID    1 35.200       0   0.00
 GRID    2 37.300       0   0.00
 GRID    3 37.400       0   0.00
 GRID    4 38.600       0   0.00
 GRID    5 40.700       0   0.00
 GRID    6 44.700       0   0.00
 GRID    7 45.600       0   0.00
 GRID    8 47.400       0   0.00
 GRID    9 52.800       0   0.00
 GRID   10 53.400       0
TIME     1       0
TIME     2       0
TIME     3       0
*** left out missing repetitious cards to save space in printing ***
TIME    37       0
TIME    38       0
```

BLTM.IN file for modeling the upper reach—Continued

```
TIME    39      0
TIME    40      1
 B  1 G  4   0.56
TIME    41      1
 B  1 G  4   5.14
TIME    42      1
 B  1 G  4   16.8
TIME    43      1
 B  1 G  4   22.1
TIME    44      1
 B  1 G  4   17.6
TIME    45      1
 B  1 G  4   13.8
TIME    46      1
 B  1 G  4   7.51
TIME    47      1
 B  1 G  4   5.16
TIME    48      1
 B  1 G  4   2.81
TIME    49      1
 B  1 G  4   1.64
TIME    50      1
 B  1 G  4   0.53
TIME    51      1
 B  1 G  4   0.46
TIME    52      1
 B  1 G  4   0.22
TIME    53      0
TIME    54      1
 B  1 G  4   0.16
TIME    55      1
 B  1 G  4   0.13
TIME    56      1
 B  1 G  4   0.08
TIME    57      0
TIME    58      0
TIME    59      1
 B  1 G  4   0.05
TIME    60      0
TIME    61      0
TIME    62      1
 B  1 G  4   0.03
TIME    63      0
TIME    64      0
TIME    65      1
 B  1 G  4   0.01
TIME    66      0
TIME    67      0
TIME    68      0
*** left out missing repetitious cards to save space in printing ***
TIME   118      0
TIME   119      0
TIME   120      0
```

The *BLTM.IN* file for modeling the middle reach:

```
pudding - branch 2 - dye input at RM 31.5
HEADER 1        3     2   240      1      0      1      1      0      1
HEADER 2     0.25  0.10
LABEL           1  DYE      1
BRANCH   1      8  0.06     3      1      1
 GRID    1  0.000     0  0.00
 GRID    2  3.500     0  0.00
 GRID    3  7.200     0  0.00
 GRID    4  7.300     0  0.00
 GRID    5 12.100     0  0.00
 GRID    6 15.900     0  0.00
 GRID    7 17.000     0  0.00
 GRID    8 21.300     0
BRANCH   2      8  0.15     1      2      1
 GRID    1 21.300     1  0.00
 GRID    2 23.700     0  0.00
 GRID    3 23.800     0  0.00
 GRID    4 25.800     1  0.00
 GRID    5 30.500     1  0.00
 GRID    6 32.600     0  0.00
 GRID    7 32.700     0  0.00
 GRID    8 35.200     0
BRANCH   3     10  0.12     2      4      1
 GRID    1 35.200     1  0.00
 GRID    2 37.300     0  0.00
 GRID    3 37.400     0  0.00
 GRID    4 38.600     0  0.00
 GRID    5 40.700     0  0.00
 GRID    6 44.700     0  0.00
 GRID    7 45.600     0  0.00
 GRID    8 47.400     0  0.00
 GRID    9 52.800     0  0.00
 GRID   10 53.400     0
TIME     1      0
TIME     2      0
TIME     3      0
*** left out missing repetitious cards to save space in printing ***
TIME    64      0
TIME    65      0
TIME    66      1
 B  2 G  1   0.08
TIME    67      1
 B  2 G  1   1.15
TIME    68      1
 B  2 G  1   4.95
TIME    69      1
 B  2 G  1  13.27
TIME    70      1
 B  2 G  1  20.66
TIME    71      1
 B  2 G  1  22.20
TIME    72      1
```

BLTM.IN file for modeling the middle reach—Continued

```
 B  2 G  1  19.21
TIME    73      1
 B  2 G  1  13.38
TIME    74      1
 B  2 G  1   8.59
TIME    75      1
 B  2 G  1   5.47
TIME    76      1
 B  2 G  1   3.08
TIME    77      1
 B  2 G  1   1.73
TIME    78      1
 B  2 G  1   0.95
TIME    79      1
 B  2 G  1   0.00
TIME    80      0
TIME    81      0
TIME    82      0
*** left out missing repetitious cards to save space in printing ***
TIME   238      0
TIME   239      0
TIME   240      0
```

The *BLTM.IN* file for modeling the lower reach:

```
pudding - branch 3 - dye input at RM 17.6
HEADER 1       3      2    240      1      0      1      1      0      1
HEADER 2     0.25   0.10
LABEL          1    DYE      1
BRANCH   1     8   0.06      3      1      1
 GRID    1  0.000      0   0.00
 GRID    2  3.500      0   0.00
 GRID    3  7.200      0   0.00
 GRID    4  7.300      0   0.00
 GRID    5 12.100      0   0.00
 GRID    6 15.900      0   0.00
 GRID    7 17.000      0   0.00
 GRID    8 21.300      0
BRANCH   2     8   0.15      1      2      1
 GRID    1 21.300      0   0.00
 GRID    2 23.700      0   0.00
 GRID    3 23.800      0   0.00
 GRID    4 25.800      0   0.00
 GRID    5 30.500      0   0.00
 GRID    6 32.600      0   0.00
 GRID    7 32.700      0   0.00
 GRID    8 35.200      0
BRANCH   3    10   0.12      2      4      1
 GRID    1 35.200      1   0.00
 GRID    2 37.300      0   0.00
 GRID    3 37.400      0   0.00
```

BLTM.IN file for modeling the lower reach—Continued

```
 GRID    4 38.600      1   0.00
 GRID    5 40.700      1   0.00
 GRID    6 44.700      1   0.00
 GRID    7 45.600      0   0.00
 GRID    8 47.400      1   0.00
 GRID    9 52.800      0   0.00
 GRID   10 53.400      0
TIME     1       0
TIME     2       0
TIME     3       0
*** left out missing repetitious cards to save space in printing ***
TIME    60       0
TIME    61       0
TIME    62       1
 B  3 G  1   0.01
TIME    63       0
TIME    64       1
 B  3 G  1   0.02
TIME    65       0
TIME    66       1
 B  3 G  1   0.03
TIME    67       0
TIME    68       0
TIME    69       1
 B  3 G  1   0.04
TIME    70       0
TIME    71       1
 B  3 G  1   0.05
TIME    72       0
TIME    73       1
 B  3 G  1   0.63
TIME    74       1
 B  3 G  1   3.52
TIME    75       1
 B  3 G  1   8.31
TIME    76       1
 B  3 G  1  14.41
TIME    77       1
 B  3 G  1  16.59
TIME    78       1
 B  3 G  1  15.66
TIME    79       1
 B  3 G  1  12.95
TIME    80       1
 B  3 G  1  10.20
TIME    81       1
 B  3 G  1   6.14
TIME    82       1
 B  3 G  1   3.69
TIME    83       1
 B  3 G  1   2.01
TIME    84       1
```

BLTM.IN file for modeling the lower reach—Continued

```
 B  3 G  1   1.04
TIME    85      1
 B  3 G  1   0.73
TIME    86      1
 B  3 G  1   0.33
TIME    87      1
 B  3 G  1   0.25
TIME    88      1
 B  3 G  1   0.18
TIME    89      1
 B  3 G  1   0.16
TIME    90      1
 B  3 G  1   0.14
TIME    91      1
 B  3 G  1   0.12
TIME    92      1
 B  3 G  1   0.11
TIME    93      0
TIME    94      0
TIME    95      1
 B  3 G  1   0.08
TIME    96      1
 B  3 G  1   0.06
TIME    97      1
 B  3 G  1   0.18
TIME    98      1
 B  3 G  1   0.08
TIME    99      1
 B  3 G  1   0.04
TIME   100      1
 B  3 G  1   0.00
TIME   101      0
TIME   102      0
TIME   103      0
*** left out missing repetitious cards to save space in printing ***
TIME   238      0
TIME   239      0
TIME   240      0
```