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Simulation of Flow and Water Quality of the Arroyo Colorado, Texas, 1989–99

Water-Resources Investigations Report 02–4110

U.S. Department of the Interior
U.S. Geological Survey

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By Timothy H. Raines and Roger M. Miranda

U.S. GEOLOGICAL SURVEY
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and the Nueces River Authority

Austin, Texas
2002

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Simulation of Flow and Water Quality of the Arroyo Colorado, Texas, 1989–99

By Timothy H. Raines[1] *and* Roger M. Miranda[2]

Abstract

A model parameter set for use with the Hydrological Simulation Program—FORTRAN watershed model was developed to simulate flow and water quality for selected properties and constituents for the Arroyo Colorado from the city of Mission to the Laguna Madre, Texas. The model simulates flow, selected water-quality properties, and constituent concentrations. The model can be used to estimate a total maximum daily load for selected properties and constituents in the Arroyo Colorado. The model was calibrated and tested for flow with data measured during 1989–99 at three streamflow-gaging stations. The errors for total flow volume ranged from -0.1 to 29.0 percent, and the errors for total storm volume ranged from -15.6 to 8.4 percent. The model was calibrated and tested for water quality for seven properties and constituents with 1989–99 data. The model was calibrated sequentially for suspended sediment, water temperature, biochemical oxygen demand, dissolved oxygen, nitrate nitrogen, ammonia nitrogen, and orthophosphate. The simulated concentrations of the selected properties and constituents generally matched the measured concentrations available for the calibration and testing periods. The model was used to simulate total point- and nonpoint-source loads for selected properties and constituents for 1989–99 for urban, natural, and agricultural land-use types. About one-third to one-half of the biochemical oxygen demand and nutrient loads are from urban point and nonpoint sources, although only 13 percent of the total land use in the basin is urban.

[1] U.S. Geological Survey
[2] Texas Natural Resource Conservation Commission

INTRODUCTION

The Arroyo Colorado is located in the Lower Rio Grande Valley of South Texas and extends from near Mission, Tex., eastward to the Laguna Madre (fig. 1). Streamflow in the Arroyo Colorado primarily is sustained by effluent from municipal wastewater-treatment plants. Additional streamflow results from irrigation return flow, storm runoff, and other point-source discharges. The Arroyo Colorado is used as a floodway, an inland waterway, and a recreational area for swimming, boating, and fishing, and is an important nursery and foraging area for shrimp, crab, and several types of marine fish.

The Texas Natural Resource Conservation Commission (TNRCC) has classified two reaches of the Arroyo Colorado on the basis of the physical characteristics of the stream (fig. 1). Segment 2201, from the port of Harlingen to the confluence with the Laguna Madre, is tidally influenced and has designated uses of contact recreation and high aquatic life. The nontidal segment of the Arroyo Colorado, Segment 2202, has designated uses of contact recreation and intermediate aquatic life. The tidal segment of the Arroyo Colorado, Segment 2201, has failed to meet the water-quality criteria required for its designated uses and is included on the State 303(d) list of impaired water bodies for dissolved oxygen (DO) levels below the criteria specified in the Texas Surface-Water-Quality Standards (Texas Natural Resource Conservation Commission, 1997).

A total maximum daily load (TMDL) must be determined for the Arroyo Colorado as required by the 1972 Federal Clean Water Act because Segment 2201 is identified on the 303(d) list for failure to meet the DO water-quality standards. The TMDL process is

Figure 1. Arroyo Colorado Basin, Texas.

designed to specify how existing and future loadings need to be allocated to meet water-quality standards. Quantitatively, a TMDL is the sum of all existing and future point-source waste-load allocations, existing and future nonpoint-source pollutant or background loadings, and a margin of safety to account for loading uncertainty.

Simulation models typically are used to estimate TMDLs because the models are developed to represent the cause-and-effect relations between natural inputs to an aquatic ecosystem and the resulting water quality. Several best-management practice (BMP) alternatives can be evaluated objectively using simulation models to determine what changes will be needed to meet the water-quality standards.

The U.S. Geological Survey, in cooperation with the TNRCC and the Nueces River Authority, began a study in 1998 to simulate the flow and the water quality of selected constituents in the Arroyo Colorado. Working jointly with the TNRCC, specific objectives of the study were to (1) set up a simulation model of the Arroyo Colorado Basin that would allow different BMPs to be used by the TNRCC to estimate the TMDL for selected constituents to meet DO water-quality standards, and (2) calibrate and test a set of process-related model parameters with available streamflow and water-quality data for the Arroyo Colorado.

Purpose and Scope

This report describes the setup, calibration, and testing of a model to simulate the flow and water quality of the Arroyo Colorado. The basin was subdivided into 12 subbasins—four in Segment 2201 and eight in Segment 2202. The basin was characterized by a set of 26 pervious land segments that were defined on the basis of types of land use and soil and a set of three impervious land segments that were defined on the basis of types of land use only. Eight reaches were defined for the eight subbasins in the non-tidal segment. No reaches were used for the tidal segment. Six basin-related parameters were defined for each stream reach. For flow, a total of 18 process-related parameters were defined and calibrated for each land segment. For water quality, a total of 31 process-related parameters were defined and calibrated for each land segment, and 75 process-related parameters were defined and calibrated for each stream reach.

Eleven years (1989–99) of precipitation, evaporation, air temperature, dewpoint temperature, wind speed, cloud cover, solar radiation, streamflow, and water-quality data were used for model calibration and testing. Precipitation data from three stations were used; evaporation data from one station were used; streamflow data from three stations were used; and suspended sediment, biochemical oxygen demand (BOD), DO, nitrate nitrogen, ammonia nitrogen, and orthophosphate from three stations were used. Additional streamflow and water-quality data were collected at several locations along the Arroyo Colorado during low flow in June 1998 and during high flow after a storm in March 1999.

Description of Study Area

The study area is in South Texas in the Lower Rio Grande Valley (fig. 1). The Arroyo Colorado flows about 90 miles from west to east and drains about 700 square miles, excluding the North Floodway. The basin is located in parts of Hidalgo, Cameron, and Willacy Counties.

The study area is located in the neotropical Southern Coastal Plain physiographic region and is characterized by long, hot summers and short, mild winters. The mean annual temperature is 73 degrees Fahrenheit (°F) with mean monthly temperatures ranging from 58 °F in January to 84 °F in July. Mean annual evaporation in the study area is about 58 inches. Mean annual precipitation ranges from about 21 to 27 inches, generally from west to east, in the basin (National Oceanic and Atmospheric Administration, 1996). Most of the annual precipitation results from frontal storms and tropical storms. Widely scattered convective thunderstorms also produce precipitation during the summer.

The soils are clays, clay loams, and sandy loams. The major soil series comprise the Harlingen, Hidalgo, Mercedes, Raymondville, Rio Grande, and Willacy (U.S. Department of Agriculture, Soil Conservation Service, 1977, 1981–82). Most soil depths range from about 63 to 78 inches. The Harlingen, Mercedes, and Raymondville soil series consist predominantly of clay soils with low permeability classified as hydrologic soil group D. A representative soil profile consists of about

71 to 78 inches of clay. The Hidalgo, Rio Grande, and Willacy soil series consist predominantly of sandy loam and sandy clay loam soils with moderate permeability classified as hydrologic soil group B. A representative soil profile consists of about 14 to15 inches of sandy loam overlying 48 to 60 inches of sandy clay loam.

The flat terrain is extensively cultivated and irrigated for agriculture. Water for irrigation is taken from the Rio Grande and moved through canals to the fields by numerous irrigation districts located in the basin. The irrigation districts provide water for irrigation of citrus, sugar cane, and several types of row crops including corn, grain sorghum, and cotton. Irrigation practices consist of flooding fields with a specified depth of water during periods of insufficient precipitation to produce desired crop yields.

Urbanization is extensive in the areas directly adjacent to the main stem of the Arroyo Colorado, particularly in the western and central parts of the basin. Principal urban areas include the cities of Mission, McAllen, Pharr, Donna, Weslaco, Mercedes, Harlingen, and San Benito (fig. 1). Recent (1995) 1:24,000-scale land-use data were obtained for this study from high-resolution aerial photography (M.P. Stier, U.S. Geological Survey, written commun., 1999).

Of the 21 permitted dischargers in the Arroyo Colorado Basin, 16 are municipal, three are industrial, and two are shrimp farms. The discharge permit limits of the municipal plants range from 0.4 to 10 million gallons per day. The shrimp farms discharge infrequently.

Description of Simulation Model

The Hydrological Simulation Program—FORTRAN (HSPF) (Bicknell and others, 1997) is a continuous-simulation model using a conceptual framework to represent infiltration, evaporation, interception storage, surface runoff, interflow, and base flow on a pervious land segment (PERLND) and retention storage and surface runoff on an impervious land segment (IMPLND). Each user-defined land segment represents its own unique hydrologic response system on the basis of land cover, soil type, watershed slope, or other basin characteristic. These land segments do not need to be contiguous. The runoff from each land segment is moved through a system of channel or reservoir reaches (RCHRES) using storage routing. In addition to runoff, water-quality concentrations for several constituents can be simulated for each land segment and reach.

HSPF uses input from three types of data: time series, process-related parameters, and basin-related parameters. At a minimum, continuous time series of precipitation and potential evaporation are needed for model simulations. Point-precipitation data, measured by rain gages, are assumed to be uniform over a land segment. Potential evaporation data can be estimated from measured pan evaporation or from minimum and maximum air temperatures. Time series of measured streamflow are needed for model calibration and testing. Time series of air temperature, dewpoint temperature, wind speed, cloud cover, and solar radiation are needed for simulation of water-quality constituents. Measured water-quality data for selected constituents are needed for calibration and testing.

Eighteen process-related parameters are used for flow and 106 process-related parameters are used for water quality for suspended sediment, water temperature, BOD, DO, nitrate nitrogen, ammonia nitrogen, and orthophosphate (table 1, at end of report). The 18 process-related parameters for flow represent the physical processes of infiltration, evapotranspiration, interception storage, surface runoff, interflow, and base flow for each land segment, and the 106 process-related parameters for water quality represent the physical processes of buildup and washoff of constituents, sediment transport, heat flux, BOD and DO kinetics, and the nutrient cycle. Some of the process-related parameters can be varied by month to represent seasonal variations. The HSPF users manual (Bicknell and others, 1997) provides a more complete description of each parameter. The process-related model parameters are adjusted to calibrate the model.

The six basin-related model parameters define the areal extent of each land segment, the reach length, and a table of values (FTABLE) of surface area, volume, and discharge as a function of depth for each reach of the basin (table 2, at end of report). These parameters represent the physical characteristics of each subbasin and associated reach and remain unchanged during model calibration and testing. These parameters can be changed to represent BMPs or other changes to the physical characteristics of the basin.

One set of process-related model parameters was developed to account for all unique land segments to provide confidence in the model results. The model parameters were calibrated with 1989–95 data for two stations and were tested temporally with 1996–99 data for the two stations. The model parameters were tested spatially with 1989–99 data for an additional station. The model calibration and testing of flow was facilitated by using an expert system interface developed by Lumb and others (1994) that provided graphics, error statistics, and advice on which parameters to modify. The model calibration and testing of water-quality constituents was done using Generation and Analysis of Model Simulation Scenarios (GenScn) developed by Kittle and others (1998).

Acknowledgments

The members of the Arroyo Colorado TMDL Science and Technical Advisory Committee provided valuable comments and suggestions during the course of the study. The streamflow data were provided by the International Boundary and Water Commission (IBWC). Tom Jobes of Aqua Terra Consultants provided valuable support and guidance during the setup and calibration of the HSPF water-quality modules.

SIMULATION OF FLOW AND WATER QUALITY OF THE ARROYO COLORADO

Time series of precipitation, evaporation, streamflow, point-source, and irrigation data were used for model input and calibration. Land-use and soils data were used to define PERLNDs and IMPLNDs. Basin-related and process-related parameters were estimated for each subbasin. The model was tested after calibration. An error analysis was done to identify sources of error.

Model Setup

The Arroyo Colorado Basin was subdivided into 12 subbasins, eight in the nontidal segment and four in the tidal segment, at locations of selected streamflow-gaging stations, water-quality sampling sites, or point sources (fig. 2). Streamflow data were available for three streamflow-gaging stations located at Weslaco, Mercedes, and Harlingen (fig. 2) that are operated by the IBWC. Daily precipitation data were available at three National Oceanic and Atmospheric Administration stations in or near the basin (McAllen, Weslaco, and Harlingen) and were disaggregated to an hourly time step using hourly precipitation data available at Brownsville. Evaporation data were available at the Weslaco station. Air temperature, dewpoint temperature, cloud cover, wind speed, and solar radiation data were available at the Brownsville station. Water-quality data for selected constituents collected periodically were available at three sites (fig. 2). Selected characteristics for each subbasin are listed in table 3 (at end of report).

Time series of monthly self-reporting data were available for the 21 point sources (fig. 3). The permitted limits of each point source are listed in table 4 at end of report. Generally the point-source dischargers were operating at about 60 percent of permitted capacity during 1989–99.

Water used for irrigation in the Arroyo Colorado Basin is diverted from the Rio Grande by about 20 irrigation districts (fig. 4) and conveyed to land owners. Monthly time series of the amount of water diverted for each irrigation district are available from TNRCC water-master reports. Because the actual amount and time that each farmer irrigated was unknown, a set irrigation schedule was used. Irrigation time series were estimated on the basis of annual crop needs corresponding to a wet, normal, or dry year and monthly distribution determined from the available monthly TNRCC water-master data from the irrigation districts. The amount of water diverted by each irrigation district was area-weighted by the percentage of the irrigation district within the Arroyo Colorado Basin. That amount was divided by the amount of irrigated land in the subbasin and summed for each year to determine an annual unit irrigation depth in inches. Thus, each year of 1989–99 was classified as either a wet, normal, or dry year by the amount of water per acre diverted each year. The irrigation schedules for each type of year and type of crop are listed in table 5 (at end of report).

Some of the water diverted for irrigation is lost to inefficiencies in the conveyance system. Daily time series of monthly irrigation losses were estimated using values for the irrigation efficiency of each irrigation district provided by Guy Fipps, Texas A&M University (written commun., 1999) and the available monthly TNRCC water-master data for each irrigation district. The sum of the water applied using the irrigation

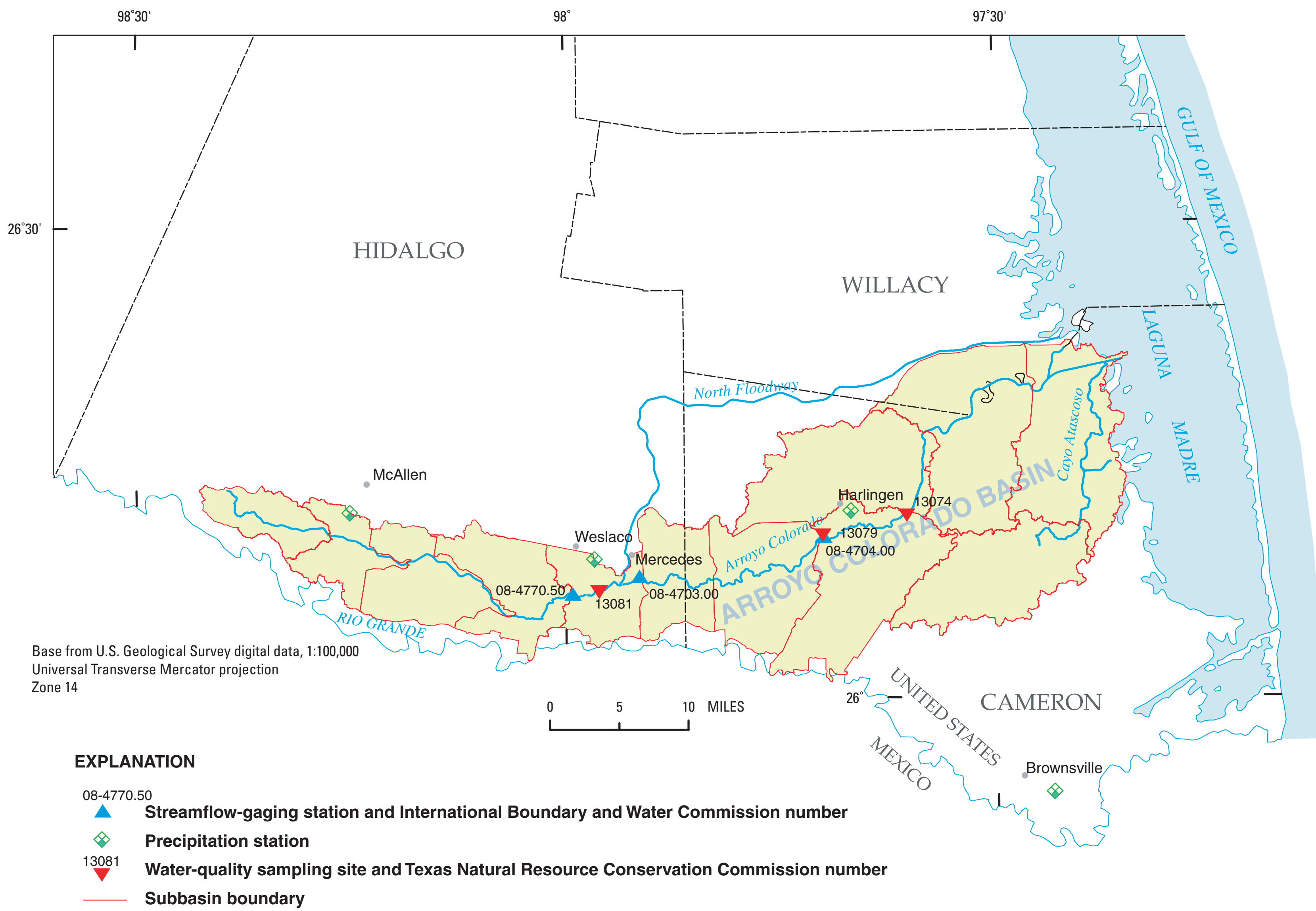

Figure 2. Arroyo Colorado subbasins and locations of selected streamflow-gaging and precipitation stations and water-quality sampling sites.

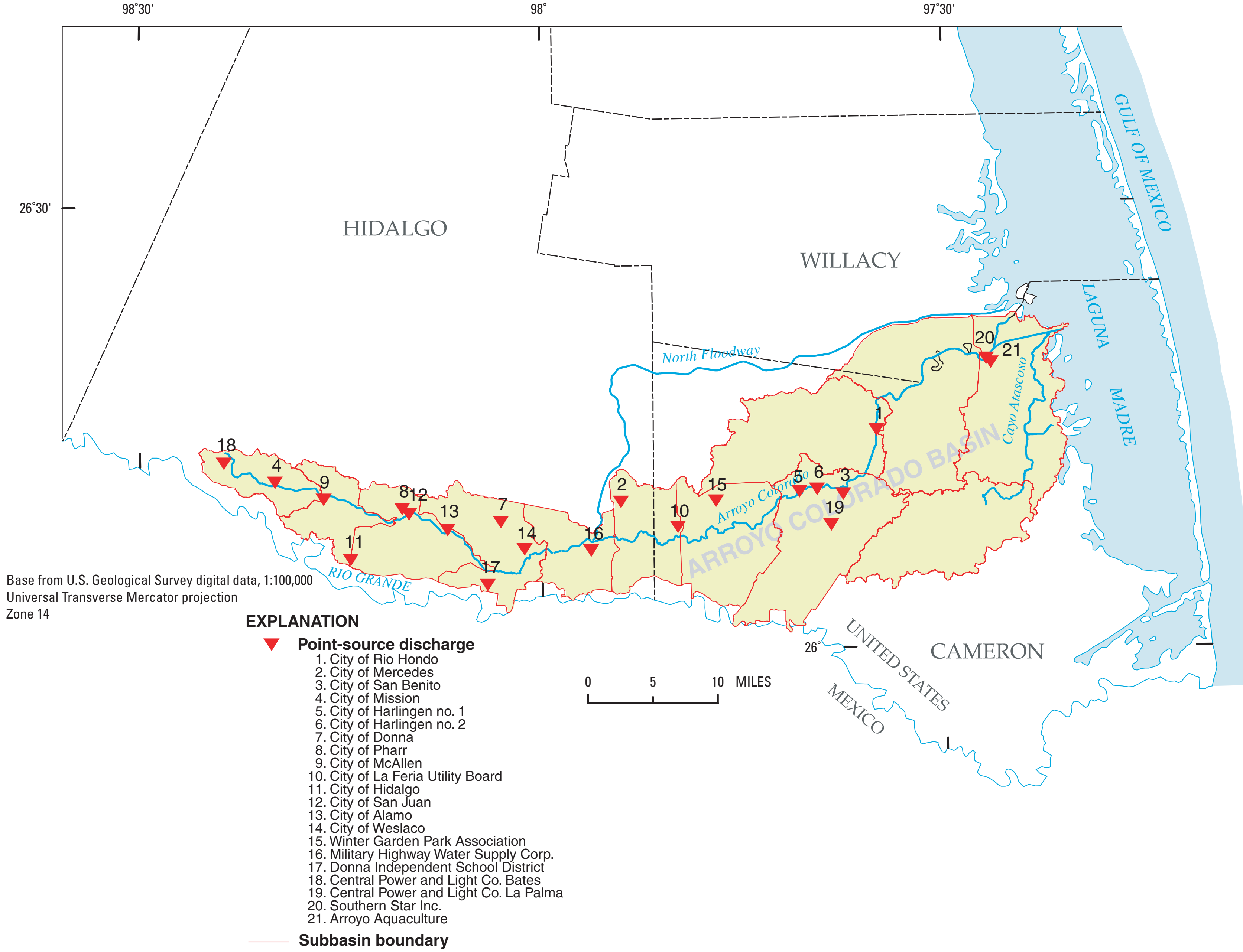

Figure 3. Locations of point-source discharges in the Arroyo Colorado subbasins.

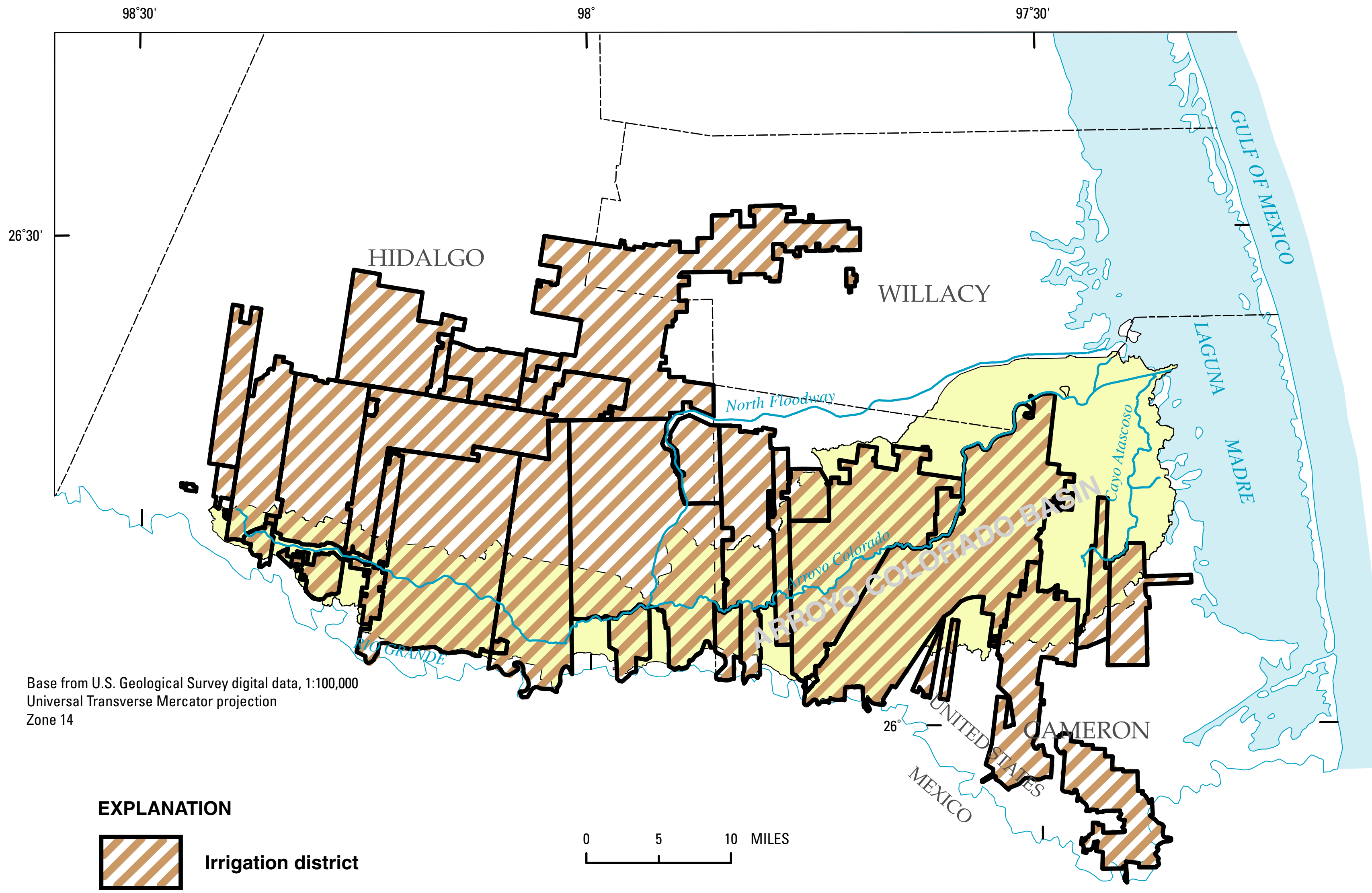

Figure 4. Irrigation districts in and adjacent to the Arroyo Colorado Basin.

schedules and the water lost during conveyance was compared to the total water diverted from the Rio Grande by the irrigation districts for a gross check of the water balance.

Eight major land-use types (low-density urban, high-density urban, natural vegetation, pasture and hay, row crops, citrus, sugar cane, and water and wetlands) were selected from the land-use data (fig. 5). All except water/wetlands were used to represent PERLNDs in the basin; three major land-use types (low-density urban, high-density urban, and water/wetlands) were used to represent IMPLNDs in the basin. The row crops were further subdivided into irrigated and nonirrigated row crops. The citrus and sugar cane were further subdivided into tile drained and nontile drained on the basis of information from Andy Garza, Texas State Soil and Water Conservation Board (written commun., 1999). The low-density urban land use was further subdivided into areas of land application of wastewater, colonias, and septic.

Soils in the basin were represented by two soil groups determined from county soil surveys (U.S. Department of Agriculture, Soil Conservation Service, 1977, 1981–82). The basin was divided into the two major soil groups on the basis of permeability and hydrologic soil group (fig. 6). Soil group 1 consists predominantly of clay soils with low permeability classified as hydrologic soil group D. Soil group 2 consists predominantly of clay loam and sandy loam soils with moderate permeability classified as hydrologic soil group B.

From the combinations of the two soil groups and the 14 land-use types, 26 unique PERLNDs (2 soil groups X 13 pervious land-use types) and three unique IMPLNDs (three impervious land-use types) were used. Because all fields are not irrigated at the same time, additional PERLNDs were used to account for the temporal variations in irrigation: The irrigated row crops were divided into 10 pieces, and the citrus and sugar cane (all irrigated) each were divided into three pieces. Therefore, an additional 34 PERLNDs (10 for row crops plus 12 each for citrus and sugar cane [2 soil groups X 2 land-use types X 3 pieces]) were used to account for all the irrigated agricultural land. All the PERLNDs associated with each major land-use type and soil group shared the same set of process-related parameters.

The basin-related parameters (table 6, at end of report) were estimated for each subbasin from geographic information system (GIS) coverages of the soils and land use, available channel cross-section data, and available rating tables for the streamflow-gaging stations.

Calibration and Testing of Flow

The HSPF model was calibrated for flow using data measured at the Weslaco and Harlingen streamflow-gaging stations (fig. 2) during January 1, 1989–December 31, 1995. Initial estimates for the 18 process-related parameters were (1) based on the physical properties of the land use or soil in the subbasins (Chow and others, 1988); (2) assigned the default values listed in table 1; or (3) taken from a previous study (Dean and others, 1984). The 15 calibrated annual parameters are listed in table 7 (at end of report), and the three calibrated monthly parameters are listed in table 8 (at end of report). Each parameter varied by land-use type or soil group corresponding to the physical process the parameter represents. For example, the parameters LZSN and INFILT varied by soil group and represented the different storage and infiltration capacities of the soil, whereas the parameters CEPSC, LZETP, and NSUR varied by land-use type and represented the different interception storages, evapotranspiration potentials, and surface roughness of the land-use types. The parameter AGWRC was assumed to be uniform for all land segments. The parameters INTFW, IRC, and NSUR were not varied monthly because iterative model simulations showed that the parameter values had little or no effect in explaining seasonal variations in runoff for this study area. For each land segment, the default values were used for the parameters AGWETP, BASETP, DEEPFR, INFEXP, INFILD, and KVARY. Values of the annual parameters AGWRC, INFILT, INTFW, IRC, LSUR, LZSN, NSUR, RETSC, and SLSUR and values of the monthly parameters CEPSC, LZETP, and UZSN were adjusted during the calibration process using the software program HSPEXP (Lumb and others, 1994). The starting values for the initial conditions were estimated from Dean and others (1984) and were revised during calibration.

The calibrated process-related parameter set for flow (tables 7–8, at end of report) was developed from 1989–95 data for the Weslaco and Harlingen

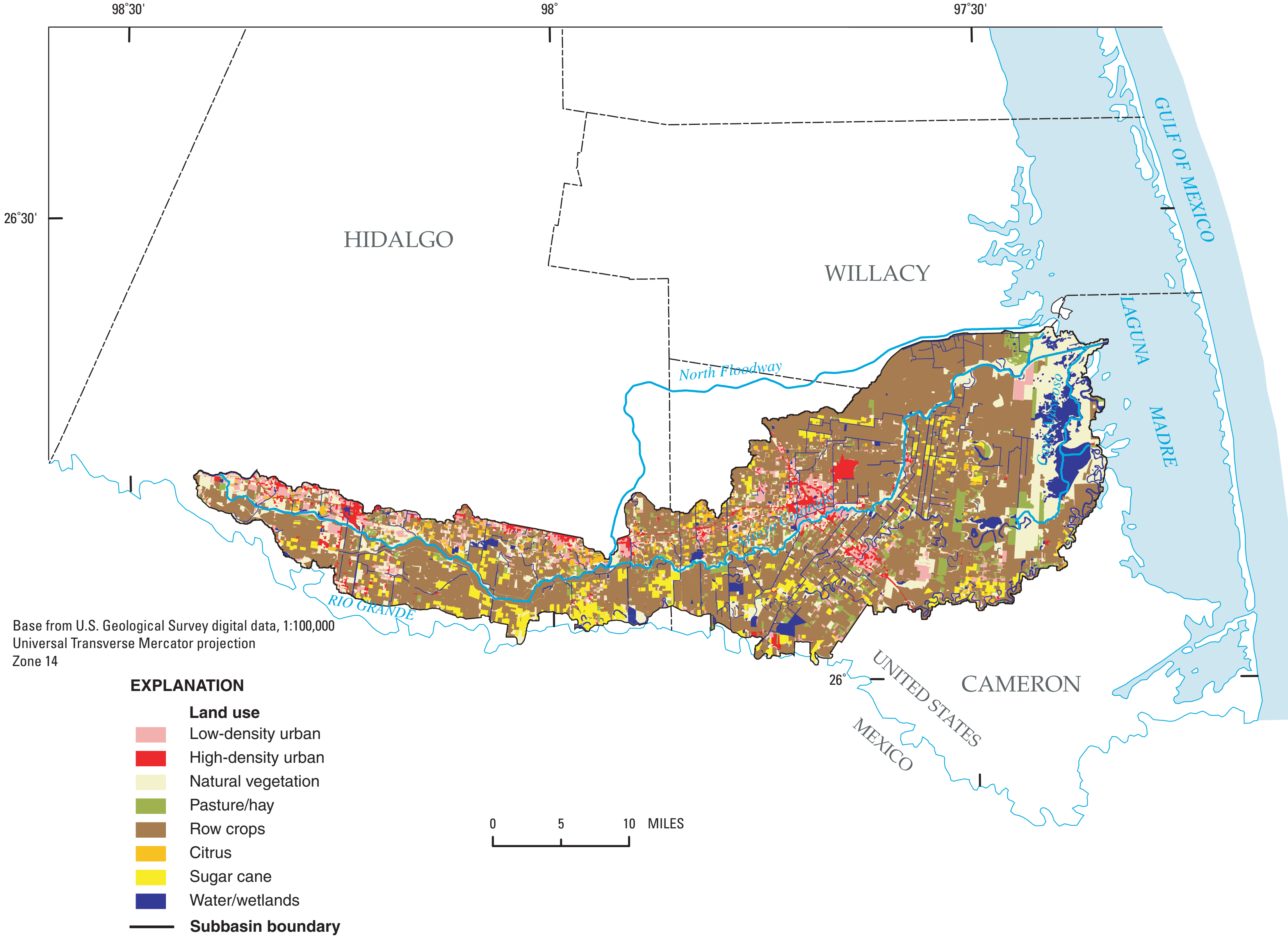

Figure 5. Land use in the Arroyo Colorado Basin, 1995 (M.P. Stier, U.S. Geological Survey, written commun., 1999).

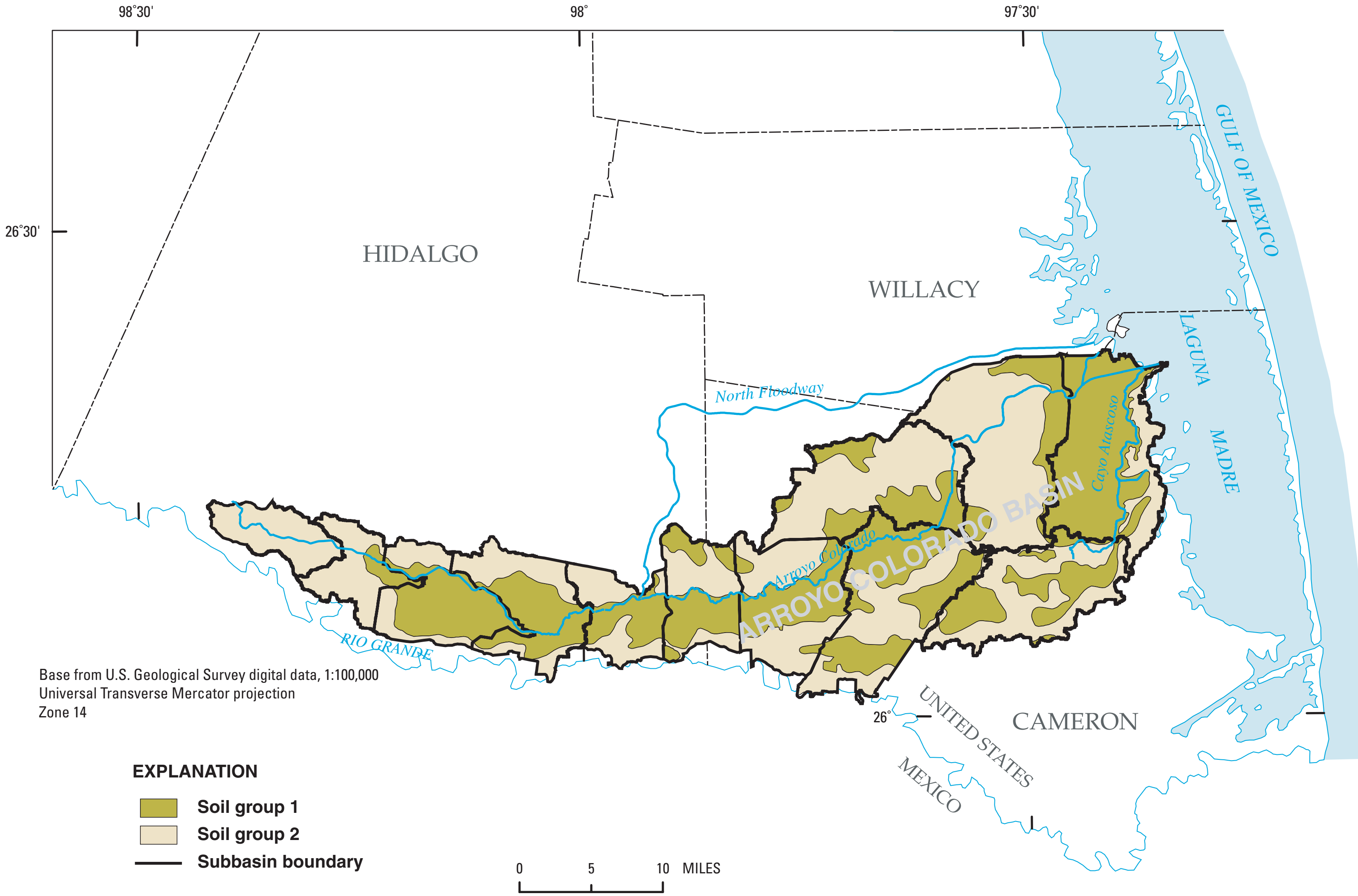

Figure 6. Major soil groups in the Arroyo Colorado Basin.

streamflow-gaging stations (fig. 2). Data collected during 1989–95 at the Mercedes streamflow-gaging station were used to test the parameters spatially, and data collected during 1996–99 at the Mercedes and Harlingen streamflow-gaging stations were used to test the parameters temporally. The parameter set was tested spatially to assess the transferability of the model parameters to ungaged subbasins including the subbasins located in the tidal segment. The spatial testing was done for the same time period that was used for model calibration. The parameter set was tested temporally to assess the ability of the model to accurately simulate under climatic conditions different from those for which the model was calibrated.

The measured and simulated flow volumes and errors for calibration and testing using HSPEXP (Lumb and others, 1994) are listed in table 9 (at end of report). The errors for total flow volume for calibration at Weslaco and Harlingen were both -0.1 percent, and the errors for total storm volume were -8.0 percent at Weslaco and -5.6 percent at Harlingen. The errors for the total of highest 10-percent and lowest 50-percent flows were all less than 6 percent for the two stations. Only the errors for summer flow and summer storm volumes at Weslaco exceeded 10 percent. Time series, flow-duration curves, and graphs of measured and simulated flow are shown in figures 7 and 8 for the Arroyo Colorado at Weslaco and at Harlingen. There appears to be a bias for low flows less than 100 ft^3/s (cubic feet per second) and high flows more than 600 ft^3/s at Weslaco (fig. 7); that is, there is a good match between measured and simulated flow between about 100 and 600 ft^3/s (between about the 90- and 1-percent exceedance probabilities). There is a good match between the measured and simulated flows at Harlingen except for discharges greater than about 1,000 ft^3/s (about 1-percent exceedance probability), which are undersimulated (fig. 8).

Data collected during 1989–95 at the Arroyo Colorado at Mercedes were used to test the parameters spatially (table 9). The error for total flow volume was 7.5 percent, and the error for total storm volume was -1.3 percent. The results are similar to the calibration results for Weslaco and Harlingen. The only errors that exceeded 10 percent were for summer flow and summer storm volumes. A time series, a flow-duration curve, and a graph of measured and simulated flow are shown in figure 9 for Arroyo Colorado at Mercedes. There is a good match between the measured and simulated flows at Mercedes except for discharges greater than about 700 ft^3/s (about 1-percent exceedance probability), which are undersimulated (fig. 9).

Data collected during 1996–99 at the Arroyo Colorado at Mercedes and at Harlingen were used to test the parameters temporally (table 9). The errors for total flow volume for the two stations were 29 and 11.2 percent, respectively, and the errors for total storm volume were 8.4 and -15.6 percent, respectively. The errors for the total of highest 10-percent flows were 13.2 and -12.5 percent, respectively; and the errors for summer flow and summer storm volumes were less than 20 percent. Time series, flow-duration curves, and graphs of measured and simulated flow are shown in figures 10 and 11 for the Arroyo Colorado at Mercedes and at Harlingen. There is a consistent bias for oversimulating discharges less than about 600 ft^3/s and undersimulating discharges greater than about 600 ft^3/s. The oversimulation appears to occur more frequently for the 1998–99 period.

Error Analysis of Flow

The types of error from the model calibration and testing can be classified as measurement errors or systematic errors. Measurement errors are introduced as a result of missing data and inaccurate rating tables of stage and discharge. Some daily precipitation data were missing and had to be estimated from other daily data. The spatial variability of precipitation for some storms might not be represented adequately with the existing network of rain gages. The streamflow-gaging station data were limited to only daily mean flows with no hourly data available for calibration and testing of the instantaneous peak flows. The main source of error in the model is associated with the distribution of irrigation water. The amount of water applied to the basin for irrigation is a substantial component of the water balance. It is impossible to accurately characterize the actual irrigation on every field in a time series for model input. The point-source data were limited to monthly data, which do not adequately represent the daily fluctuations of the effluent. Another substantial source of error in the water balance is evapotranspiration. More accurate estimates of actual evapotranspiration might reduce model error.

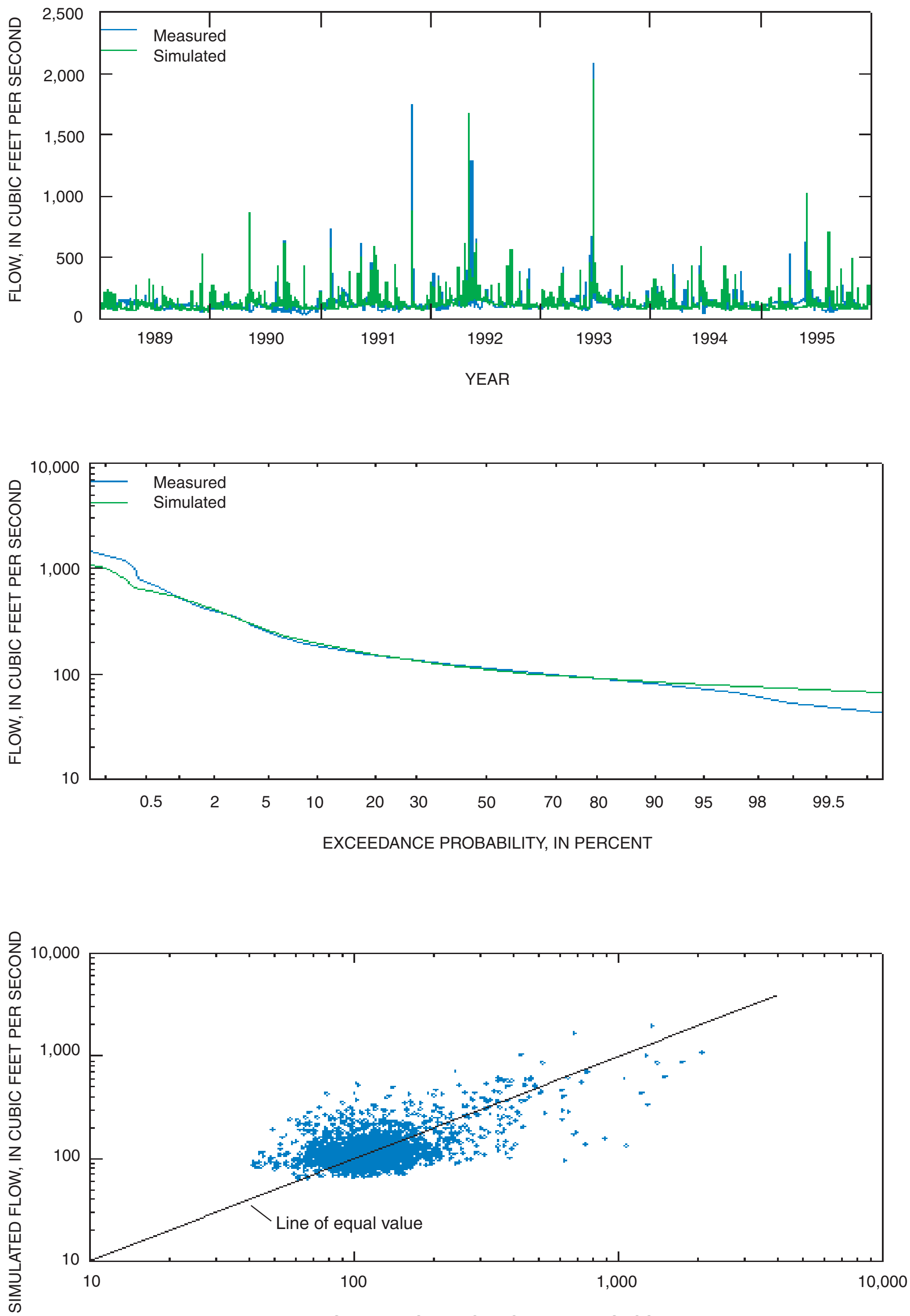

Figure 7. Measured and simulated daily streamflow at Arroyo Colorado at Weslaco, 1989–95.

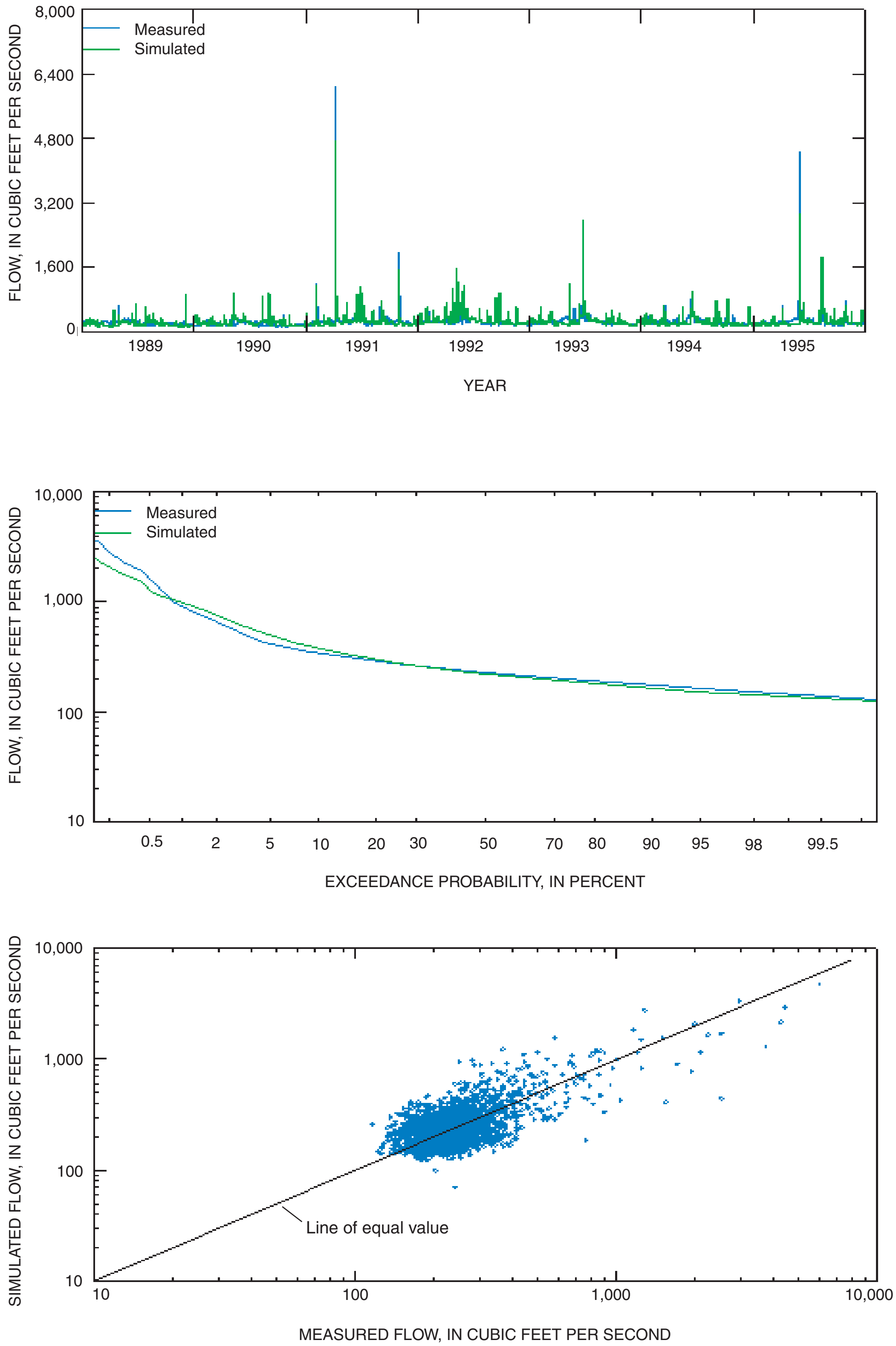

Figure 8. Measured and simulated daily streamflow at Arroyo Colorado at Harlingen, 1989–95.

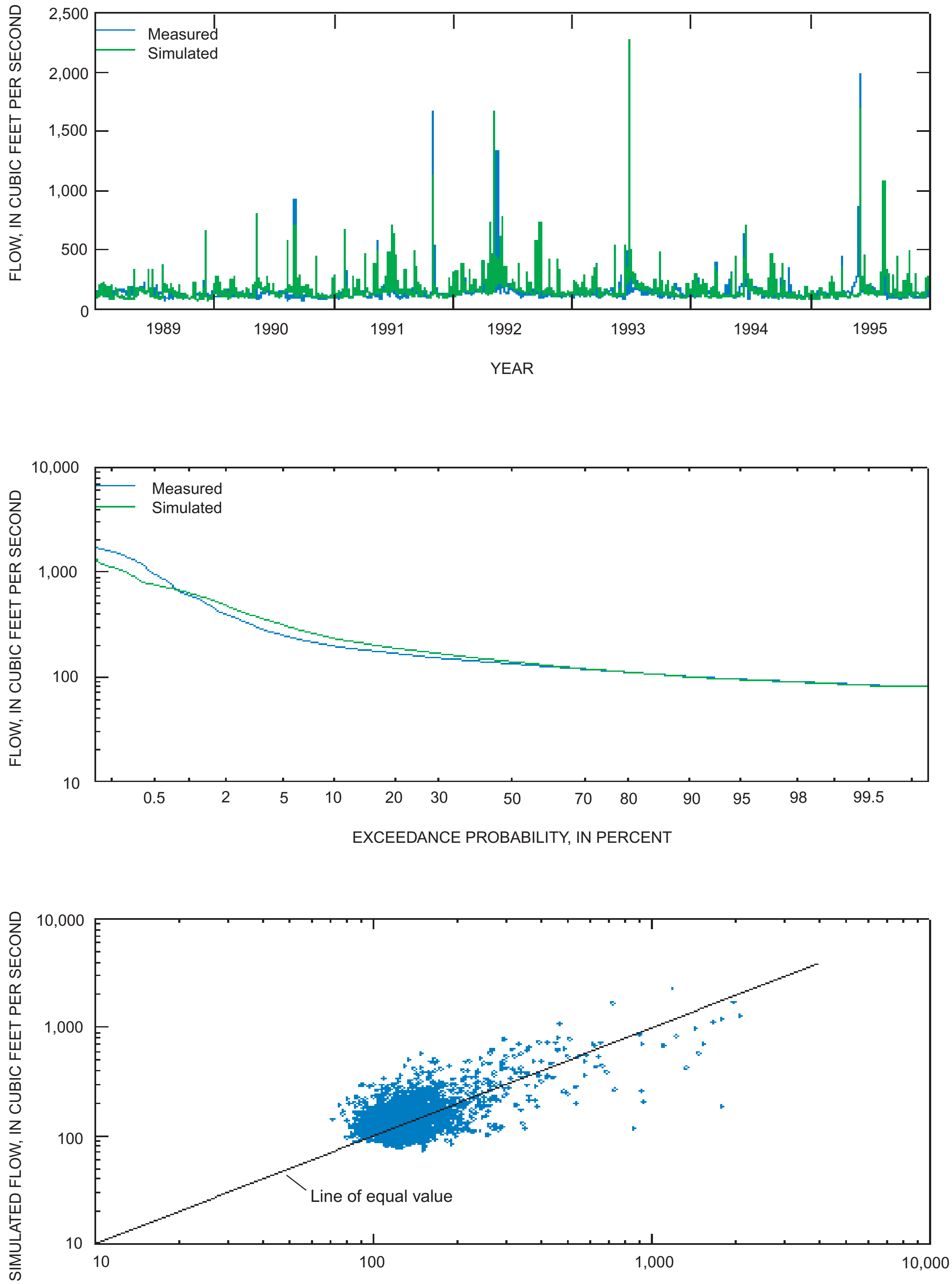

Figure 9. Measured and simulated daily streamflow at Arroyo Colorado at Mercedes, 1989–95.

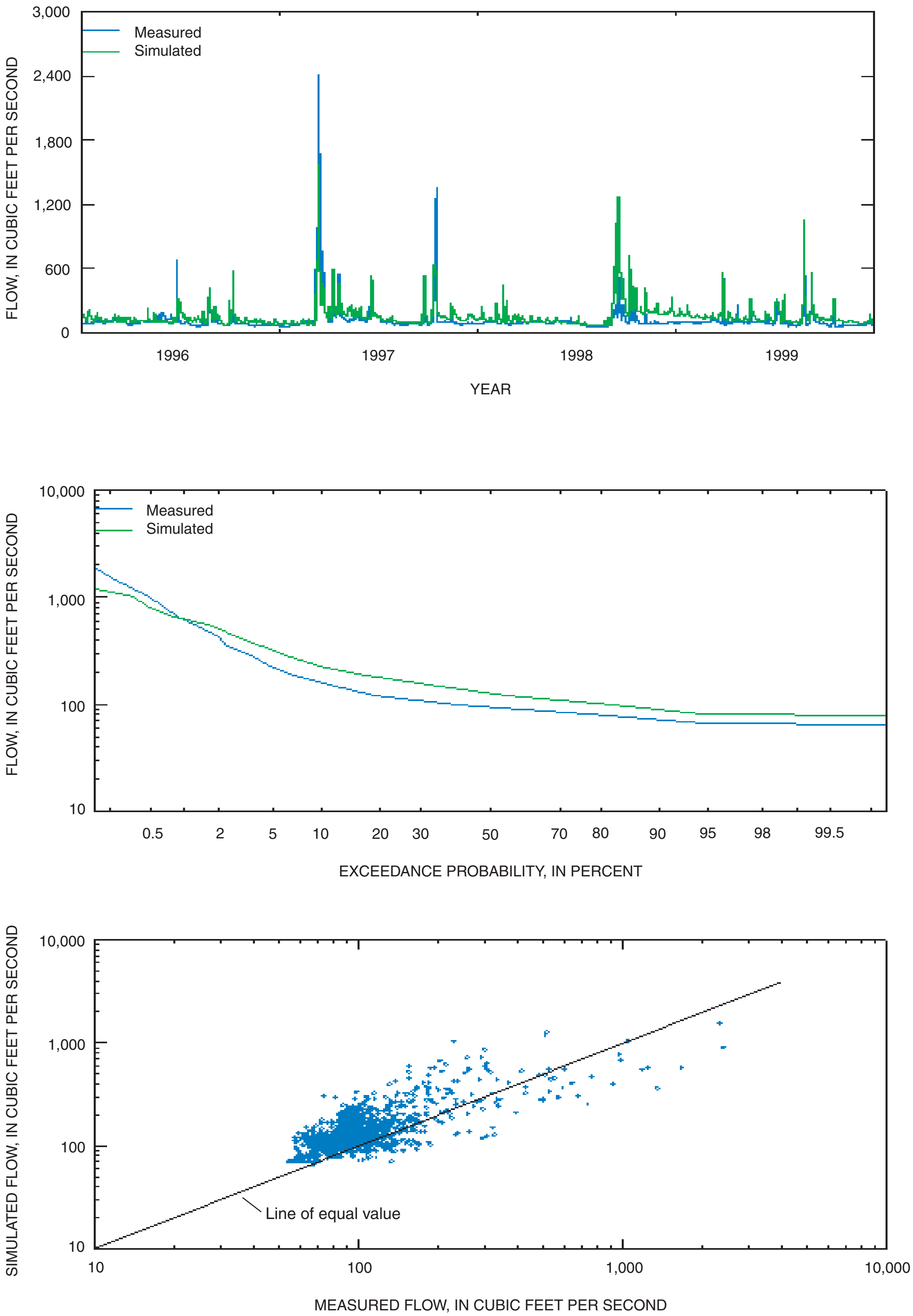

Figure 10. Measured and simulated daily streamflow at Arroyo Colorado at Mercedes, 1996–99.

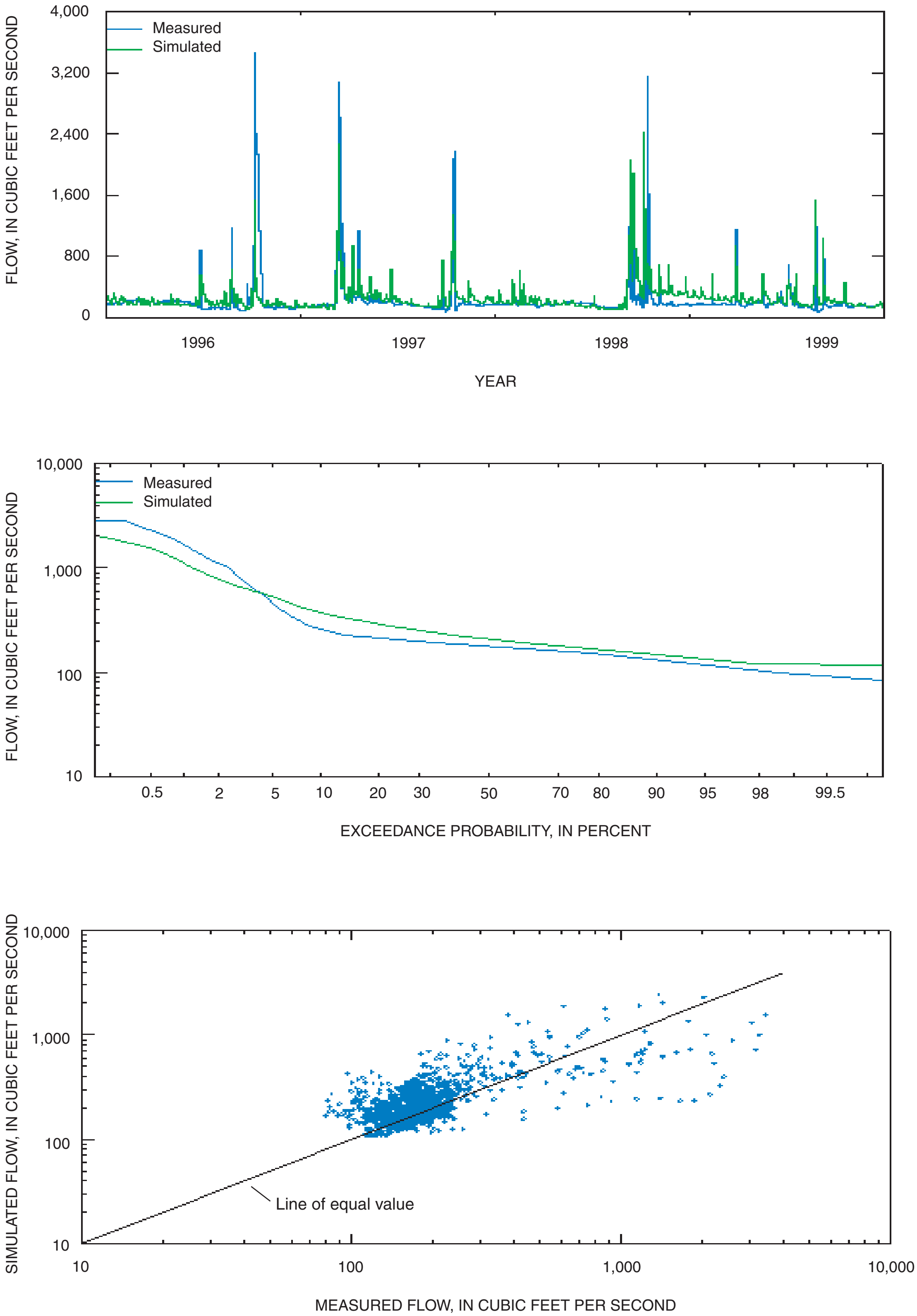

Figure 11. Measured and simulated daily streamflow at Arroyo Colorado at Harlingen, 1996–99.

Systematic errors are associated with the inability of the simulation model to represent the physical processes of runoff. These errors are contained in the model parameters and model equations, as the model parameters and equations inherently fall short of accurately and precisely accounting for all the variations in runoff. The PERLNDs used in this model are general representations of the different hydrologic response units of the study area. Also, the values of FTABLES are somewhat uncertain for the reach volume and the corresponding discharge.

The measurement and systematic errors account for some of the error and bias of the simulated flow. From the results listed in table 9 and shown in figures 7–11, the calibrated parameter set adequately simulates flow in the Arroyo Colorado. There could be a bias for undersimulating peak flows; but because low DO typically occurs during low flows, more emphasis was placed on fitting the model to low flows than to peak flows.

Calibration and Testing of Water Quality

The HSPF model was calibrated for selected water-quality properties and constituents primarily using data measured at the Weslaco and Harlingen streamflow-gaging stations (fig. 2) during January 1, 1989–December 31, 1995. The model was used to simulate suspended sediment, water temperature, BOD, DO, nitrate nitrogen, ammonia nitrogen, and orthophosphate. Initial estimates for the water-quality process-related parameters were (1) assigned the default values listed in table 1 or (2) taken from a previous study (Dean and others, 1984). Of the 106 process-related parameters used for water quality, the 19 calibrated annual parameters for each PERLND and IMPLND are listed in table 10 (at end of report), the 12 calibrated monthly parameters for each PERLND and IMPLND are listed in table 11 (at end of report), and the 75 calibrated annual parameters for each RCHRES are listed in table 12 (at end of report). Each parameter varied by land-use type for each PERLND or IMPLND or by reach for each RCHRES corresponding to the physical process the parameter represents. For example, the parameters AFFIX and COVER varied by land-use type and by month (COVER). The two parameters represented the different fractions for detached sediment storage and fractions of land surface shielded from erosion for each PERLND. The parameters TAUCD and TAUCS varied by RCHRES and streambed material and represented the different critical shear stress needed for deposition and for scour in each reach.

The calibrated parameter set (tables 10–12) was developed primarily from 1989–95 data collected at the Weslaco and Harlingen stations. Data collected during 1989–95 at the Segment 2202 outlet station were used to test the parameters spatially, and data collected during 1996–99 at the Weslaco, Harlingen, and Segment 2202 outlet stations were used to test the parameters temporally. Some intermediate calibration and testing results from selected PERLNDs and IMPLNDs for suspended sediment, BOD, nitrate nitrogen, ammonia nitrogen, and orthophosphate were compared to available event-mean concentration data from previous studies near the study area or in other parts of the State (table 13, at end of report). These comparisons were useful in modifying the buildup-washoff model parameters for the selected PERLNDs or IMPLNDs. However, event-mean concentrations were not available for all PERLNDs and IMPLNDs; in those cases, the model parameters were modified on the basis of professional judgment. The associated model parameters for each RCHRES were then calibrated and tested with data from the Weslaco, Harlingen, and Segment 2202 outlet stations.

The model was calibrated and spatially tested sequentially for seven selected properties and constituents in the following order: suspended sediment, water temperature, BOD, DO, nitrate nitrogen, ammonia nitrogen, and orthophospate for the period 1989–95. Because only periodic water-quality data were available for the calibration, the objective of the calibration and testing was to match the general shape of the time series of measured data. Instantaneous measured time series and daily simulated data for the seven selected properties and constituents are shown in figs. 12–18.

The simulated suspended sediment concentrations (fig. 12) for the Weslaco and Harlingen stations appear to match the low concentrations (less than 400 milligrams per liter); there are no measured concentrations to calibrate the high concentrations, however. No measured suspended sediment data were collected at the Segment 2202 outlet station.

The simulated water temperature matches the annual cycle of the measured water temperature fairly well at the three sites, although some of the higher

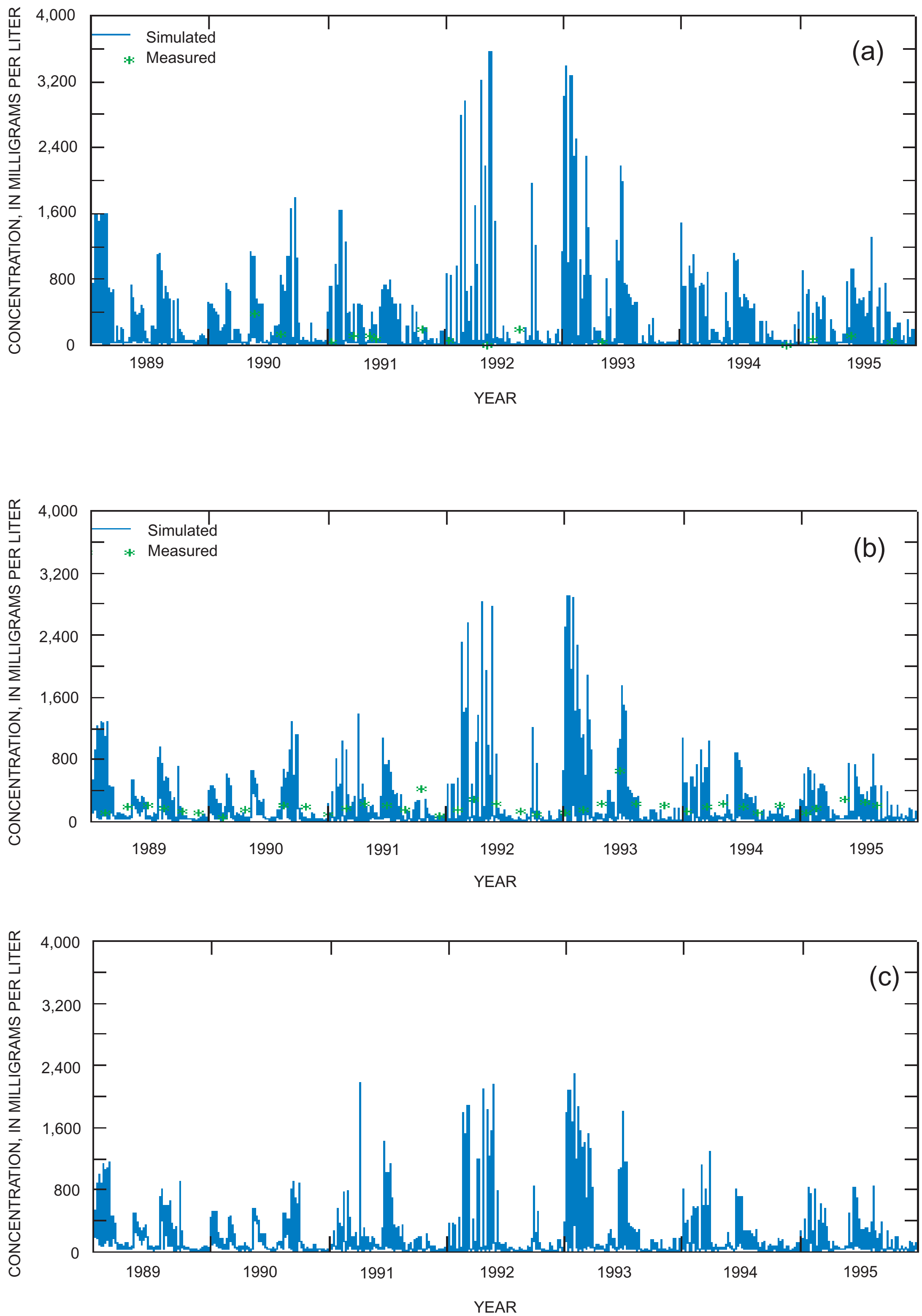

Figure 12. Measured and simulated suspended sediment concentrations, 1989–95, at Arroyo Colorado at (a) Weslaco, (b) Harlingen, and (c) Segment 2202 outlet (simulated only).

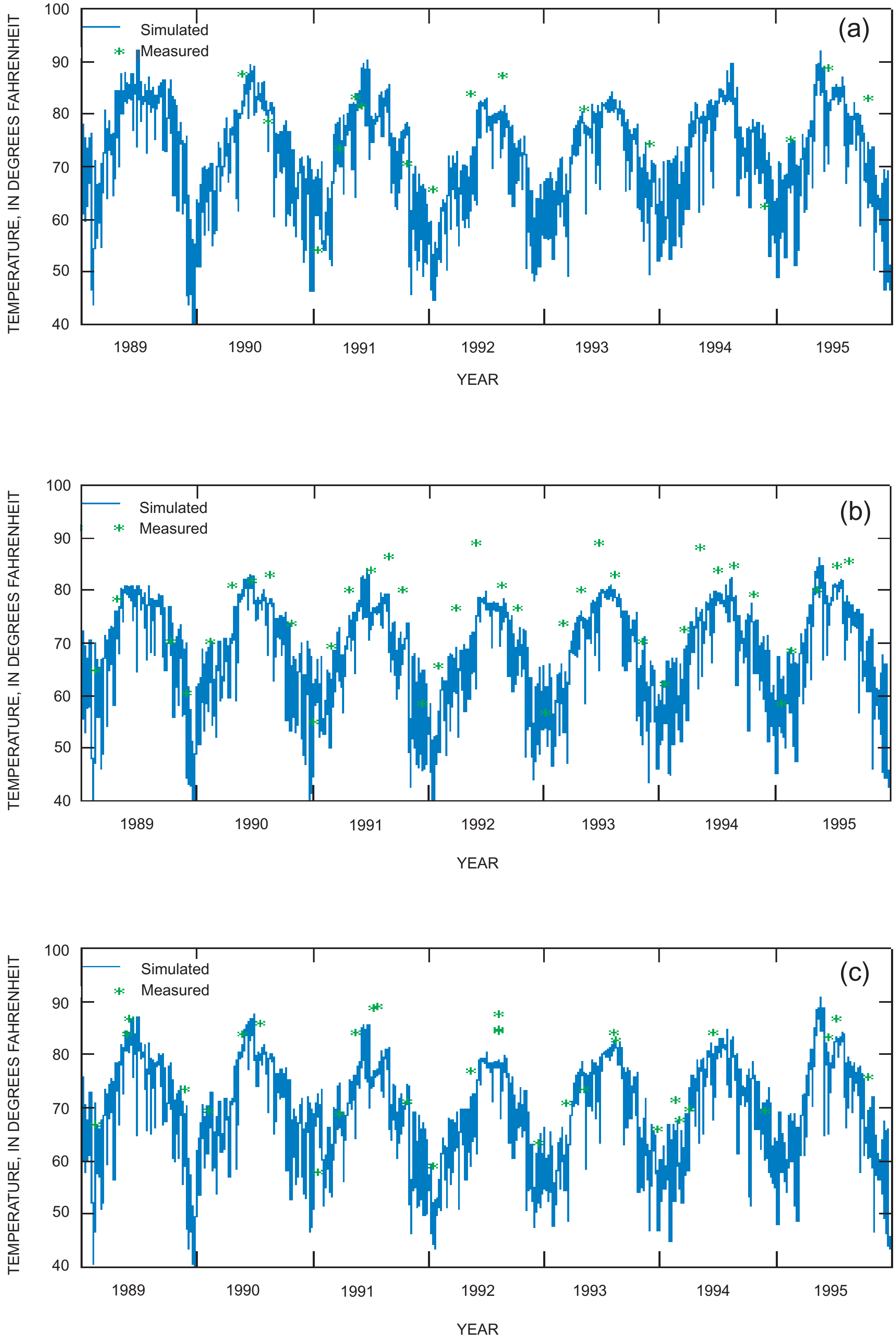

Figure 13. Measured and simulated water temperature, 1989–95, at Arroyo Colorado at (a) Weslaco, (b) Harlingen, and (c) Segment 2202 outlet.

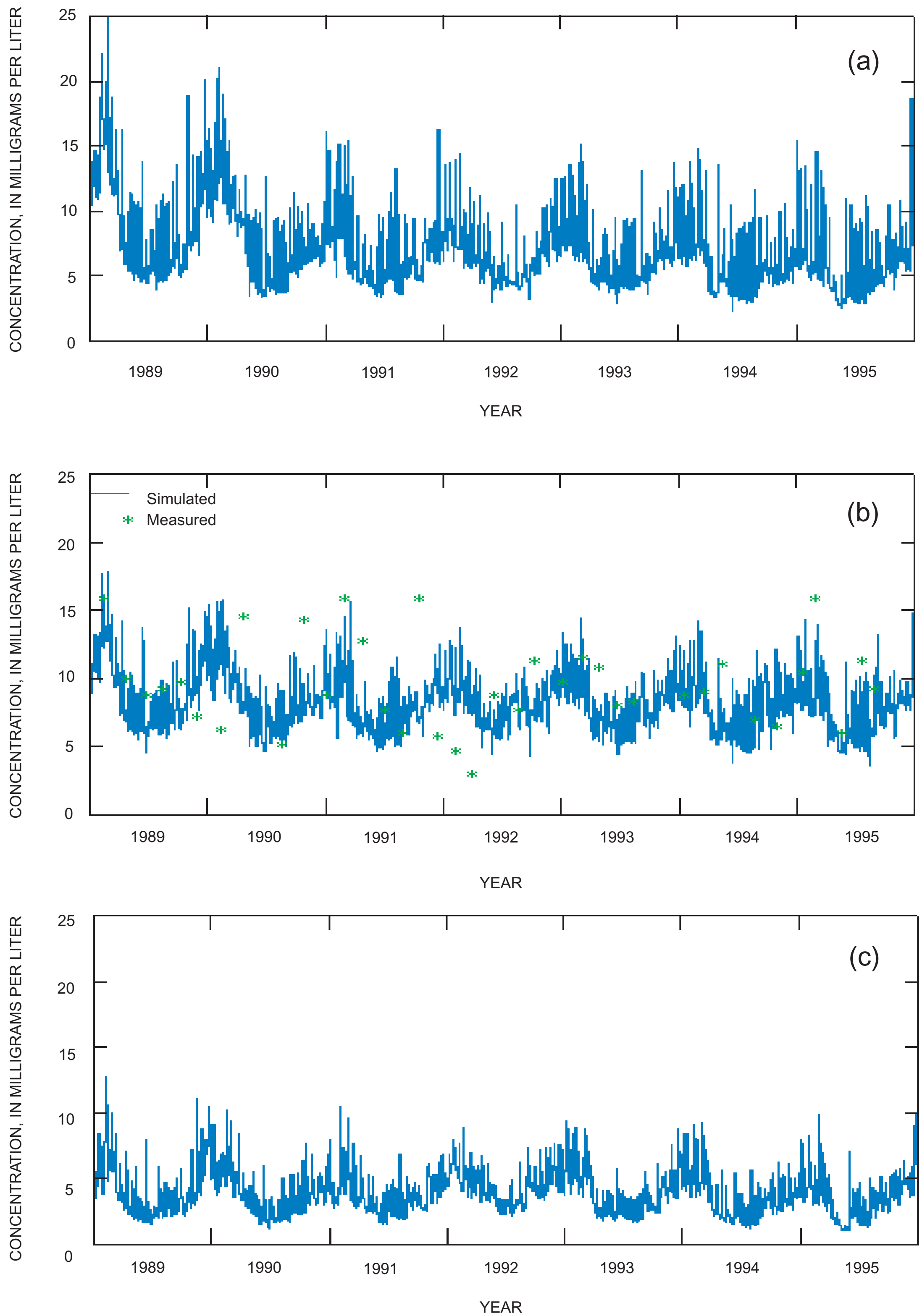

Figure 14. Measured and simulated biochemical oxygen demand concentrations, 1989–95, at Arroyo Colorado at (a) Weslaco (simulated only), (b) Harlingen, and (c) Segment 2202 outlet (simulated only).

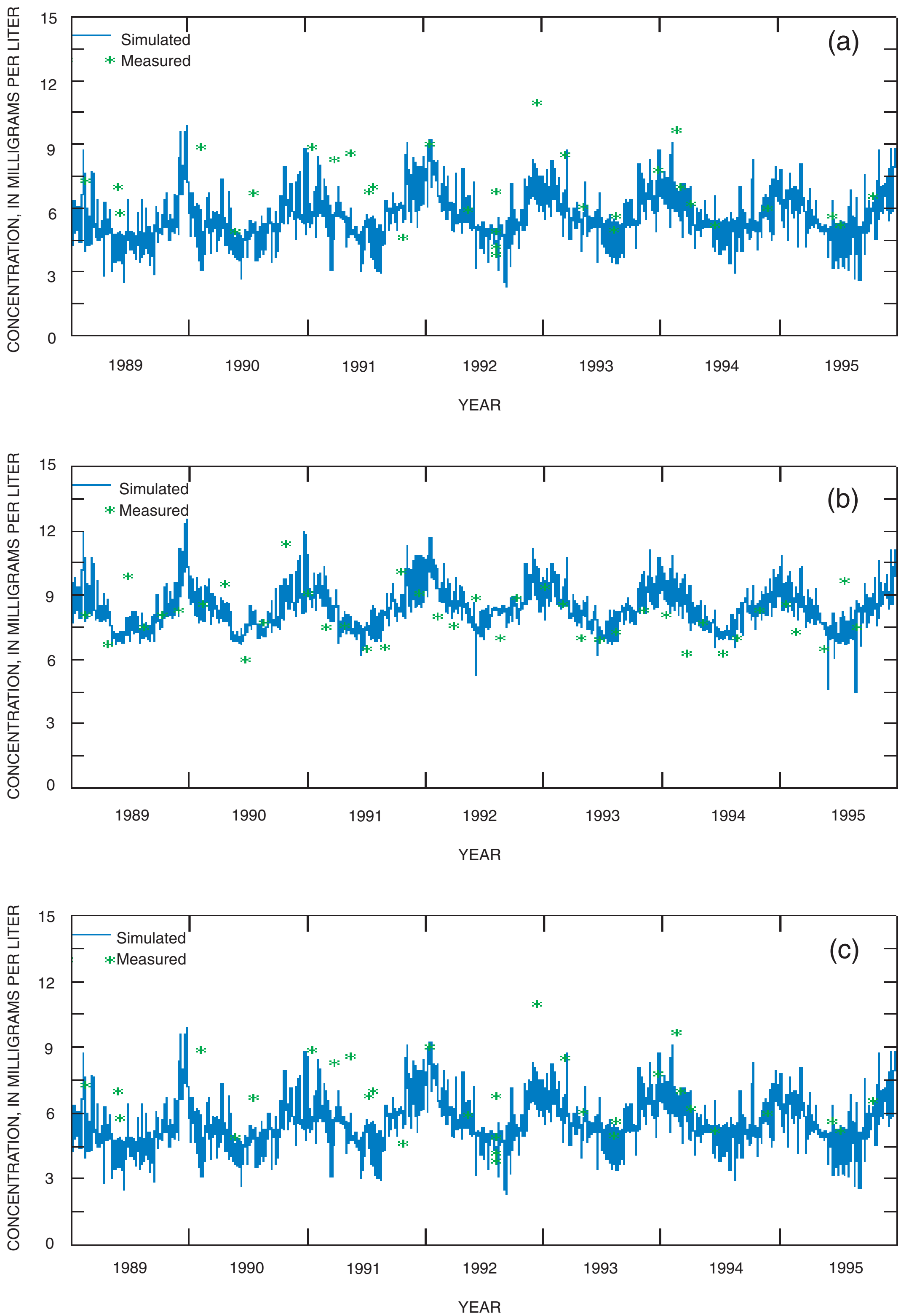

Figure 15. Measured and simulated dissolved oxygen concentrations, 1989–95, at Arroyo Colorado at (a) Weslaco, (b) Harlingen, and (c) Segment 2202 outlet.

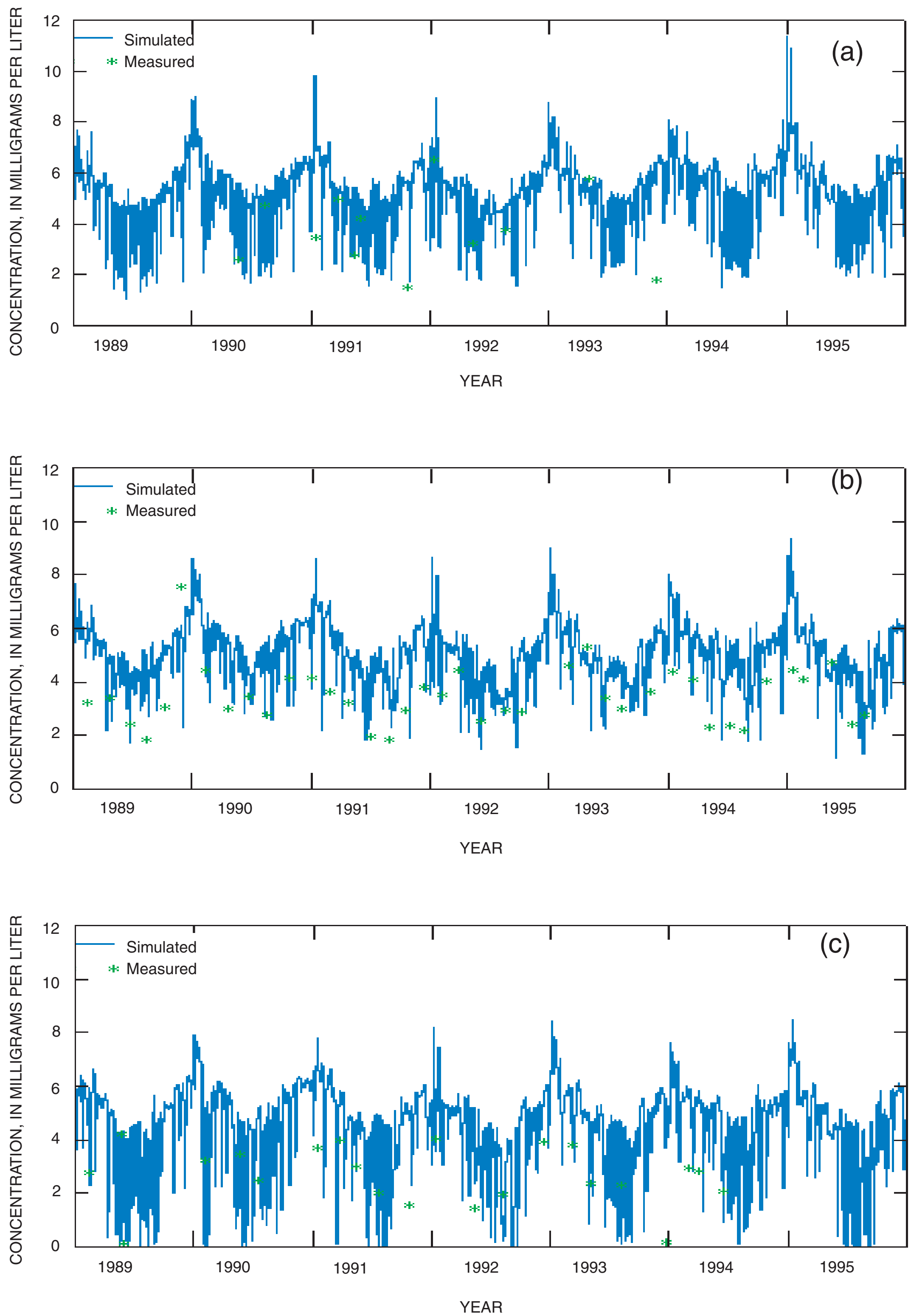

Figure 16. Measured and simulated nitrate nitrogen concentrations, 1989–95, at Arroyo Colorado at (a) Weslaco, (b) Harlingen, and (c) Segment 2202 outlet.

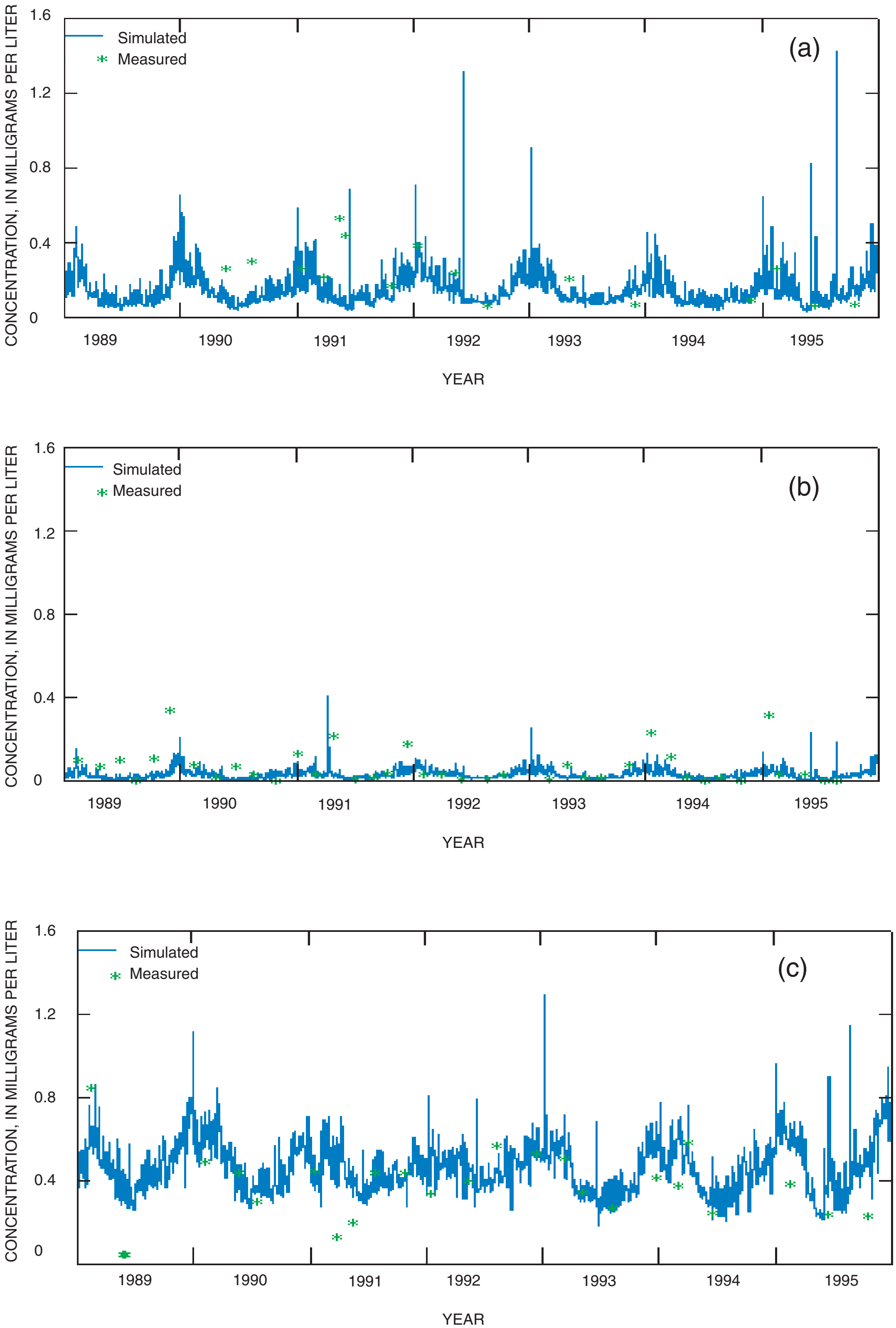

Figure 17. Measured and simulated ammonia nitrogen concentrations, 1989–95, at Arroyo Colorado at (a) Weslaco, (b) Harlingen, and (c) Segment 2202 outlet.

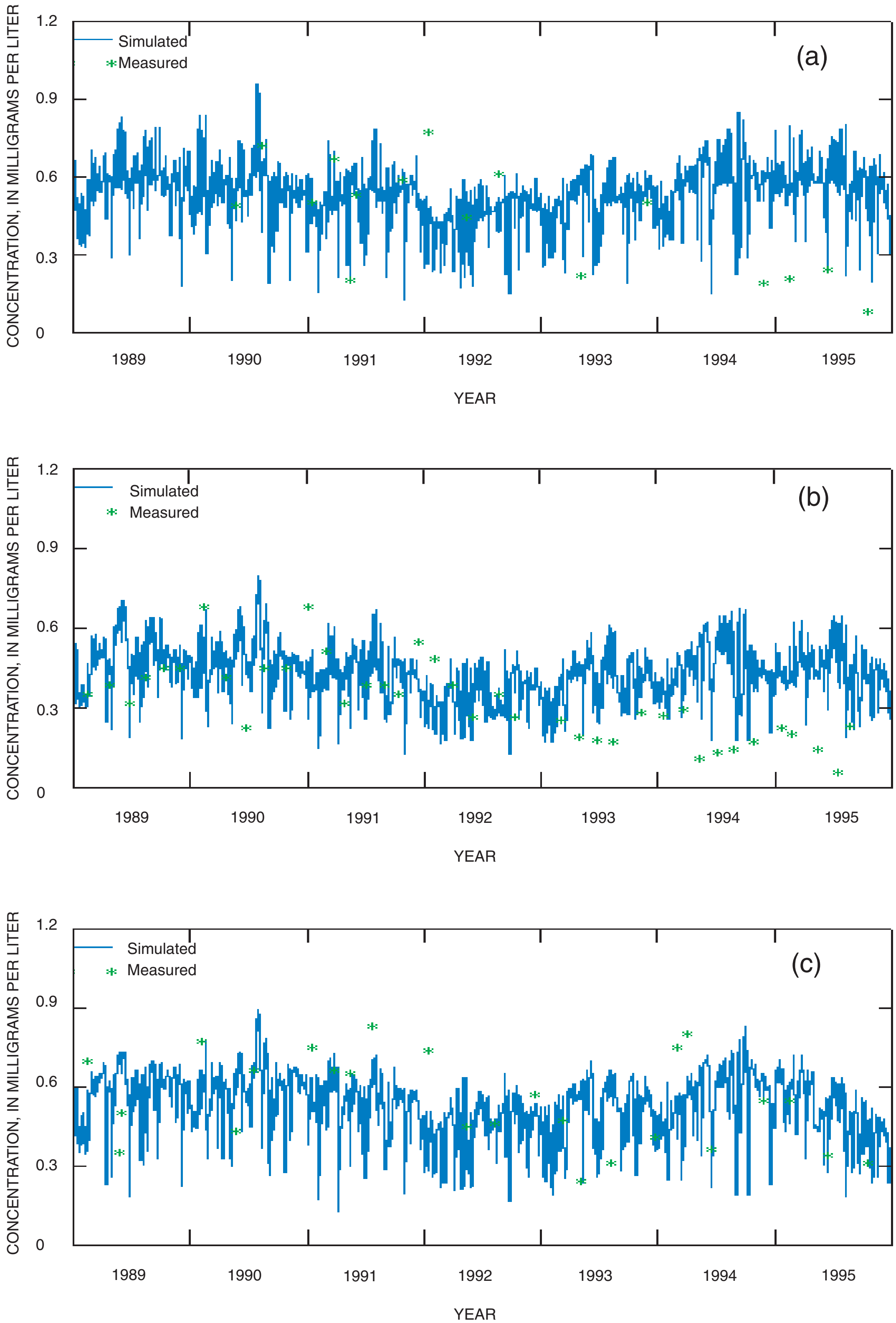

Figure 18. Measured and simulated orthophosphate concentrations, 1989–95, at Arroyo Colorado at (a) Weslaco, (b) Harlingen, and (c) Segment 2202 outlet.

temperatures are undersimulated (fig. 13). The simulated BOD matches the measured data for the Harlingen station (fig. 14). No BOD data were measured at the Weslaco or Segment 2202 outlet stations during 1989–95. The simulated DO concentrations (fig. 15) follow the same cyclical pattern as the simulated water temperature and BOD data. There is some scatter in the measured DO concentrations that is higher and lower than the simulated DO concentrations.

The simulated concentrations of nitrate nitrogen, ammonia nitrogen, and orthophosphate all show a general annual cyclical pattern (figs. 16–18). The simulated concentrations generally match the measured concentrations. The measured and simulated concentrations of nitrate and orthophosphate show the same range in magnitude for all three stations. The measured and simulated concentrations of ammonia are substantially lower at the Harlingen station than at the other two stations (fig. 17).

Data collected during 1996–99 at the Arroyo Colorado at Weslaco, Harlingen, and Segment 2202 outlet stations were used to test the parameters temporally. The results for the 1996–99 period for the seven properties and constituents (figs. 19–25) are very similar to the results for the 1989–95 period. No measured BOD data for the Segment 2202 outlet station and no measured nitrate nitrogen data for the Weslaco and Segment 2202 outlet stations were available for comparison to simulated data.

Error Analysis of Water Quality

Because few water-quality data were available at the stations along the Arroyo Colorado for model calibration and testing, a substantial amount of error can be introduced. In addition, few data were available to calibrate and test the nonpoint-source loads prior to their entry into the main stem of the Arroyo Colorado. A continuous time series of DO would have been useful for model calibration. The majority of the existing water-quality data were collected at low flow. More frequent measurements for a range of flows would improve model calibration.

Systematic errors are introduced with the numerous parameters used to simulate water quality. As with the simulation of runoff, some of the inability of the model to represent the physical processes is in the model parameters and model equations. The buildup and washoff parameters used in this model are general approximations of the physical processes for the generation of nutrient loads in the basin.

The measurement and systematic errors account for some of the error and bias of the simulated water quality. From the results listed in table 9 and shown in figures 7–11, the calibrated parameter set adequately simulates water quality in the Arroyo Colorado for selected properties and constituents.

Simulated Point- and Nonpoint-Source Loads

The model can be used to simulate loads for selected water-quality properties and constituents. The TNRCC will use the model to simulate different scenarios to determine the effects of various BMPs. To provide a baseline for the current (1998) loadings relative to the major land-use types in the Arroyo Colorado Basin, the simulated loads were aggregated for point and nonpoint sources for 1989–99. The loads from low-density urban, colonias, septic, permitted land application, and high-density urban were combined into urban nonpoint-source loads. The loads from pasture and hay, nonirrigated and irrigated row crops, all citrus, and all sugar cane were combined into agricultural nonpoint-source loads. The relative percentage of total load for suspended sediment, BOD, nitrate nitrogen, ammonia nitrogen, and orthophosphate are shown in figure 26.

The fractions of major land-use type by area, excluding water and wetlands (aggregated from data in table 6), for the Arroyo Colorado Basin is about 13 percent urban, 19 percent natural, and 68 percent agricultural. The fraction of the total load for each of the five properties and constituents that is agricultural nonpoint-source load ranges from 41 to 87 percent (fig. 26). The fraction of the total load for each of the five properties and constituents that is urban nonpoint-source load ranges from 10 to 30 percent. The fraction of the total load for each of the five properties and constituents that is urban point-source load ranges from 1 to 40 percent. The fraction of the total load for each of the five properties and constituents that is natural nonpoint-source load ranges from 1 to 6 percent. A substantial fraction, from about one-third to one-half, of the BOD and nutrient loads is from urban point and nonpoint sources compared to the relatively small fraction of the total land use (13 percent) that is urban.

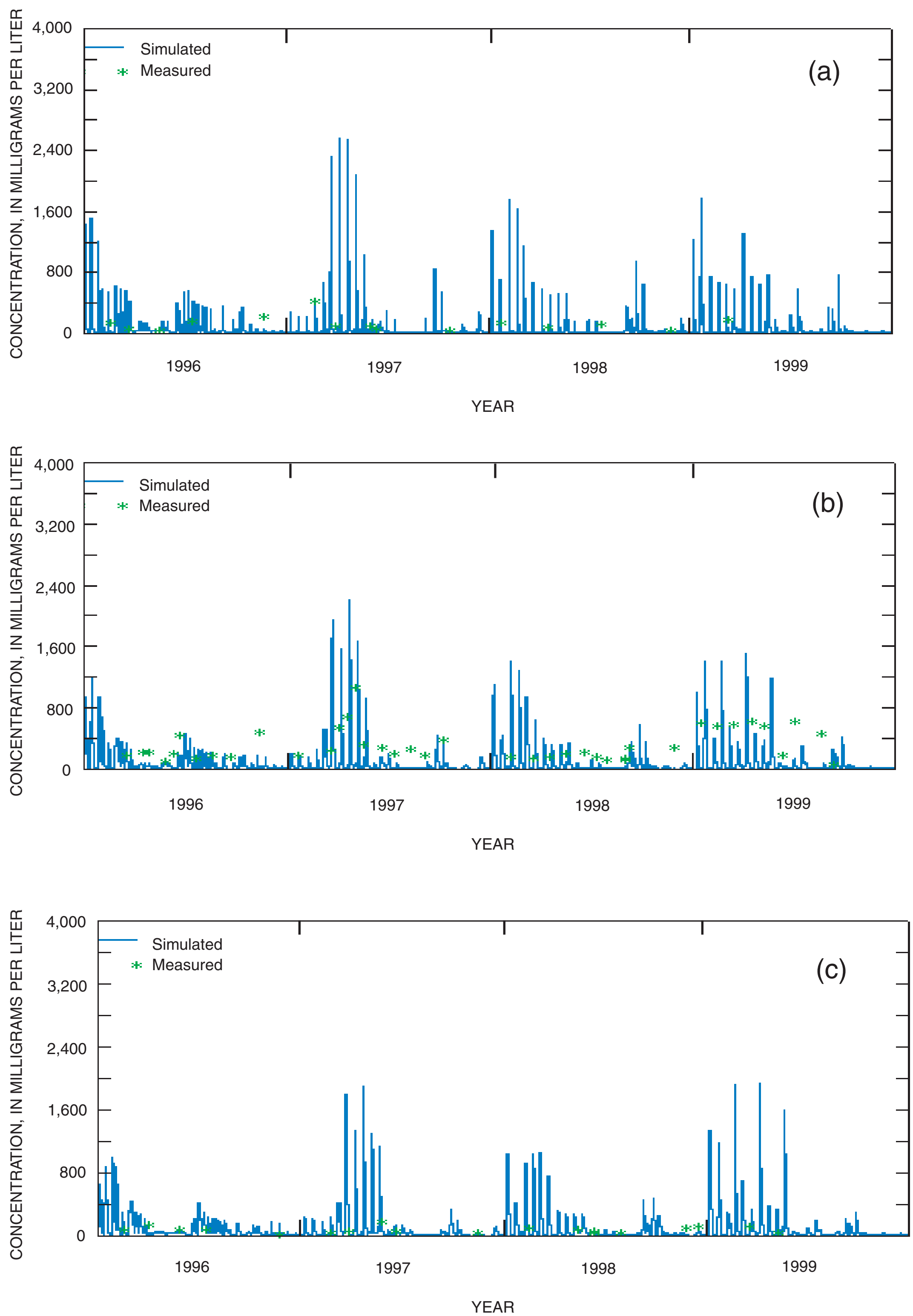

Figure 19. Measured and simulated suspended sediment concentrations, 1996–99, at Arroyo Colorado at (a) Weslaco, (b) Harlingen, and (c) Segment 2202 outlet.

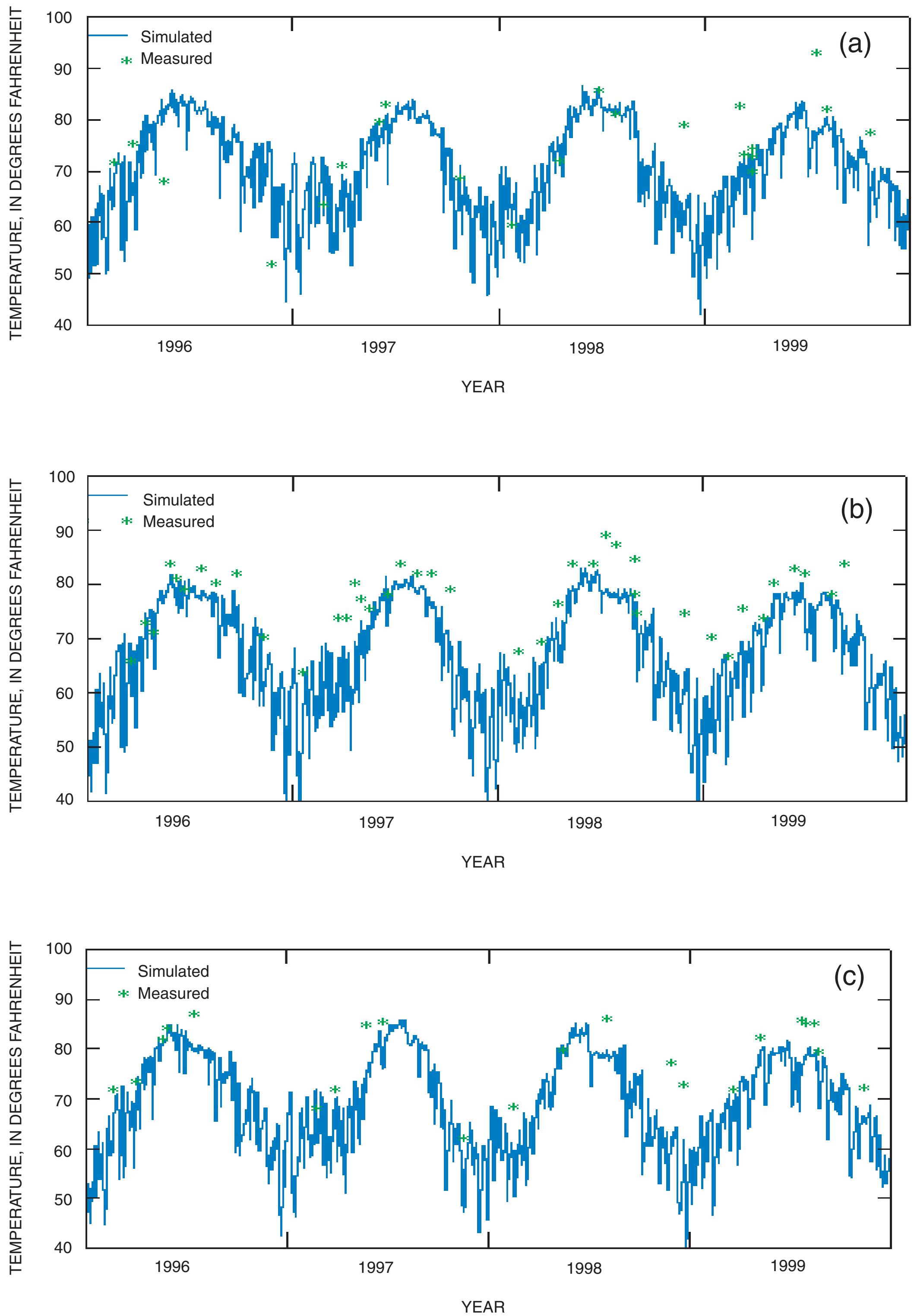

Figure 20. Measured and simulated water temperature, 1996–99, at Arroyo Colorado at (a) Weslaco, (b) Harlingen, and (c) Segment 2202 outlet.

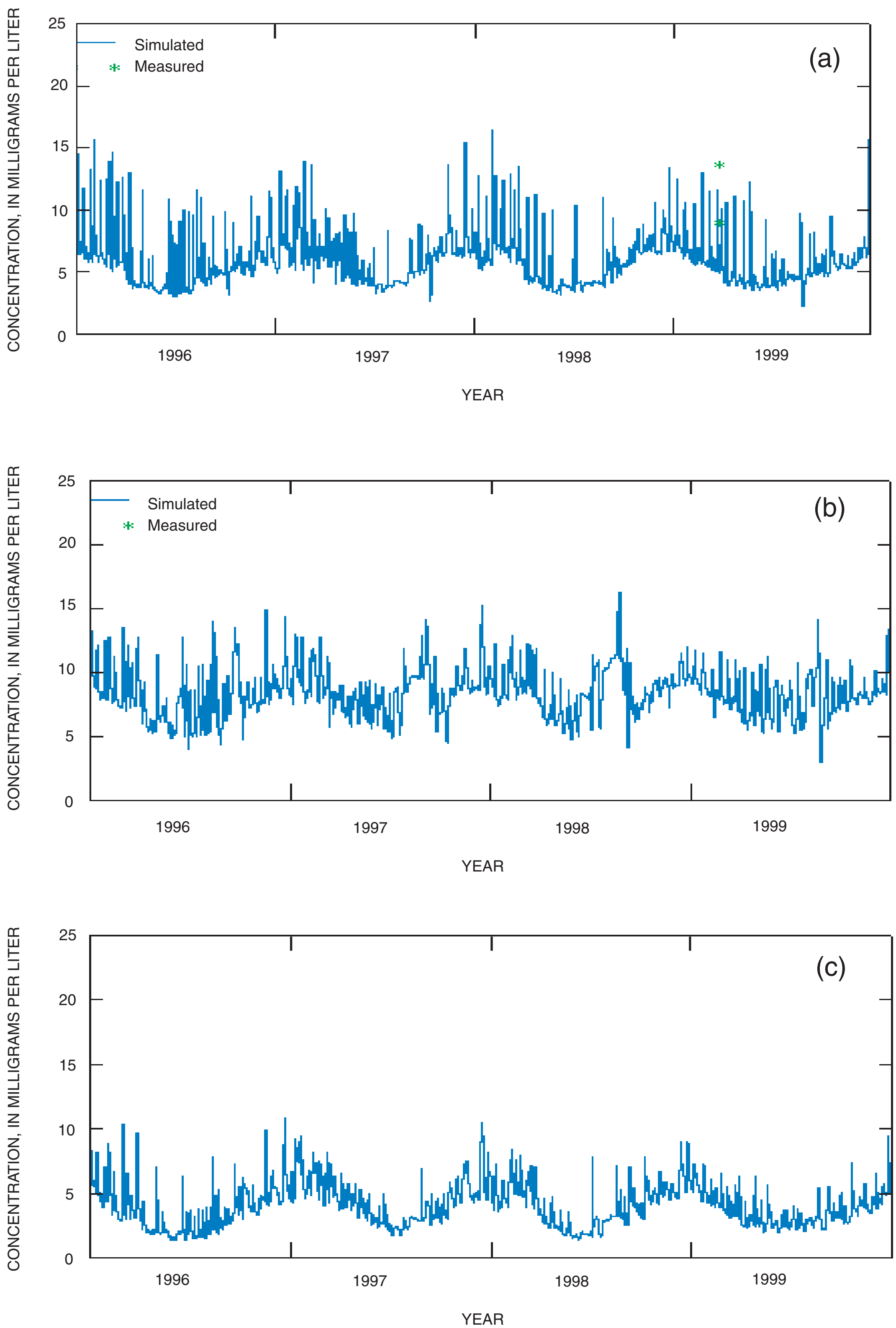

Figure 21. Measured and simulated biochemical oxygen demand concentrations, 1996–99, at Arroyo Colorado at (a) Weslaco, (b) Harlingen, and (c) Segment 2202 outlet (simulated only).

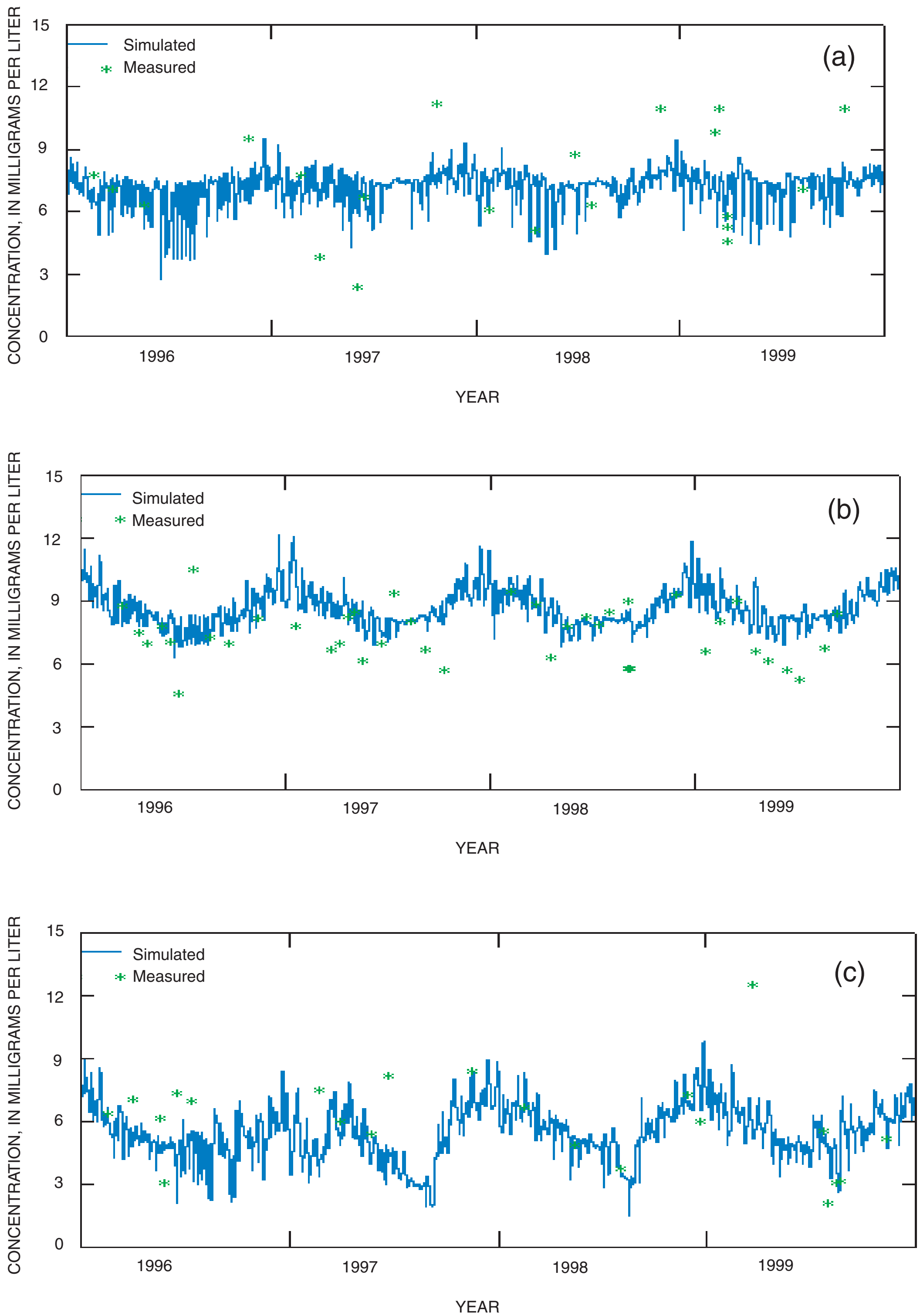

Figure 22. Measured and simulated dissolved oxygen concentrations, 1996–99, at Arroyo Colorado at (a) Weslaco, (b) Harlingen, and (c) Segment 2202 outlet.

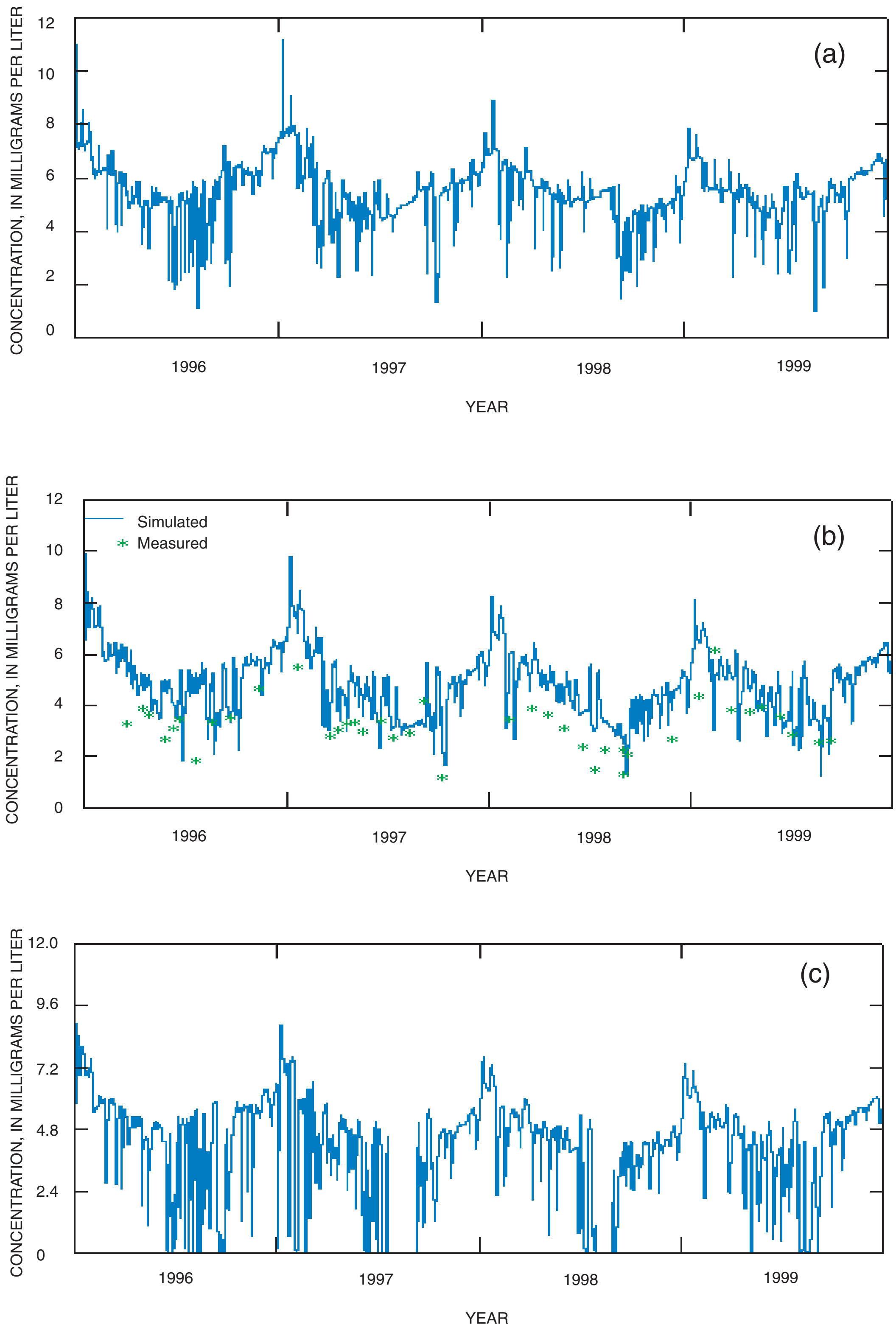

Figure 23. Measured and simulated nitrate nitrogen concentrations, 1996–99, at Arroyo Colorado at (a) Weslaco (simulated only), (b) Harlingen, and (c) Segment 2202 outlet (simulated only).

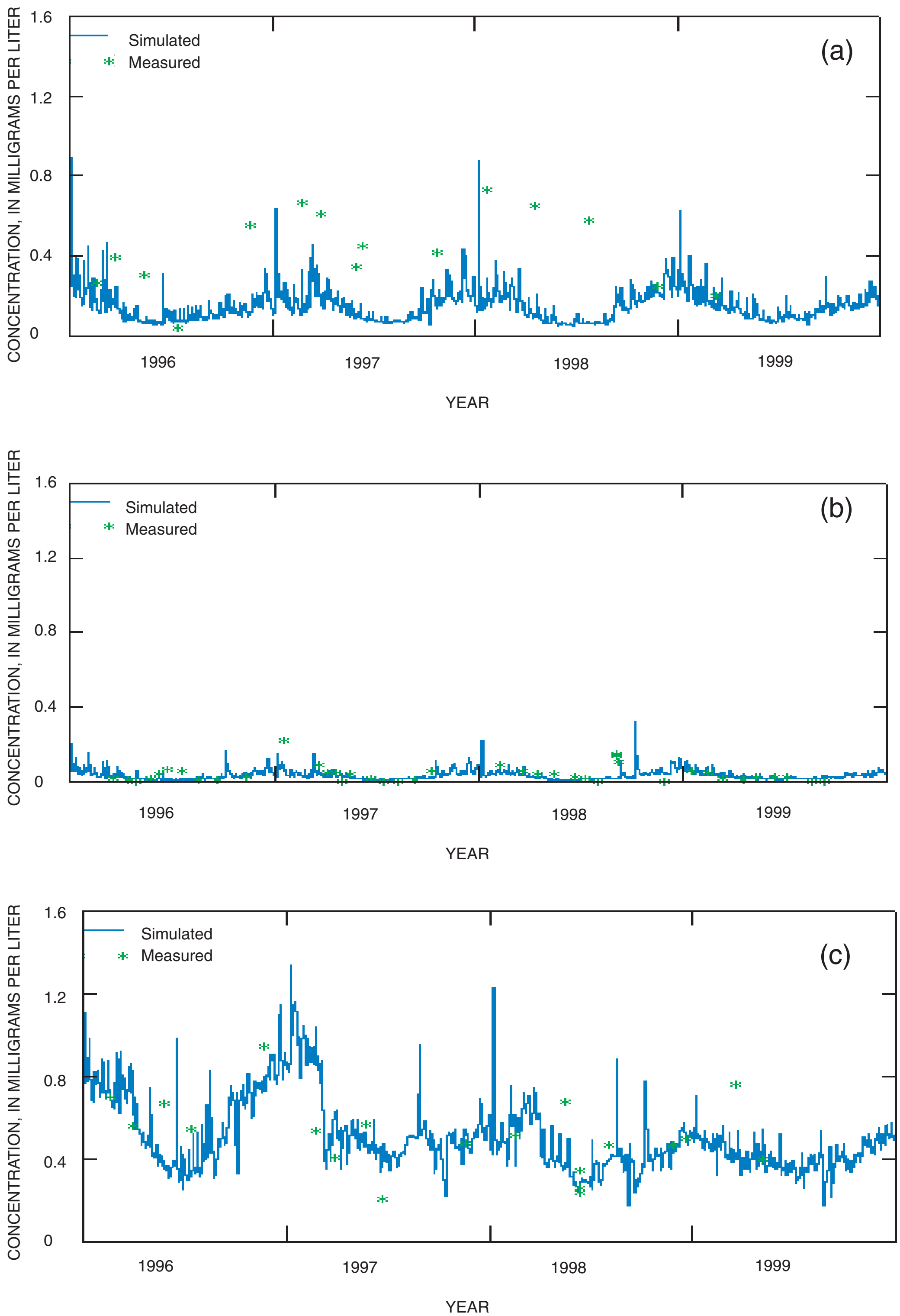

Figure 24. Measured and simulated ammonia nitrogen concentrations, 1996–99, at Arroyo Colorado at (a) Weslaco, (b) Harlingen, and (c) Segment 2202 outlet.

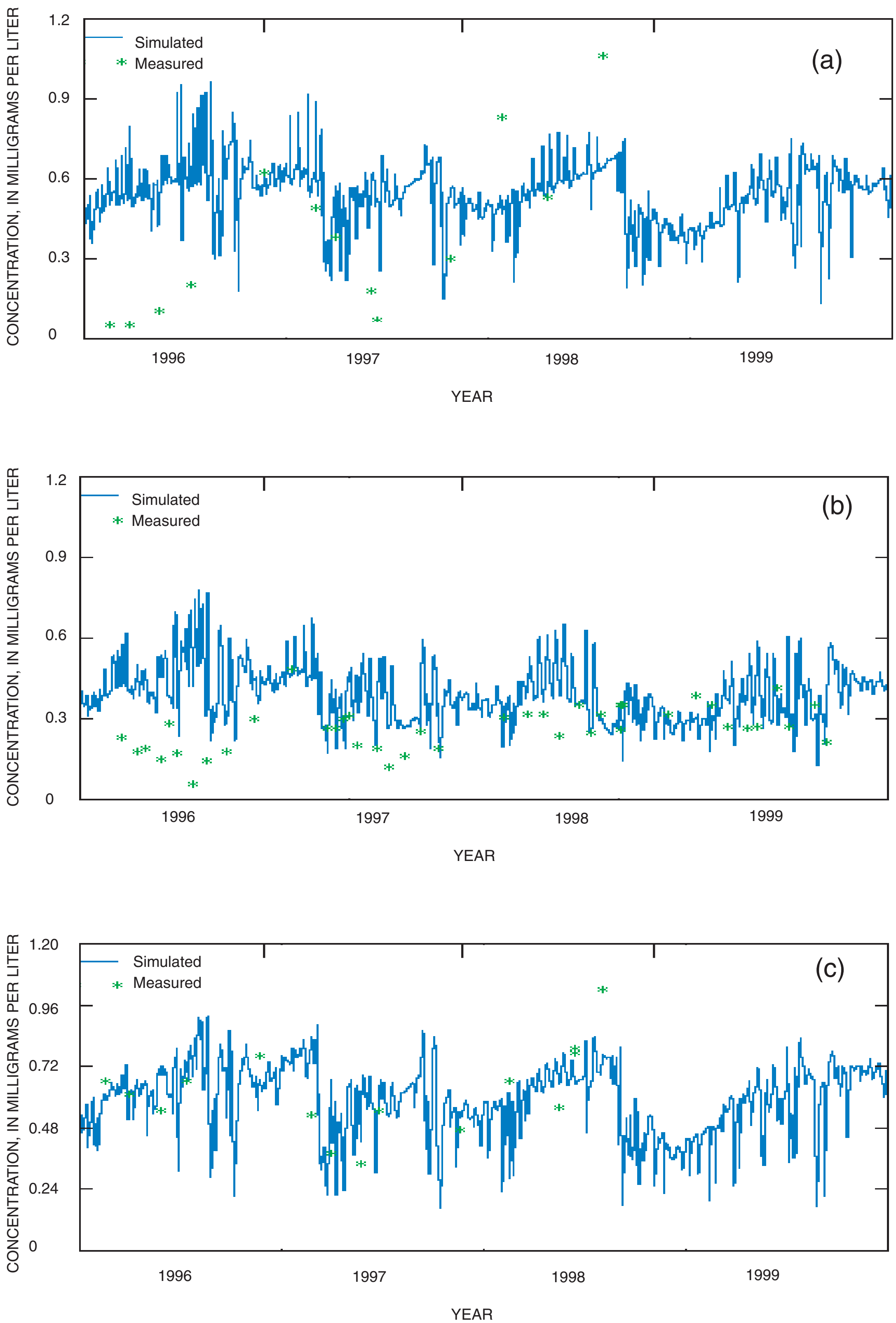

Figure 25. Measured and simulated orthophosphate concentrations, 1996–99, at Arroyo Colorado at (a) Weslaco, (b) Harlingen, and (c) Segment 2202 outlet.

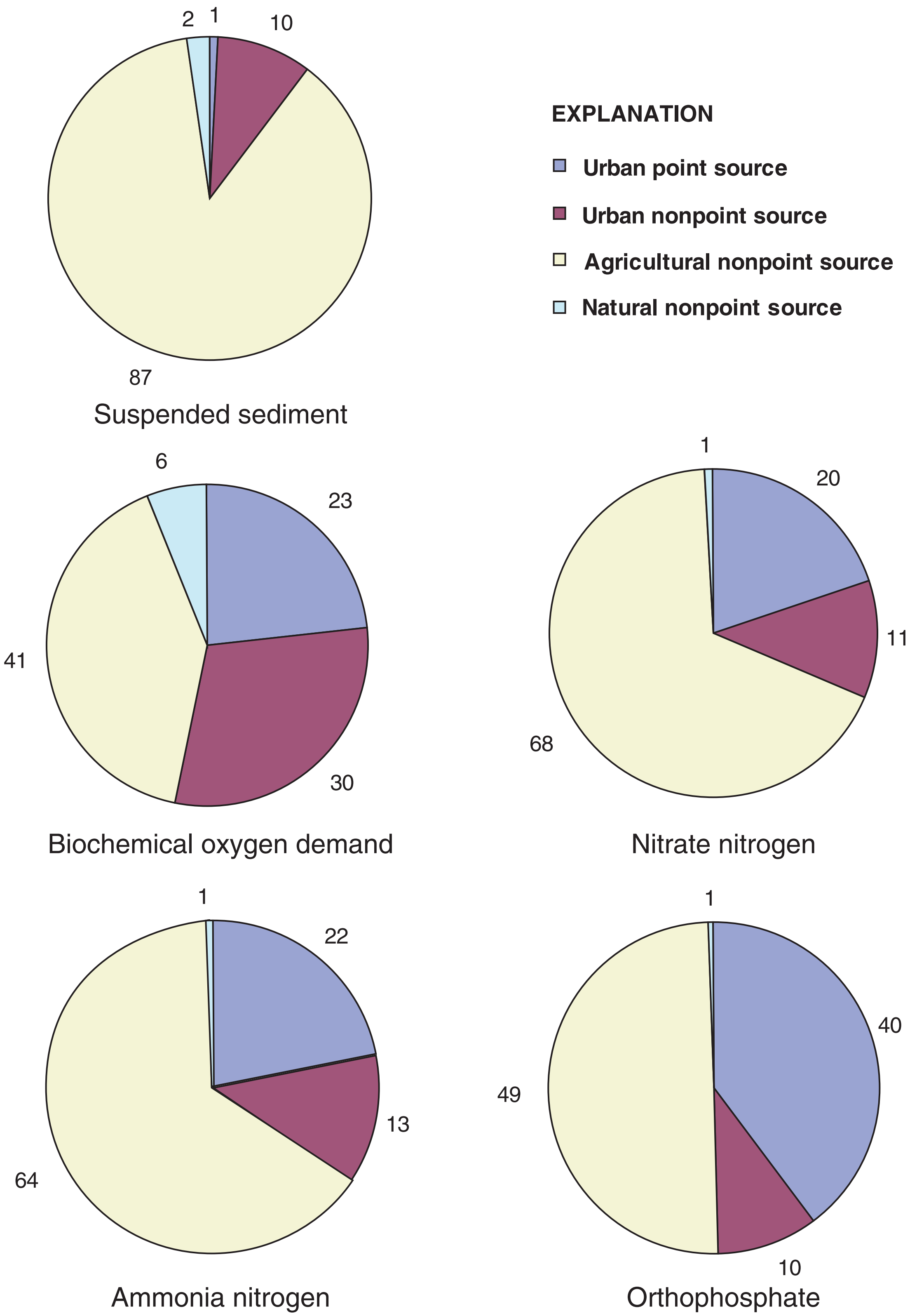

Figure 26. Simulated total point- and nonpoint-source loads in percent by land-use type for selected properties and constituents, Arroyo Colorado Basin, 1989–99.

SUMMARY

The purpose of this study was to set up, calibrate, and test a simulation model (HSPF) using a set of process-related model parameters with available flow and water-quality data for the Arroyo Colorado from Mission to the Laguna Madre, Texas. The model simulates flow, selected water-quality properties, and constituent concentrations. The model can be used by the TNRCC to simulate different BMPs to estimate a TMDL for selected constituents to meet water-quality standards for DO in the Arroyo Colorado.

Time series of precipitation, evaporation, air temperature, dewpoint temperature, wind speed, cloud cover, solar radiation, streamflow, and concentrations of selected properties and constituents for January 1, 1989–December 31, 1999, were used in this study. Twenty-six pervious land segments and three impervious land segments were defined for the study on the basis of 14 land-use types and two soil groups. Eighteen process-related parameters were defined and calibrated for each land segment for flow, 31 process-related parameters were defined and calibrated for each land segment for water quality, and 75 process-related parameters were defined and calibrated for each stream reach for water quality.

The model was calibrated for flow with 1989–95 data for two stations, tested spatially with 1989–95 data for one station, and tested temporally with 1996–99 data for two stations using HSPEXP. The errors for total flow volume ranged from -0.1 to 29.0 percent, and the errors for total storm volume ranged from -15.6 to 8.4 percent. The errors for the total of highest 10-percent flows ranged from -12.5 to 13.2 percent, and the errors for lowest 50-percent flows ranged from -5.0 to 27.6 percent. The errors were larger for the 1996–99 period.

The model was calibrated for water quality for seven properties and constituents with 1989–95 data for two stations, tested spatially with 1989–95 data for one station, and tested temporally with 1996–99 data for three stations. The model was calibrated sequentially for suspended sediment, water temperature, BOD, DO, nitrate nitrogen, ammonia nitrogen, and orthophosphate. The simulated concentrations of the selected properties and constituents generally matched the measured concentrations available for the calibration and testing periods.

The model was used to simulate total point- and nonpoint-source loads for selected water-quality properties and constituents for 1989–99 for urban, natural, and agricultural land-use types. About one-third to one-half of the BOD and nutrient loads are from urban point and nonpoint sources, although only 13 percent of the total land use in the basin is urban.

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Table 1. Process-related model parameters for the Hydrological Simulation Program—FORTRAN

[ET, evapotranspiration; --, not applicable; /d, per day; in., inches; in/hr; inches per hour; /in., per inch; ft, feet; ft/ft, feet per foot; tons/ac-d, tons per acre per day; lb/ft^2-d, pounds per square foot per day; lb/ac-d, pounds per acre per day; g/cm^3, grams per cubic centimeter; lb/ft^2, pounds per square foot; in/s, inches per second; °F, degrees Fahrenheit; DO, dissolved oxygen; BOD, biochemical oxygen demand; mg C/L, milligrams carbon per liter; mg/L, milligrams per liter; °C, degrees Celsius; mg/m^2-hr, milligrams per square meter per hour; /hr, per hour; lb/ac, pounds per acre; mL/g, milliliters per gram; mg/kg, milligrams per kilogram; mg/mg, milligrams per milligram; mol/mol, moles per mole; µg/L, micrograms per liter; ly/min, langleys per minute; /ft, per foot; L/mg-ft, liters per milligram per foot; ft^3/s, cubic feet per second; ft/hr, feet per hour]

Parameter	Description[1]	Default	Minimum	Maximum	Units
Flow					
AGWETP	Available ET satisfied by active ground water	0	0	1.0	--
AGWRC	Active ground-water recession rate	--	.001	1.0	/d
BASETP	Available ET satisfied by base flow	0	0	1.0	--
CEPSC	Interception storage capacity	0	0	1.0	in.
DEEPFR	Fraction of inflow that enters inactive ground water	0	0	1.0	--
INFEXP	Infiltration equation exponent	2.0	0	10.0	--
INFILD	Ratio of maximum and mean infiltration capacities	2.0	1.0	2.0	--
INFILT	Index to infiltration capacity of soil	--	.0001	100.0	in/hr
INTFW	Interflow inflow	--	0	--	--
IRC	Interflow recession rate	--	0	1.0	/d
KVARY	Nonexponential ground-water recession rate	0	0	--	/in.
LSUR	Length of assumed overland flow plane	--	1.0	--	ft
LZETP	Lower-zone ET	0	0	1.0	--
LZSN	Lower-zone nominal storage	--	.01	100.0	in.
NSUR	Manning's n for assumed overland flow plane	.1	.001	1.0	--
RETSC	Retention storage capacity for impervious areas	0	0	10	ft
SLSUR	Slope of assumed overland flow plane	--	.000001	10.0	ft/ft
UZSN	Upper-zone nominal storage	--	.01	10.0	in.
Water quality					
	Sediment				
ACCSDP	Rate solids are placed on land surface	0	0	--	tons/ac-d
AFFIX	Fraction detached sediment storage decreases	0	0	1.0	/d
BEDWID	Width of cross section for bed-sediment deposition	--	1.0	--	ft
BEDWRN	Bed depth for warning message	100	.001	--	ft
COVER	Fraction of land surface shielded from erosion	0	0	1.0	--
D	Effective diameter of sand, silt, or clay particles	--	.001	100	in.
EXPSAND	Exponent of sandload equation	0	0	--	--
JEIM	Exponent of solids washoff equation	--	--	--	--
JGER	Exponent of matrix soil scour equation	--	--	--	--
JRER	Exponent of soil detachment equation	--	--	--	--
JSER	Exponent of detached sediment washoff equation	--	--	--	--
KEIM	Coefficient of solids washoff equation	0	0	--	--
KGER	Coefficient of matrix soil scour equation	0	0	--	--
KRER	Coefficient of soil detachment equation	0	0	--	--
KSAND	Coefficient of sandload equation	0	0	--	--

Footnote at end of table.

Table 1. Process-related model parameters for the Hydrological Simulation Program—FORTRAN—Continued

Parameter	Description[1]	Default	Minimum	Maximum	Units
KSER	Coefficient of detached sediment washoff equation	0	0	--	--
M	Erodibility coefficient of sediment	0	0	--	lb/ft^2-d
NVSI	Rate sediment enters detached storage from atmosphere	0	--	--	lb/ac-d
POR	Bed porosity	.5	.1	0.9	--
REMSDP	Fraction solid storage removed daily during no runoff	0	0	1.0	/d
RHO	Density of sand, silt, or clay particles	2.65	1.0	4.0	g/cm^3
SMPF	Supporting management factor	1.0	.001	1.0	--
TAUCD	Critical bed shear stress for deposition	--	--	--	lb/ft^2
TAUCS	Critical bed shear stress for scour	--	--	--	lb/ft^2
W	Fall velocity of sand, silt, or clay particles	--	.02	500	in/s
	Temperature				
ASLT	Intercept of surface layer temperature equation	32	0	100	°F
BSLT	Slope of surface layer temperature equation	1.0	.001	2.0	°F
CFSAEX	Correction factor for solar radiation	1.0	.001	2.0	--
ELEV	Mean RCHRES elevation above sea level	0	0	30,000	ft
ELDAT	Difference between ELEV and air temperature gage elevation	0	--	10,000	ft
KATRAD	Longwave radiation coefficient	9.37	1.0	20	--
KCOND	Conduction-convection heat transport coefficient	6.12	1.0	20	--
KEVAP	Evaporation coefficient	2.24	1.0	10	--
LGTP1	Smoothing factor in lower layer temperature equation	--	--	--	°F
ULTP1	Smoothing factor in upper layer temperature equation	--	--	--	°F
ULTP2	Mean difference between upper layer soil and air temperature	--	--	--	°F
	DO and BOD				
ACO2P	Concentration of dissolved carbon dioxide in active ground water	0	0	1.0	mg C/L
ADOXP	Concentration of DO in active ground water	0	0	20	mg/L
AWTF	Intercept of surface-water regression equation	32	0	100	°F
BENOD	Benthal oxygen demand at 20 °C	0	0	--	mg/m^2-hr
BRBOD1	Benthal release of BOD at high oxygen concentrations	72	.0001	--	mg/m^2-hr
BRBOD2	Increment to benthal release of BOD	100	.0001	--	mg/m^2-hr
BWTF	Slope of surface-water regression equation	1.0	.001	2.0	°F
ELEV	Mean PERLND and IMPLND elevation above sea level	0	-1,000	30,000	ft
EXPOD	Exponent of DO term in benthal oxygen demand equation	1.22	.1	--	--
EXPRED	Exponent to death for reaeration coefficient equation	0	--	0	--
EXPREL	Exponent of DO term in benthal BOD release equation	2.82	.1	--	--
EXPREV	Exponent to velocity for reaeration coefficient equation	0	0	--	--
ICO2P	Concentration of dissolved carbon dioxide in interflow	0	0	1.0	mg C/L
IDOXP	Concentration of DO in interflow	0	0	20.0	mg/L
KBOD20	Unit BOD decay rate at 20 °C	--	1.0^{-30}	--	/hr

Footnote at end of table.

Table 1. Process-related model parameters for the Hydrological Simulation Program—FORTRAN—Continued

Parameter	Description[1]	Default	Minimum	Maximum	Units
KODSET	Rate of BOD settling	0	0	--	ft/hr
REAK	Empirical constant for reaeration coefficient equation	--	1.0^{-30}	--	/hr
SUPSAT	Allowable DO supersaturation as fraction of saturation	1.15	1.0	2.0	--
TCBEN	Temperature correction coefficient for benthal oxygen demand	1.074	1.0	2.0	--
TCBOD	Temperature correction coefficient for BOD decay	1.075	1.0	2.0	--
TCGINV	Temperature correction coefficient for surface gas invasion	1.047	1.0	2.0	--
	PERLND and IMPLND nutrients				
ACQOP	Rate of accumulation	0	0	--	lb/ac-d
AOQC	Concentration of constituent in ground-water outflow	0	0	--	mg/L
IOQC	Concentration of constituent in interflow outflow	0	0	--	mg/L
SQOLIM	Maximum storage of constituent	1.0^{-6}	1.0^{-6}	--	lb/ac
WSQOP	Rate of runoff that will remove 90 percent of storage	1.64	.01	--	in/hr
	RCHRES nutrients				
ADNHPM	Partition coefficients for NH_4 adsorbed to sand, silt, and clay	1.0^{-10}	1.0^{-10}	--	mL/g
ADPOPM	Partition coefficients for PO_4 adsorbed to sand, silt, and clay	1.0^{-10}	1.0^{-10}	--	mL/g
ANAER	DO concentration below which anaerobic conditions exist	.005	.0001	1.0	mg/L
BNH4	Constant bed concentrations of NH_4 adsorbed to sand, silt, and clay	0	0	--	mg/kg
BPCNTC	Percentage by weight of biomass that is carbon	1.98	1.0	5.0	--
BP04	Constant bed concentrations of PO_4 adsorbed to sand, silt, and clay	0	0	--	mg/kg
BRPO41	Aerobic rate of benthic release of orthophosphate	0	0	--	mg/m^2-hr
BRPO42	Anaerobic rate of benthic release of orthophosphate	0	0	--	mg/m^2-hr
BRTAM1	Aerobic rate of benthic release of total ammonia	0	0	--	mg/m^2-hr
BRTAM2	Anaerobic rate of benthic release of total ammonia	0	0	--	mg/m^2-hr
CVBO	Conversion from milligrams biomass to oxygen	1.98	1.0	5.0	mg/mg
CVBPC	Conversion from biomass as phosphorous to carbon	106	50	200	mol/mol
CVBPN	Conversion from biomass as phosphorous to nitrogen	16	10	50	mol/mol
DENOXT	DO concentration threshold for denitrification	2.00	0	--	mg/L
KNO220	Nitrification rate of nitrite at 20 °C	--	.001	--	/hr
KNO320	Denitrification rate at 20 °C	--	.001	--	/hr
KTAM20	Nitrification rate of ammonia at 20 °C	--	.001	--	/hr
TCDEN	Temperature correction coefficients for denitrification	1.07	1.0	2.0	--
TCNIT	Temperature correction coefficients for nitrification	1.07	1.0	2.0	--
	RCHRES phytoplankton				
ALDH	High algal unit death rate	.01	1.0^{-6}	--	/hr
ALDL	Low algal unit death rate	.001	1.0^{-6}	--	/hr
ALR20	Algal unit respiration rate at 20 °C	.004	1.0^{-6}	--	/hr
ALNPR	Fraction of nitrogen required for phytoplankton satisfied by nitrate	1.0	.01	1.0	--
CLALDH	Chlorophyll A concentration above which high algal death rate occurs	50	.01	--	µg/L

Footnote at end of table.

Table 1. Process-related model parameters for the Hydrological Simulation Program—FORTRAN—Continued

Parameter	Description[1]	Default	Minimum	Maximum	Units
CMMLT	Michaelis-Menton constant for light-limited growth	0.033	1.0^{-6}	--	ly/min
CMMN	Nitrate Michaelis-Menton constant for nitrogen-limited growth	.045	1.0^{-6}	--	mg/L
CMMNP	Nitrate Michaelis-Menton constant for phosphorous-limited growth	.0284	1.0^{-6}	--	mg/L
CMMP	Phosphate Michaelis-Menton constant for phosphorous-limited growth	.015	1.0^{-6}	--	mg/L
EXTB	Base extinction coefficient for light	--	.001	--	/ft
LITSED	Multiplication factor for sediment contribution to light extinction	0	0	--	L/mg-ft
MALGR	Maximal unit algal growth rate	.3	.001	--	/hr
MXSTAY	Plankton concentration not subject to advection at very low flow	0	0	--	mg/L
NALDH	Inorganic nitrogen concentration below which high algal death rate occurs	0	0	--	mg/L
NONREF	Nonrefractory fraction of algae and zooplankton biomass	.5	.01	1.0	--
OREF	Outflow at which plankton concentration is midway between SEED and MXSTAY	.0001	.0001	--	ft^3/s
OXALD	Increment to phytoplankton unit death rate (anaerobic)	.03	1.0^{-6}	--	/hr
PALDH	Inorganic phosphorous concentration below which high algal death rate occurs	0	0	--	mg/L
PHYSET	Rate of phytoplankton settling	0	0	--	ft/hr
RATCLP	Ratio of chlorophyll A of biomass to phosphorous content	.6	.01	--	--
REFSET	Rate of settling for dead refractory organics	0	0	--	ft/hr
SEED	Minimum plankton concentration not subject to advection	0	0	--	mg/L
TALGRH	Temperature above which algal growth ceases	95	50	212	°F
TALGRL	Temperature below which algal growth ceases	43	32	212	°F
TALGRM	Temperature below which algal growth is retarded	77	32	212	°F

[1] The user's manual for Hydrological Simulation Program—FORTRAN (Bicknell and others, 1997) provides a more complete description of each parameter.

Table 2. Basin-related model parameters for the Hydrological Simulation Program—FORTRAN

[PERLND, pervious land segment; IMPLND, impervious land segment; ac, acres; mi, miles; FTABLE, table of depth, surface area, volume, and discharge for each reach; ft, feet; ac-ft, acre-feet; ft^3/s, cubic feet per second]

Parameter	Description[1] (unit)
AREA	Drainage area of each PERLND or IMPLND (ac)
LEN	Reach length (mi)
DEPTH	FTABLE depth (ft)
SAREA	FTABLE surface area (ac)
VOL	FTABLE volume (ac-ft)
DISCH	FTABLE discharge (ft^3/s)

[1] The user's manual for Hydrological Simulation Program—FORTRAN (Bicknell and others, 1997) provides a more complete description of each parameter.

Table 3. Selected physical and hydrologic characteristics of the Arroyo Colorado subbasins

[mi, miles; mi^2, square miles]

Subbasin/ reach	Location of subbasin outlet	Reach length (mi)	Drainage area (m^2)	Precipitation station name[1]	Streamflow-gaging station no.[2]	Water-quality sampling site no.[3]
			Segment 2202 (nontidal segment)			
1	McAllen	10.0	26.9	--	--	--
2	Donna	6.6	28.1	McAllen	--	--
3	Pharr	9.8	43.8	--	--	--
4	Weslaco	5.2	46.1	Weslaco	08–4770.50	13081
5	Mercedes	6.0	33.0	--	08–4703.00	--
6	La Feria	6.5	45.1	--	--	--
7	Harlingen	11.5	62.4	Harlingen	08–4704.00	13079
8	Segment outlet	--	82.0	--	--	13074
			Segment 2201 (tidal segment)			
9	Rio Hondo	--	80.2	--	--	--
10	La Leona	--	97.1	--	--	--
11	Laguna Atascosa	--	71.1	--	--	--
12	Segment outlet	--	86.7	--	--	--

[1] Station operated by National Oceanic and Atmospheric Administration.
[2] Station operated by International Boundary and Water Commission.
[3] Station operated by Texas Natural Resource Conservation Commission.

Table 4. Permitted point-source daily effluent limits, Arroyo Colorado Basin

[Mgal/d, million gallons per day; mg/L, milligrams per liter; --, no limit]

Permit no.	Name of discharger	Subbasin/ reach	Permitted limit			
			Flow (Mgal/d)	Sus-pended solids (mg/L)	Bio-chemical oxygen demand (mg/L)	Ammonia nitrogen (mg/L)
WQ0001254–000	Central Power and Light Co. Bates	1	2.00	48	--	--
WQ0010484–001	City of Mission	1	4.60	15	10	3.0
WQ0010633–003	City of McAllen	2	10.00	15	10	3.0
WQ0011080–001	City of Hidalgo	2	.41	90	30	--
WQ0010596–001	City of Pharr	3	5.00	15	10	3.0
WQ0011512–001	City of San Juan	3	1.15	20	20	--
WQ0013633–001	City of Alamo	3	2.00	90	30	--
WQ0013680–001	Donna Independent School District	4	.02	20	20	--
WQ0010504–001	City of Donna	4	2.30	20	20	--
WQ0010619–005	City of Weslaco	4	2.00	--	10	3.0
WQ0013462–001	Military Highway Water Supply Corp.	5	.40	90	30	--
WQ0010347–001	City of Mercedes	6	2.30	15	10	3.0
WQ0010697–001	City of La Feria Utility Board	6	.50	90	30	--
WQ0011628–001	Winter Garden Park Association	7	.01	20	20	--
WQ0001256–000	Central Power and Light Co. La Palma	8	1.12	30	--	--
WQ0010490–002	City of Harlingen no. 1	8	3.10	20	20	--
WQ0010490–003	City of Harlingen no. 2	8	7.50	15	10	3.0
WQ0010473–002	City of San Benito	8	2.16	30	30	--
WQ0010475–002	City of Rio Hondo	9	.40	20	20	--
WQ0003457–000	Southern Star Inc. (Hung Group)	12	50.00	15	20	1.0
WQ0003596–000	Arroyo Aquaculture (formerly Taiwan Farms)	12	100.00	30	4	1.0

Table 5. Irrigation schedule for row crops, citrus, and sugar cane for dry, normal, and wet years, Arroyo Colorado Basin, 1989–99

[ac-in/ac, acre-inches per acre; in., inches; >, greater than; <, less than]

Year	Water diverted from Rio Grande (ac-in/ac)	No. of irrigations	Depth of irrigation (in.)	Annual irrigation (in.)
		Row crops		
Dry	>25	3	6	18
Normal	13–25	2	6	12
Wet	<13	1	6	6
		Citrus		
Dry	>25	6	5	30
Normal	13–25	5	5	25
Wet	<13	4	5	20
		Sugar cane		
Dry	>25	8	6	48
Normal	13–25	6	6	36
Wet	<13	4	6	24

Table 6. Basin-related parameters, Arroyo Colorado Basin

[ac, acres; mi, miles; --, not applicable; ft, feet; ac-ft, acre-feet; ft^3/s, cubic feet per second]

Parameter[1]	Subbasin/reach											
	1	2	3	4	5	6	7	8	9	10	11	12
PERLND AREA (ac)												
Low-density urban–1	0	82.0	886.8	242.8	487.5	411.6	1,034.5	3,403.3	1,294.3	123.9	1,138.9	222.8
Low-density urban–2	2,340.9	1,892.4	808	1,694.5	1,976.4	918.6	1,530.7	2,189.7	2,386.0	503.3	1,182.6	117.7
Land application–1	0	0	0	0	0	0	29.0	0	0	0	0	0
Land application–2	1.4	0	0	0	0	60.0	0	59.0	151.7	0	0	0
Colonias–1	0	0	3.3	14.5	10.4	4.4	2.5	6.6	2.2	9.3	11.3	0
Colonias–2	55.2	2.4	10.7	69.8	52.7	30.3	6.4	15.5	49.6	0	9.3	0
Septic–1	0	0	0	32.5	0	58.0	72.4	0	1.1	0.6	0	1.2
Septic–2	0	0	0	18.8	0	10.4	2.0	0	46.0	4.5	0	0.9
High-density urban–1	0	99.2	63.4	8.6	23.5	31.3	121.5	654.3	675.9	2.0	51.2	14.0
High-density urban–2	278.7	603.5	69.2	139.6	253.8	146.3	160.1	237.3	282.1	22.2	78.2	11.3
Natural vegetation–1	0	1,394.9	2,755.4	2,161.4	1,256.7	1,984.0	3,392.2	3,574.4	1,544.2	1,578.3	4,605.6	17,489.6
Natural vegetation–2	4,443.9	2,647.9	1,637.3	1,739.3	1,138.0	2,322.0	3,342.5	2,700.3	2,476.3	4,772.5	4,764.6	6,004.9
Pasture/hay–1	0	175.8	725.0	254.6	566.1	713.1	988.0	2,238.5	123.4	78.3	2,416.8	3,360.6
Pasture/hay–2	602.0	202.4	255.2	361.3	390.5	680.4	733.6	2,132.6	1,183.2	2005.4	2,057.5	131.8
Row crops nonirrigated–1	0	0	0	0	0	0	0	0	0	5,179.0	2,264.0	10,363.4
Row crops nonirrigated–2	0	0	0	0	0	0	0	0	3,305.1	16,542.1	3,336.6	2,243.9
Row crops irrigated–1	0	1,146.3	13,971.7	11,473.3	5,663.2	9,467.1	9,931.2	16,364.2	10,535.9	6,143.0	6,794.0	1,134.0
Row crops irrigated–2	7,066.4	5,212.2	3,510.8	5,744.9	3,118.8	7,168.9	10,477.0	9,601.0	19,206.0	20,217.0	10,010.0	249.0
Citrus–1	0	0	6.3	58.2	94.2	0	0	0	0	0	84.6	0
Citrus–2	274.8	220.5	69.3	916.2	664.8	368.1	570.9	67.5	187.2	323.1	573.0	0
Citrus tile drain–1	0	0	0	0	0	133.8	26.1	0	72.3	0	0	0
Citrus tile drain–2	0	0	0	0	0	64.2	1,034.1	125.7	246.6	180.0	0	0
Sugar cane–1	0	62.7	1,155.9	2,050.5	678.6	825.9	0	0	0	0	353.4	15
Sugar cane–2	117.0	415.8	641.4	362.1	2,509.2	448.5	948.6	390.9	692.4	1,282.2	1,636.2	49.2
Sugar cane tile drain–1	0	0	0	0	0	665.7	981.3	149.7	639.9	0	0	0
Sugar cane tile drain–2	0	0	0	0	0	0	918.9	1,119.0	539.1	713.4	0	0
IMPLND AREA (ac)												
Low-density urban	793.4	658.9	577.9	684.8	840.7	475.8	881.2	1,871.5	1,310.3	213.6	780.7	114.2
High-density urban	840.2	2,108.2	398.0	446.5	832.5	535.0	844.7	2,674.8	2,873.9	72.7	388.3	76.0
Water/wetlands	396.2	1,027.7	453.4	1,039.2	572.1	1,366	1,888.4	2,871.7	1,472.4	2,183.2	2,960.7	12,544.6
LEN (mi)	10.0	6.6	9.8	5.2	6.0	6.5	11.5	--	--	--	--	--
FTABLE												
DEPTH (ft)	0–16.0	0–16.0	0–20.0	0–20.0	0–22.0	0–24.0	0–24.0	0–24.0	--	--	--	--
SAREA (ac)	0–132	0–143	0–164	0–100	0–400	0–200	0–551	0–443	--	--	--	--
VOL (ac-ft)	0–1,880	0–1,910	0–2,740	0–2,770	0–5,000	0–6,080	0–8,520	0–10,400	--	--	--	--
DISCH (ft^3/s)	0–4,280	0–3,580	0–7,150	0–7,590	0–24,100	0–16,900	0–20,500	0–23,500	--	--	--	--

[1] The user's manual for Hydrological Simulation Program—FORTRAN (Bicknell and others, 1997) provides a more complete description of each parameter.

Table 7. Annual PERLND and IMPLND process-related parameters for flow, Arroyo Colorado Basin

[Parameter definitions in table 1; units below parameter except where no units. /d, per day; in/hr, inches per hour; /in., per inch; ft, feet; in., inches; ft/ft, feet per foot]

Land segment	AGWETP[1]	AGWRC[2,3] (/d)	BASETP[1]	DEEPFR[1]	INFEXP[1]	INFILD[1]	INFILT[2,3] (in/hr)	INTFW[2,3]	IRC[2,3] (/d)	KVARY[1] (/in.)	LSUR[2,3] (ft)	LZSN[2,3] (in.)	NSUR[2,3]	RETSC[2,3] (ft)	SLSUR[2,3] (ft/ft)
PERLND															
Low-density urban–1	0	0.995	0	0	2.0	2.0	0.10	2.0	0.60	0	300	1.0	0.10	--	0.001
Low-density urban–2	0	.995	0	0	2.0	2.0	.60	2.0	.60	0	300	3.0	.10	--	.001
Land application–1	0	.995	0	0	2.0	2.0	.10	2.0	.60	0	300	1.0	.10	--	.001
Land application–2	0	.995	0	0	2.0	2.0	.60	2.0	.60	0	300	3.0	.10	--	.001
Colonias–1	0	.995	0	0	2.0	2.0	.10	2.0	.60	0	300	1.0	.10	--	.001
Colonias–2	0	.995	0	0	2.0	2.0	.60	2.0	.60	0	300	3.0	.10	--	.001
Septic–1	0	.995	0	0	2.0	2.0	.10	2.0	.60	0	300	1.0	.10	--	.001
Septic–2	0	.995	0	0	2.0	2.0	.60	2.0	.60	0	300	3.0	.10	--	.001
High-density urban–1	0	.995	0	0	2.0	2.0	.10	2.0	.60	0	300	1.0	.10	--	.001
High-density urban–2	0	.995	0	0	2.0	2.0	.60	2.0	.60	0	300	3.0	.10	--	.001
Natural vegetation–1	0	.995	0	0	2.0	2.0	.10	3.0	.60	0	500	2.0	.30	--	.0008
Natural vegetation–2	0	.995	0	0	2.0	2.0	.60	3.0	.60	0	500	4.0	.30	--	.0008
Pasture/hay–1	0	.995	0	0	2.0	2.0	.10	3.0	.60	0	500	2.0	.25	--	.0008
Pasture/hay–2	0	.995	0	0	2.0	2.0	.60	3.0	.60	0	500	4.0	.25	--	.0008
Row crops nonirrigated–1	0	.995	0	0	2.0	2.0	.10	3.0	.60	0	500	3.0	.20	--	.0005
Row crops nonirrigated–2	0	.995	0	0	2.0	2.0	.60	3.0	.60	0	500	5.0	.20	--	.0005
Row crops irrigated–1	0	.995	0	0	2.0	2.0	.10	3.0	.60	0	500	3.0	.22	--	.0005
Row crops irrigated–2	0	.995	0	0	2.0	2.0	.60	3.0	.60	0	500	5.0	.22	--	.0005
Citrus–1	0	.995	0	0	2.0	2.0	.10	3.0	.60	0	500	3.0	.18	--	.0005
Citrus–2	0	.995	0	0	2.0	2.0	.60	3.0	.60	0	500	5.0	.18	--	.0005
Citrus tile drain–1	0	.995	0	0	2.0	2.0	.05	9.0	.80	0	300	3.0	.15	--	.0008
Citrus tile drain–2	0	.995	0	0	2.0	2.0	.30	9.0	.80	0	300	5.0	.15	--	.0008
Sugar cane–1	0	.995	0	0	2.0	2.0	.10	3.0	.60	0	500	3.0	.35	--	.0005
Sugar cane–2	0	.995	0	0	2.0	2.0	.60	3.0	.60	0	500	5.0	.35	--	.0005
Sugar cane tile drain–1	0	.995	0	0	2.0	2.0	.05	9.0	.80	0	300	3.0	.32	--	.0008
Sugar cane tile drain–2	0	.995	0	0	2.0	2.0	.30	9.0	.80	0	300	5.0	.32	--	.0008
IMPLND															
Low-density urban	--	--	--	--	--	--	--	--	--	--	300	--	.08	.01	.01
High-density urban	--	--	--	--	--	--	--	--	--	--	300	--	.08	.01	.01
Water/wetlands	--	--	--	--	--	--	--	--	--	--	300	--	.04	.01	.01

[1] Default value used.
[2] Initial estimates from Dean and others (1984).
[3] Parameter revised during calibration.

Table 8. Monthly PERLND and IMPLND process-related parameters for flow, Arroyo Colorado Basin

[Parameter definitions in table 1; units below parameter except where no units. in., inches]

Land segment	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
					CEPSC[1,2] (in.)							
Low-density urban	0.03	0.03	0.05	0.06	0.10	0.15	0.15	0.12	0.10	0.06	0.03	0.03
High-density urban	.03	.03	.05	.06	.10	.15	.15	.12	.10	.06	.03	.03
Natural vegetation	.03	.03	.05	.06	.10	.15	.15	.12	.10	.06	.03	.03
Pasture/hay	.03	.03	.05	.06	.10	.15	.15	.12	.10	.06	.03	.03
Row crops nonirrigated	.13	.13	.15	.16	.20	.25	.25	.25	.15	.16	.03	.03
Row crops irrigated	.13	.13	.15	.16	.20	.25	.25	.25	.15	.16	.03	.03
Citrus	.20	.20	.20	.25	.25	.25	.25	.25	.20	.20	.20	.20
Sugar cane	.15	.15	.15	.20	.25	.25	.25	.25	.20	.15	.15	.15
					LZETP[1,2]							
Low-density urban	.30	.30	.50	.60	.70	.75	.85	.85	.70	.45	.30	.30
High-density urban	.30	.30	.50	.60	.70	.75	.85	.85	.70	.45	.30	.30
Natural vegetation	.40	.40	.50	.60	.70	.75	.85	.85	.70	.55	.40	.40
Pasture/hay	.40	.40	.50	.60	.70	.75	.85	.85	.70	.55	.40	.40
Row crops nonirrigated	.40	.45	.50	.65	.70	.75	.85	.85	.75	.65	.40	.40
Row crops irrigated	.40	.45	.55	.65	.70	.75	.85	.85	.75	.65	.45	.40
Citrus	.40	.45	.55	.65	.75	.80	.90	.90	.75	.65	.45	.45
Sugar cane	.45	.45	.55	.60	.75	.80	.90	.90	.75	.65	.45	.45
					UZSN[1,2] (in.)							
Low-density urban	.15	.15	.15	.20	.20	.20	.15	.15	.15	.15	.15	.15
High-density urban	.15	.15	.15	.20	.20	.20	.15	.15	.15	.15	.15	.15
Natural vegetation	.15	.20	.25	.20	.25	.20	.20	.20	.25	.25	.15	.15
Pasture/hay	.15	.20	.35	.30	.25	.20	.20	.20	.25	.25	.15	.15
Row crops nonirrigated	.15	.20	.35	.30	.25	.20	.20	.20	.25	.25	.15	.15
Row crops irrigated	.15	.20	.35	.30	.25	.20	.20	.20	.25	.25	.15	.15
Citrus	.20	.25	.35	.35	.35	.35	.35	.35	.25	.25	.25	.20
Sugar cane	.20	.25	.30	.35	.35	.35	.35	.35	.25	.25	.25	.20

[1] Initial estimates from Dean and others (1984).
[2] Parameter revised during calibration.

Table 9. Selected calibration and testing results using HSPEXP, Arroyo Colorado Basin

[Error, ([simulated–measured]/measured)*100; in., inches; --, not used]

	Weslaco			Mercedes			Harlingen		
	Measured (in.)	Simulated (in.)	Error (percent)	Measured (in.)	Simulated (in.)	Error (percent)	Measured (in.)	Simulated (in.)	Error (percent)
Calibration 1989–95									
Total flow volume	87.8	87.7	-0.1	--	--	--	88.6	88.5	-0.1
Total of highest 10-percent flows	22.0	21.5	-2.3	--	--	--	20.3	21.5	5.9
Total of lowest 50-percent flows	30.3	30.5	.7	--	--	--	32.2	30.6	-5.0
Summer flow volume	23.1	25.9	12.1	--	--	--	24.7	26.2	6.1
Winter flow volume	19.0	18.8	-1.1	--	--	--	18.4	18.5	.5
Total storm volume	8.7	8.0	-8.0	--	--	--	8.9	8.4	-5.6
Summer storm volume	2.4	2.8	16.7	--	--	--	2.5	2.6	4.0
Spatial testing 1989–95									
Total flow volume	--	--	--	81.4	87.5	7.5	--	--	--
Total of highest 10-percent flows	--	--	--	19.2	21.0	9.4	--	--	--
Total of lowest 50-percent flows	--	--	--	29.9	30.4	1.7	--	--	--
Summer flow volume	--	--	--	22.2	26.3	18.5	--	--	--
Winter flow volume	--	--	--	17.3	18.6	7.5	--	--	--
Total storm volume	--	--	--	8.0	7.9	-1.3	--	--	--
Summer storm volume	--	--	--	2.5	2.9	16.0	--	--	--
Temporal testing 1996–99									
Total flow volume	--	--	--	36.5	47.1	29.0	43.6	48.5	11.2
Total of highest 10-percent flows	--	--	--	10.6	12.0	13.2	14.4	12.6	-12.5
Total of lowest 50-percent flows	--	--	--	12.3	15.7	27.6	14.1	15.9	12.8
Summer flow volume	--	--	--	8.7	10.2	17.2	8.8	10.1	14.8
Winter flow volume	--	--	--	6.9	10.1	46.4	8.3	10.3	24.1
Total storm volume	--	--	--	10.7	11.6	8.4	14.7	12.4	-15.6
Summer storm volume	--	--	--	2.3	2.5	8.7	2.1	2.5	19.0

Table 10. Annual PERLND and IMPLND process-related parameters for water quality, Arroyo Colorado Basin

[Parameter definitions in table 1; units below parameter except where no units. tons/ac-d, tons per acre per day; /d, per day; --, not used or not applicable; lb/ac-d, pounds per acre per day; mg C/L, milligrams carbon per liter; °F, degrees Fahrenheit; ft, feet; in/hr, inches per hour]

Land segment	ACCSDP (tons/ac-d)	AFFIX (/d)	JEIM	JGER	JRER	JSER	KEIM	KGER	KRER	KSER
PERLND										
Low-density urban	--	0.001	--	1.0	2.2	2.5	--	0	0.40	1.6
Land application	--	.001	--	1.0	2.2	2.5	--	0	.40	1.6
Colonias	--	.001	--	1.0	2.2	2.5	--	0	.40	1.6
Septic	--	.001	--	1.0	2.2	2.5	--	0	.40	1.6
High-density urban	--	.001	--	1.0	2.2	2.5	--	0	.40	1.8
Natural vegetation	--	.001	--	1.0	2.2	2.5	--	0	.40	1.6
Pasture/hay	--	.001	--	1.0	2.0	2.0	--	0	.35	2.0
Row crops nonirrigated	--	.005	--	1.0	2.0	2.0	--	0	.35	2.0
Row crops irrigated	--	.005	--	1.0	2.0	2.0	--	0	.35	1.2
Citrus	--	.005	--	1.0	2.0	2.0	--	0	.30	3.5
Citrus tile drain	--	.005	--	1.0	2.0	2.0	--	0	.30	3.0
Sugar cane	--	.005	--	1.0	2.0	2.0	--	0	.35	2.5
Sugar cane tile drain	--	.005	--	1.0	2.0	2.0	--	0	.35	2.0
IMPLND										
Low-density urban	0.005	--	2.0	--	--	--	0.02	--	--	--
High-density urban	.005	--	2.0	--	--	--	.02	--	--	--
Water/wetlands	--	--	--	--	--	--	--	--	--	--

Land segment	NVSI (lb/ac-d)	REMSDP (/d)	SMPF	ACO2P (mg C/L)	AWTF (°F)	BWTF (°F)	ELEV (ft)	ICO2P (mg C/L)	WSQOP (in/hr)
PERLND									
Low-density urban	0	--	1.0	--	--	--	100	--	0.50
Land application	0	--	1.0	--	--	--	100	--	.50
Colonias	0	--	1.0	--	--	--	100	--	.50
Septic	0	--	1.0	--	--	--	100	--	.50
High-density urban	0	--	1.0	--	--	--	100	--	.50
Natural vegetation	0	--	1.0	--	--	--	100	--	.50
Pasture/hay	0	--	1.0	--	--	--	100	--	.50
Row crops nonirrigated	0	--	1.0	--	--	--	100	--	.50
Row crops irrigated	0	--	1.0	--	--	--	100	--	.50
Citrus	0	--	1.0	--	--	--	100	--	.50
Citrus tile drain	0	--	1.0	--	--	--	100	--	.50
Sugar cane	0	--	1.0	--	--	--	100	--	.50
Sugar cane tile drain	0	--	1.0	--	--	--	100	--	.50
IMPLND									
Low-density urban	--	0.01	--	--	34	0.6	100	--	.50
High-density urban	--	.01	--	--	34	.6	100	--	.50
Water/wetlands	--	--	--	--	--	--	--	--	--

Table 11. Monthly PERLND and IMPLND process-related parameters for water quality, Arroyo Colorado Basin

[Parameter definitions in table 1; units shown for parameter except where no units. °F, degrees Fahrenheit; mg/L, milligrams per liter; lb/ac-d, pounds per acre per day; BOD, biochemical oxygen demand; lb/ac, pounds per acre]

Land segment (PERLND unless labeled IMPLND)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
COVER[1,2]												
Low-density urban[3]	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
High-density urban	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70
Natural vegetation	.80	.80	.80	.80	.80	.80	.80	.80	.80	.80	.80	.80
Pasture/hay	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60
Row crops nonirrigated	.21	.17	.24	.36	.58	.65	.72	.72	.36	.24	.21	.21
Row crops irrigated	.31	.27	.34	.46	.58	.65	.72	.72	.46	.34	.31	.31
Citrus	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45
Citrus tile drain	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50
Sugar cane	.31	.27	.34	.46	.58	.65	.72	.72	.46	.34	.31	.31
Sugar cane tile drain	.45	.42	.49	.61	.73	.0	.82	.82	.61	.49	.45	.45
ASLT[1,2] (°F)												
All pervious land uses	34	34	37.5	43	50	60	60	60	53.5	45	40	35.5
BSLT[1,2] (°F)												
All pervious land uses	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50
LGTP1[1,2] (°F)												
All pervious land uses	45	45	50	55	55	60	60	60	60	55	50	45
ULTP1[1,2] (°F)												
All pervious land uses	34.5	34.5	41	51	62.5	74	81	81	70	53.5	45	37.5
ULTP2[1,2] (°F)												
All pervious land uses	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
ADOXP[1,2] (mg/L)												
All pervious land uses	11	10	10	9	8	8	7	7	8	8	10	11
IDOXP[1,2] (mg/L)												
All pervious land uses	11	10	10	9	8	8	7	7	8	8	10	11
ACQOP[1,2] (lb/ac-d) -BOD												
Low-density urban[3]	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25
High-density urban	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
Natural vegetation	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
Pasture/hay	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
Row crops nonirrigated	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
Row crops irrigated	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50
Citrus	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
Citrus tile drain	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
Sugar cane	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
Sugar cane tile drain	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
Low-density urban IMPLND	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
High-density urban IMPLND	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35

Footnotes at end of table.

Table 11. Monthly PERLND and IMPLND process-related parameters for water quality, Arroyo Colorado Basin—Continued

Land segment (PERLND unless labeled IMPLND)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
AOQC[1,2] (mg/L) - BOD												
Low-density urban[3]	16	16	14	10	10	10	10	10	12	14	16	16
Land application	20	20	20	20	20	20	20	20	20	20	20	20
Colonias	20	20	20	20	20	20	20	20	20	20	20	20
Septic	20	20	20	20	20	20	20	20	20	20	20	20
High-density urban	16	16	14	10	10	10	10	10	12	14	16	16
Natural vegetation	14	14	14	10	10	10	10	10	12	14	14	14
Pasture/hay	14	14	14	10	10	10	10	10	12	14	14	14
Row crops nonirrigated	6	6	6	4	4	4	4	4	6	6	6	6
Row crops irrigated	6	6	6	4	4	4	4	4	6	6	6	6
Citrus	6	6	6	4	4	4	4	4	6	6	6	6
Citrus tile drain	6	6	6	4	4	4	4	4	6	6	6	6
Sugar cane	6	6	6	4	4	4	4	4	6	6	6	6
Sugar cane tile drain	6	6	6	4	4	4	4	4	6	6	6	6
IOQC[1,2] (mg/L) - BOD												
Low-density urban[3]	16	16	14	10	10	10	10	10	12	14	16	16
Land application	20	20	20	20	20	20	20	20	20	20	20	20
Colonias	20	20	20	20	20	20	20	20	20	20	20	20
Septic	20	20	20	20	20	20	20	20	20	20	20	20
High-density urban	16	16	14	10	10	10	10	10	12	14	16	16
Natural vegetation	14	14	14	10	10	10	10	10	12	14	14	14
Pasture/hay	14	14	14	10	10	10	10	10	12	14	14	14
Row crops nonirrigated	6	6	6	4	4	4	4	4	6	6	6	6
Row crops irrigated	6	6	6	4	4	4	4	4	6	6	6	6
Citrus	6	6	6	4	4	4	4	4	6	6	6	6
Citrus tile drain	6	6	6	4	4	4	4	4	6	6	6	6
Sugar cane	6	6	6	4	4	4	4	4	6	6	6	6
Sugar cane tile drain	6	6	6	4	4	4	4	4	6	6	6	6
SQOLIM[1,2] (lb/ac) - BOD												
Low-density urban[3]	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
High-density urban	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Natural vegetation	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Pasture/hay	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Row crops nonirrigated	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Row crops irrigated	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Citrus	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Citrus tile drain	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Sugar cane	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Sugar cane tile drain	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Low-density urban IMPLND	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
High-density urban IMPLND	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0

Footnotes at end of table.

Table 11. Monthly PERLND and IMPLND process-related parameters for water quality, Arroyo Colorado Basin—Continued

Land segment (PERLND unless labeled IMPLND)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
ACQOP[1,2] (lb/ac-d) - NO_3												
Low-density urban[3]	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
High-density urban	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08
Natural vegetation	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08
Pasture/hay	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08
Row crops nonirrigated	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30
Row crops irrigated	.90	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30
Citrus	.30	.90	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30
Citrus tile drain	.30	.90	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30
Sugar cane	.90	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30
Sugar cane tile drain	.30	.30	.30	.30	.30	.30	.30	.30	.90	.30	.30	.30
Low-density urban IMPLND	.016	.016	.016	.016	.016	.016	.016	.016	.016	.016	.016	.016
High-density urban IMPLND	.015	.015	.015	.015	.015	.015	.015	.015	.015	.015	.015	.015
AOQC[1,2] (mg/L) - NO_3												
Low-density urban[3]	.4	.4	.4	.4	.3	.3	.3	.3	.3	.3	.4	.4
Land application	10	10	10	10	10	10	10	10	10	10	10	10
Colonias	10	10	10	10	10	10	10	10	10	10	10	10
Septic	10	10	10	10	10	10	10	10	10	10	10	10
High-density urban	.4	.4	.4	.4	.3	.3	.3	.3	.3	.3	.4	.4
Natural vegetation	.5	.5	.5	.5	.4	.4	.4	.4	.4	.4	.5	.5
Pasture/hay	.4	.4	.4	.4	.3	.3	.3	.3	.3	.3	.4	.4
Row crops nonirrigated	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Row crops irrigated	6.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Citrus	4.0	6.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Citrus tile drain	4.0	6.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Sugar cane	4.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Sugar cane tile drain	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	4.0	2.5	2.5	2.5
IOQC[1,2] (mg/L) - NO_3												
Low-density urban[3]	.4	.4	.4	.4	.3	.3	.3	.3	.3	.3	.4	.4
Land application	10	10	10	10	10	10	10	10	10	10	10	10
Colonias	10	10	10	10	10	10	10	10	10	10	10	10
Septic	10	10	10	10	10	10	10	10	10	10	10	10
High-density urban	.4	.4	.4	.4	.3	.3	.3	.3	.3	.3	.4	.4
Natural vegetation	.5	.5	.5	.5	.4	.4	.4	.4	.4	.4	.5	.5
Pasture/hay	.4	.4	.4	.4	.3	.3	.3	.3	.3	.3	.4	.4
Row crops nonirrigated	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Row crops irrigated	6.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Citrus	4.0	6.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Citrus tile drain	4.0	6.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Sugar cane	4.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Sugar cane tile drain	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	4.0	2.5	2.5	2.5

Footnotes at end of table.

Table 11. Monthly PERLND and IMPLND process-related parameters for water quality, Arroyo Colorado Basin—Continued

Land segment (PERLND unless labeled IMPLND)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
SQOLIM[1,2] (lb/ac) - NO_3												
Low-density urban[3]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
High-density urban	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2
Natural vegetation	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2
Pasture/hay	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2
Row crops nonirrigated	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Row crops irrigated	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Citrus	1.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Citrus tile drain	1.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sugar cane	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	1.0	1.0	1.0
Sugar cane tile drain	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Low-density urban IMPLND	.16	.16	.16	.16	.16	.16	.16	.16	.16	.16	.16	.16
High-density urban IMPLND	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
ACQOP[1,2] (lb/ac-d) - NH_3												
Low-density urban[3]	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
High-density urban	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
Natural vegetation	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
Pasture/hay	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
Row crops nonirrigated	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
Row crops irrigated	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
Citrus	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
Citrus tile drain	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
Sugar cane	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
Sugar cane tile drain	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
Low-density urban IMPLND	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
High-density urban IMPLND	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
AOQC[1,2] (mg/L) - NH_3												
Low-density urban[3]	.25	.25	.25	.25	.20	.10	.10	.10	.10	.20	.25	.25
Land application	5	5	5	5	5	5	5	5	5	5	5	5
Colonias	5	5	5	5	5	5	5	5	5	5	5	5
Septic	5	5	5	5	5	5	5	5	5	5	5	5
High-density urban	.25	.25	.25	.25	.20	.10	.10	.10	.10	.20	.25	.25
Natural vegetation	.20	.20	.20	.20	.15	.10	.10	.10	.10	.15	.20	.20
Pasture/hay	.20	.20	.20	.20	.15	.10	.10	.10	.10	.15	.20	.20
Row crops nonirrigated	1.0	1.0	1.0	.8	.7	.6	.6	.6	.6	.7	.8	.8
Row crops irrigated	1.7	1.7	1.7	1.7	1.7	1.6	1.6	1.6	1.6	1.7	1.7	1.7
Citrus	1.4	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3
Citrus tile drain	1.4	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3
Sugar cane	2.0	2.0	2.0	1.8	1.7	1.6	1.6	1.6	1.6	1.7	1.8	2.0
Sugar cane tile drain	2.0	2.0	2.0	1.8	1.7	1.6	1.6	1.6	1.6	1.7	1.8	2.0

Footnotes at end of table.

Table 11. Monthly PERLND and IMPLND process-related parameters for water quality, Arroyo Colorado Basin—Continued

Land segment (PERLND unless labeled IMPLND)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
IOQC[1,2] (mg/L) - NH_3												
Low-density urban[3]	0.25	0.25	0.25	0.25	0.20	0.10	0.10	0.10	0.10	0.20	0.25	0.25
Land application	5	5	5	5	5	5	5	5	5	5	5	5
Colonias	5	5	5	5	5	5	5	5	5	5	5	5
Septic	5	5	5	5	5	5	5	5	5	5	5	5
High-density urban	.25	.25	.25	.25	.20	.10	.10	.10	.10	.20	.25	.25
Natural vegetation	.20	.20	.20	.20	.15	.10	.10	.10	.10	.15	.20	.20
Pasture/hay	.20	.20	.20	.20	.15	.10	.10	.10	.10	.15	.20	.20
Row crops nonirrigated	1.0	1.0	1.0	.8	.7	.6	.6	.6	.6	.7	.8	.8
Row crops irrigated	1.7	1.7	1.7	1.7	1.7	1.6	1.6	1.6	1.6	1.7	1.7	1.7
Citrus	1.4	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3
Citrus tile drain	1.4	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3
Sugar cane	2.0	2.0	2.0	1.8	1.7	1.6	1.6	1.6	1.6	1.7	1.8	2.0
Sugar cane tile drain	2.0	2.0	2.0	1.8	1.7	1.6	1.6	1.6	1.6	1.7	1.8	2.0
SQOLIM[1,2] (lb/ac) - NH_3												
Low-density urban[3]	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
High-density urban	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
Natural vegetation	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
Pasture/hay	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
Row crops nonirrigated	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30
Row crops irrigated	.40	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30
Citrus	.30	.40	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30
Citrus tile drain	.30	.40	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30
Sugar cane	.40	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30
Sugar cane tile drain	.30	.30	.30	.30	.30	.30	.30	.30	.40	.30	.30	.30
Low-density urban IMPLND	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06
High-density urban IMPLND	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
ACQOP[1,2] (lb/ac-d) - PO_4												
Low-density urban[3]	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
High-density urban	.012	.012	.012	.012	.012	.012	.012	.012	.012	.012	.012	.012
Natural vegetation	.012	.012	.012	.012	.012	.012	.012	.012	.012	.012	.012	.012
Pasture/hay	.012	.012	.012	.012	.012	.012	.012	.012	.012	.012	.012	.012
Row crops nonirrigated	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2
Row crops irrigated	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2
Citrus	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2
Citrus tile drain	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2
Sugar cane	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2
Sugar cane tile drain	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2
Low-density urban IMPLND	.004	.004	.004	.004	.004	.004	.004	.004	.004	.004	.004	.004
High-density urban IMPLND	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003

Footnotes at end of table.

Table 11. Monthly PERLND and IMPLND process-related parameters for water quality, Arroyo Colorado Basin—Continued

Land segment (PERLND unless labeled IMPLND)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
AOQC[1,2] (mg/L) - PO_4												
Low-density urban[3]	0.10	0.10	0.17	0.20	0.40	0.45	0.45	0.45	0.40	0.30	0.17	0.10
Land application	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Colonias	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Septic	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
High-density urban	.03	.03	.04	.06	.08	.10	.10	.10	.08	.06	.04	.03
Natural vegetation	.03	.03	.04	.06	.08	.10	.10	.10	.08	.06	.04	.03
Pasture/hay	.03	.03	.04	.06	.08	.10	.10	.10	.08	.06	.04	.03
Row crops nonirrigated	.10	.10	.20	.30	.40	.40	.40	.40	.40	.30	.20	.10
Row crops irrigated	.10	.10	.20	.30	.40	.40	.40	.40	.40	.30	.20	.10
Citrus	.10	.10	.20	.30	.40	.40	.40	.40	.40	.30	.20	.10
Citrus tile drain	.10	.10	.20	.30	.40	.40	.40	.40	.40	.30	.20	.10
Sugar cane	.10	.10	.20	.30	.40	.40	.40	.40	.40	.30	.20	.10
Sugar cane tile drain	.10	.10	.20	.30	.40	.40	.40	.40	.40	.30	.20	.10
IOQC[1,2] (mg/L) - PO_4												
Low-density urban[3]	.10	.10	.17	.20	.40	.45	.45	.45	.40	.30	.17	.10
Land application	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Colonias	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Septic	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
High-density urban	.03	.03	.04	.06	.08	.10	.10	.10	.08	.06	.04	.03
Natural vegetation	.03	.03	.04	.06	.08	.10	.10	.10	.08	.06	.04	.03
Pasture/hay	.03	.03	.04	.06	.08	.10	.10	.10	.08	.06	.04	.03
Row crops nonirrigated	.10	.10	.20	.30	.40	.40	.40	.40	.40	.30	.20	.10
Row crops irrigated	.10	.10	.20	.30	.40	.40	.40	.40	.40	.30	.20	.10
Citrus	.10	.10	.20	.30	.40	.40	.40	.40	.40	.30	.20	.10
Citrus tile drain	.10	.10	.20	.30	.40	.40	.40	.40	.40	.30	.20	.10
Sugar cane	.10	.10	.20	.30	.40	.40	.40	.40	.40	.30	.20	.10
Sugar cane tile drain	.10	.10	.20	.30	.40	.40	.40	.40	.40	.30	.20	.10
SQOLIM[1,2] (lb/ac) - PO_4												
Low-density urban[3]	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
High-density urban	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
Natural vegetation	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
Pasture/hay	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
Row crops nonirrigated	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
Row crops irrigated	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
Citrus	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
Citrus tile drain	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
Sugar cane	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
Sugar cane tile drain	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
Low-density urban IMPLND	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04
High-density urban IMPLND	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03

[1] Initial estimates from Dean and others (1984).
[2] Parameter revised during calibration.
[3] Low-density urban not subdivided into land application, colonias, septic.

Table 12. Annual RCHRES process-related parameters for water quality, Arroyo Colorado Basin

[Parameter definitions in table 1; units below parameter except where no units. ft, feet; in., inches; lb/ft^2-d, pounds per square foot per day; g/cm^3, grams per cubic centimeter; lb/ft^2, pounds per square foot; in/s, inches per second; mg/m^2-hr, milligrams per square meter per hour; /hr, per hour; ft/hr, feet per hour; mL/g, milliliters per gram; mg/L, milligrams per liter; mg/kg, milligrams per kilogram; mg/mg, milligrams per milligram; mol/mol, moles per mole; µg/L, micrograms per liter; ly/min, langleys per minute; /ft, per foot; L/mg-ft, liters per milligram per foot; ft^3/s, cubic feet per second; ft/hr, feet per hour; °F, degrees Fahrenheit]

Land segment	BEDWID (ft)	BEDWRN (ft)	D sand (in.)	D silt (in.)	D clay (in.)	EXPSND	KSAND	M silt (lb/ft^2-day)	M clay (lb/ft^2-day)	POR	RHO sand (g/cm^3)	RHO silt (g/cm^3)	RHO clay (g/cm^3)
RCHRES													
1	20.0	6.0	0.01	0.0006	0.00006	2.0	1.9	0.004	0.0006	0.8	2.5	2.2	2.0
2	20.0	6.0	.01	.0006	.00006	2.0	2.8	.003	.001	.8	2.5	2.2	2.0
3	20.0	6.0	.01	.0006	.00006	2.0	4.6	.008	.001	.8	2.5	2.2	2.0
4	20.0	6.0	.01	.0006	.00006	2.0	11.5	.012	.001	.8	2.5	2.2	2.0
5	20.0	6.0	.01	.0006	.00006	2.0	13.3	.025	.0006	.8	2.5	2.2	2.0
6	20.0	6.0	.01	.0006	.00006	2.0	11.4	.020	.004	.8	2.5	2.2	2.0
7	20.0	6.0	.01	.0006	.00006	2.0	3.6	.025	.003	.8	2.5	2.2	2.0
8	20.0	6.0	.01	.0006	.00006	2.0	4.9	.033	.002	.8	2.5	2.2	2.0

Land segment	TAUCD silt (lb/ft^2)	TAUCD clay (lb/ft^2)	TAUCS silt (lb/ft^2)	TAUCS clay (lb/ft^2)	W sand (in/s)	W silt (in/s)	W clay (in/s)	CFSAEX	ELEV (ft)	ELDAT (ft)	KATRAD	KDCOND	KEVAP
RCHRES													
1	0.016	0.016	0.019	0.019	0.03	0.0003	0.000006	0.85	100.0	0	6.37	3.12	4.24
2	.037	.037	.049	.049	.03	.0003	.000006	.85	100.0	0	6.37	3.12	4.24
3	.063	.063	.077	.077	.03	.0003	.000006	.85	100.0	0	6.37	3.12	4.24
4	.076	.075	.080	.080	.03	.0003	.000006	.85	100.0	0	6.37	3.12	4.24
5	.040	.038	.053	.053	.03	.0003	.000006	.85	100.0	0	6.37	3.12	4.24
6	.075	.079	.095	.095	.03	.0003	.000006	.85	100.0	0	6.37	3.12	4.24
7	.070	.077	.087	.087	.03	.0003	.000006	.85	100.0	0	6.37	3.12	4.24
8	.096	.096	.100	.100	.03	.0003	.000006	.85	100.0	0	6.37	3.12	4.24

Land segment	BENOD (mg/m^2-hr)	BRBOD1 (mg/m^2-hr)	BRBOD2 (mg/m^2-hr)	EXPOD	EXPRED	EXPREL	EXPREV	KBOD20 (/hr)	KODSET (ft/hr)	REAK (/hr)	SUPSAT	TCBEN	TCBOD	TCGINV
RCHRES														
1–4	60	72	100	1.22	0	2.82	0	0.03	0.004	0.20	1.15	1.07	1.07	1.03
5–7	50	72	100	1.22	0	2.82	0	.005	.004	.20	1.15	1.07	1.07	1.03
8	100	72	100	1.22	0	2.82	0	.08	.004	.10	1.15	1.07	1.07	1.03

Table 12. Annual RCHRES process-related parameters for water quality, Arroyo Colorado Basin—Continued

Land segment	ADNHPM sand (mL/g)	ADNHPM silt (mL/g)	ADNHPM clay (mL/g)	ADPOPM sand (mL/g)	ADPOPM silt (mL/g)	ADPOPM clay (mL/g)	ANAER (mg/L)	BNH4 sand (mg/kg)	BNH4 silt (mg/kg)	BNH4 clay (mg/kg)	BPCNTC	BPO4 sand (mg/kg)	BPO4 silt (mg/kg)
RCHRES													
1–4	10	100	100	100	1,000	1,000	0.2	10	50	50	49	20	100
5–7	10	100	100	100	1,000	1,000	.2	10	50	50	49	20	100
8	10	100	100	100	1,000	1,000	.2	10	50	50	49	20	100

Land segment	BPO4 clay (mg/kg)	BRPO41 (mg/m^2-hr)	BRPO42 (mg/m^2-hr)	BRTAM1 (mg/m^2-hr)	BRTAM2 (mg/m^2-hr)	CVBO (mg/mg)	CVBPC (mol/mol)	CVBPN (mol/mol)	DENOXT (mg/L)	KNO220 (/hr)	KNO320 (/hr)	KTAM20 (/hr)	TCDEN
RCHRES													
1–4	100	1	4	10	20	1.98	106	16	4	0.25	0.2	0.3	1.07
5–7	100	1	4	10	20	1.98	106	16	4	.25	.5	.5	1.07
8	100	1	4	10	20	1.98	106	16	4	.25	.7	.05	1.07

Land segment	TCNIT	ALDH (/hr)	ALDL (/hr)	ALR20 (/hr)	ALNPR	CLALDH (µg/L)	CMMLT (ly/min)	CMMN (mg/L)	CMMNP (mg/L)	CMMP (mg/L)	EXTB (/ft)	LITSED (L/mg-ft)	MALGR (/hr)
RCHRES													
1–4	1.07	0.01	0.001	0.005	1.0	50	0.03	0.045	0.0284	0.015	0.1	0.04	0.17
5–7	1.07	.01	.001	.005	1.0	50	.03	.045	.0284	.015	.1	.04	.18
8	1.07	.01	.001	.005	1.0	50	.03	.045	.0284	.015	.1	.04	.065

Land segment	MXSTAY (mg/L)	NALDH (mg/L)	NONREF	OREF (ft^3/s)	OXALD (/hr)	PALDH (mg/L)	PHYSET (ft/hr)	RATCLP	REFSET (ft/hr)	SEED (mg/L)	TALGRH (°F)	TALGRL (°F)	TALGRM (°F)
RCHRES													
1–4	2	0	0.5	130	0.03	0	0.06	0.60	0.10	1.0	95	45	78
5–7	2	0	.5	130	.03	0	.06	.60	.10	1.0	95	45	78
8	2	0	.5	130	.03	0	.08	.60	.10	1.0	95	45	78

Table 13. Selected nonpoint-source event-mean concentrations for calibration and testing of water quality, Arroyo Colorado Basin

[mg/L, milligrams per liter; --, no local or regional data available]

Land segment	Suspended sediment (mg/L)	Biochemical oxygen demand (mg/L)	Nitrate nitrogen (mg/L)	Ammonia nitrogen (mg/L)	Orthophosphate (mg/L)
Low-density urban	--	[1]7.3	[1]0.58	[1]0.18	[1]0.21
High-density urban	--	[1]7.0	[1].52	[1].16	[1].08
Natural vegetation	--	[2]6.0	[3].54	[3].96	[3].03
Pasture/hay	--	[3]6.0	[3].40	[3].30	[3].03
Row crops nonirrigated	[4]366	[5]4	[5].24	[5].04	[5].32
Row crops irrigated	--	[6]2.8	[7]7.6	--	[7].06
Citrus	--	--	[8]34	--	--
Citrus tile drain	--	--	--	--	--
Sugar cane	--	--	--	--	--
Sugar cane tile drain	--	--	[9]3.5	--	--

[1] Baldys and others (1998).
[2] Newell and others (1992).
[3] Texas Natural Resource Conservation Commission (1998).
[4] Ockerman and Petri (2001).
[5] Flowers and others (1998).
[6] Ambiotech Environmental Consultants, Inc. (1998).
[7] Moore (1995).
[8] Texas A&M University (1995).
[9] Guy Fipps, Texas A&M University (written commun., 1999).

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