Computer Programs for Obtaining and Analyzing Daily Mean Streamflow Data from the U.S. Geological Survey National Water Information System Web Site

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Conversion Factors and Abbreviations

Multiply	By	To obtain
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]

Abbreviations

1B3	1-day 3-year biological low flow
4B3	4-day 3-year biological low flow
7Q10	7-day 10-year low flow
ADAPS	USGS Automated Data Processing System
BCF	bias correction factor
BMP(s)	best management practice(s)
CD-ROM	computer disk-read only memory
dv	daily value
dd	data descriptor
EMC	event mean concentration
FHWA	Federal Highway Administration
GNWISQ	Get National Water Information System Streamflow (Q)
KTRLine	Kendall-Theil robust line
log10	common logarithm
MkDF	Make U.S. Environmental Protection Agency DFLOW3 batch input Files
MkPP	Make plotting position file
MOVE	maintenance of variance
NWIS	National Water Information System
NWISWeb	National Water Information System Web
PC	Personal Computer
Q	Streamflow
QSTATS	Streamflow (Q) Statistics
RDB	relational database
ROS	regression-on-order statistics
SELDM	stochastic empirical loading and dilution model
SQL	structured query language
SREF	Streamflow Record Extension Facilitator
TMDL(s)	Total Maximum Daily Load(s)
USGS	U.S. Geological Survey

Computer programs for Obtaining and Analyzing Daily Mean Streamflow Data from the U.S. Geological Survey National Water Information System Web Site

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Abstract

Five computer programs were developed for obtaining and analyzing streamflow from the National Water Information System (NWISWeb). The programs were developed as part of a study by the U.S. Geological Survey, in cooperation with the Federal Highway Administration, to develop a stochastic empirical loading and dilution model. The programs were developed because reliable, efficient, and repeatable methods are needed to access and process streamflow information and data. The first program is designed to facilitate the downloading and reformatting of NWISWeb streamflow data. The second program is designed to facilitate graphical analysis of streamflow data. The third program is designed to facilitate streamflow-record extension and augmentation to help develop long-term statistical estimates for sites with limited data. The fourth program is designed to facilitate statistical analysis of streamflow data. The fifth program is a preprocessor to create batch input files for the U.S. Environmental Protection Agency DFLOW3 program for calculating low-flow statistics. These computer programs were developed to facilitate the analysis of daily mean streamflow data for planning-level water-quality analyses but also are useful for many other applications pertaining to streamflow data and statistics.

These programs and the associated documentation are included on the CD-ROM accompanying this report. This report and the appendixes on the CD-ROM describe the implementation and use of the programs and the interpretation of results from the programs. The body of this report provides an overview of the five programs included on this CD-ROM. The appendixes are the software manuals for each program. These manuals describe statistical and numerical methods used to implement each program, input-file formats, output-file formats, installation of the programs, and use of the programs. Each appendix is written as a self-contained manual because each program may have many uses alone or in tandem with other programs on the CD-ROM. Each of these programs uses graphical user interface that follows standard Microsoft Windows interface conventions.

Introduction

Streamflow information is important for many planning and design activities including water-supply analysis, habitat protection, bridge and culvert design, calibration of surface and ground-water models, and water-quality assessments. Streamflow information is especially critical for water-quality assessments (Warn and Brew, 1980; Di Toro, 1984; Driscoll and others, 1989; Driscoll and others, 1990, a,b). Calculation of streamflow statistics for receiving waters is necessary to estimate the potential effects of point sources such as wastewater-treatment plants and nonpoint sources such as highway and urban-runoff discharges on receiving water. Streamflow statistics indicate the amount of flow that may be available for dilution and transport of contaminants (U.S. Environmental Protection Agency, 1986; Driscoll and others, 1990, a,b). Streamflow statistics also may be used to indicate receiving-water quality because concentrations of water-quality constituents commonly vary naturally with streamflow. For example, concentrations of suspended sediment and sediment-associated constituents (such as nutrients, trace elements, and many organic compounds) commonly increase with increasing flows, and concentrations of many dissolved constituents commonly decrease with increasing flows in streams and rivers (O'Connor, 1976; Glysson, 1987; Vogel and others, 2003, 2005).

Reliable, efficient and repeatable methods are needed to access and process streamflow information and data. For example, the Nation's highway infrastructure includes an innumerable number of stream crossings and stormwater-outfall points for which estimates of stream-discharge statistics may be needed. The U.S. Geological Survey (USGS) streamflow data-collection program is designed to provide streamflow data at gaged sites and to provide information that can be used to estimate streamflows at almost any point along any stream in the United States (Benson and Carter, 1973; Wahl and others, 1995; National Research Council, 2004). The USGS maintains the National Water Information System (NWIS), a distributed network of computers and file servers used to store and retrieve hydrologic data (Mathey, 1998; U.S. Geological Survey, 2008). NWISWeb is an online version of this database that includes water data from more than 24,000 streamflow-gaging stations throughout the United States (U.S. Geological Survey, 2002, 2008). Information from NWISWeb is commonly used to characterize streamflows at gaged sites and to help predict streamflows at ungaged sites.

Streamflow Analysis for Water-Quality Modeling

The USGS, in cooperation with the Federal Highway Administration (FHWA), began a study to develop the stochastic empirical loading and dilution model (SELDM) in 2003. SELDM is a water-quality model that uses available data and stochastic Monte Carlo methods to generate planning-level estimates of water-quality constituent concentrations, discharges, and loads from the watershed upstream of the highway, from the highway, and in the receiving water downstream from the highway discharge for storm events (fig. 1). This information can be used to evaluate highway runoff as a source of constituents, the potential effects of these loads on receiving-water quality, and the potential effectiveness of best management practices (BMPs) to control the highway-runoff contribution to the downstream water discharge, constituent concentrations, and loads. Use of such a runoff-quality model creates a need for national, regional, and local estimates of streamflow statistics. The effort, time, and expense required to collect and analyze streamflow data at a site of interest, however, limit the availability of such data for any given site. Therefore, methods to develop robust planning-level estimates of these data at unmonitored sites across the country would be needed. These estimates would be made on a regional basis with data that are available from the USGS for a national-scale model.

A mass-balance approach (fig. 1) commonly is applied to estimate the concentrations and loads of water-quality constituents in receiving waters downstream of an urban- or highway-runoff outfall during storm events (Driscoll and others, 1979; Warn and Brew, 1980; Di Toro, 1984; Driscoll and others 1989; Driscoll and others 1990a,b). In a mass-balance model, the loads (the product of measured water discharge and concentration) of the upstream and runoff components are added to calculate the discharge, concentration, and load in the (fully mixed) receiving water downstream of the outfall. In the application of a mass-balance model, however, statistics describing the frequency distributions of component discharges and concentrations are used to determine the statistics for downstream discharges, concentrations, and loads (Warn and Brew, 1980). For example, DiToro (1984) used information about probability distributions of event mean concentrations (EMCs) and storm-runoff discharges from the outfall and the upstream basin to develop an empirical probabilistic-dilution model for planning-level estimates of downstream EMCs and water discharges. DiToro (1984) based his method on the assumption that contributing discharges and concentrations are independent and lognormally distributed. Planning-level estimates from this model indicate the potential for exceeding water-quality criteria and, therefore, the potential need for more information and data that may be used to identify suitable mitigation measures.

Estimating prestorm flows and runoff from the site of interest and the upstream basin is central to the conceptualization and implementation of a mass-balance approach for predicting the water discharge, constituent concentrations, and associated constituent loads from runoff and receiving waters (Warn and Brew, 1980; Schwartz and Naiman, 1999). Warn and Brew (1980) indicate that upstream concentrations and loads are correlated. Similarly, Schwartz and Naiman (1999) demonstrate the importance of good streamflow estimates and the effect of the correlation between constituent concentrations and streamflow in receiving waters on the adequacy of planning-level estimates of constituent concentrations and loads. Although surface runoff for the upstream watershed and at the site of interest would be correlated with rainfall for a given storm event, total upstream flow would have a lower correlation because of the potential variation in prestorm flow. Granato and others (2009) describe methods for developing planning-level estimates of background constituent concentrations by use of streamflow-based water-quality transport curves. Estimates of upstream flow and concentration may be used with statistics describing the population of highway-runoff discharges and constituent concentrations (Granato and Cazenas, 2009) to derive mass-balance estimates of the population of downstream concentrations, flows, and loads in a receiving water body.

As part of this study, data from 2,783 selected USGS streamflow-gaging stations across the conterminous United States (fig. 2) were identified and analyzed to help characterize prestorm streamflow statistics. Long records (years to decades) are commonly needed to characterize variations in streamflow through time. Therefore, streamflow statistics were calculated from data available for the period 1960–2003. One 40-year record may include about 14,610 daily mean streamflow values and require about 400,000 bytes of computer-disk space. Hundreds to thousands of such data files are necessary to characterize national variations in streamflow because streamflow statistics vary from site to site and are affected by a number of natural and anthropogenic factors (Langbein, 1949; Thomas and Benson, 1970; Poff, 1996; Lins, 1997; Poff and others, 2006). Assuming that the U.S. Environmental Protection Agency (2004b) level III ecoregions are hydrologically similar regions, each ecoregion may be used to estimate streamflow statistics for planning-level water-quality analyses. Automated data-collection and processing methods were needed to compile and analyze streamflow information and data. Data from additional stations or data from subsequent years may be obtained from NWISWeb and analyzed by use of the tools and techniques described in the appendixes of this report. The computer programs documented in this report also are applicable for many other types of hydrologic studies at a local, state or regional scale.

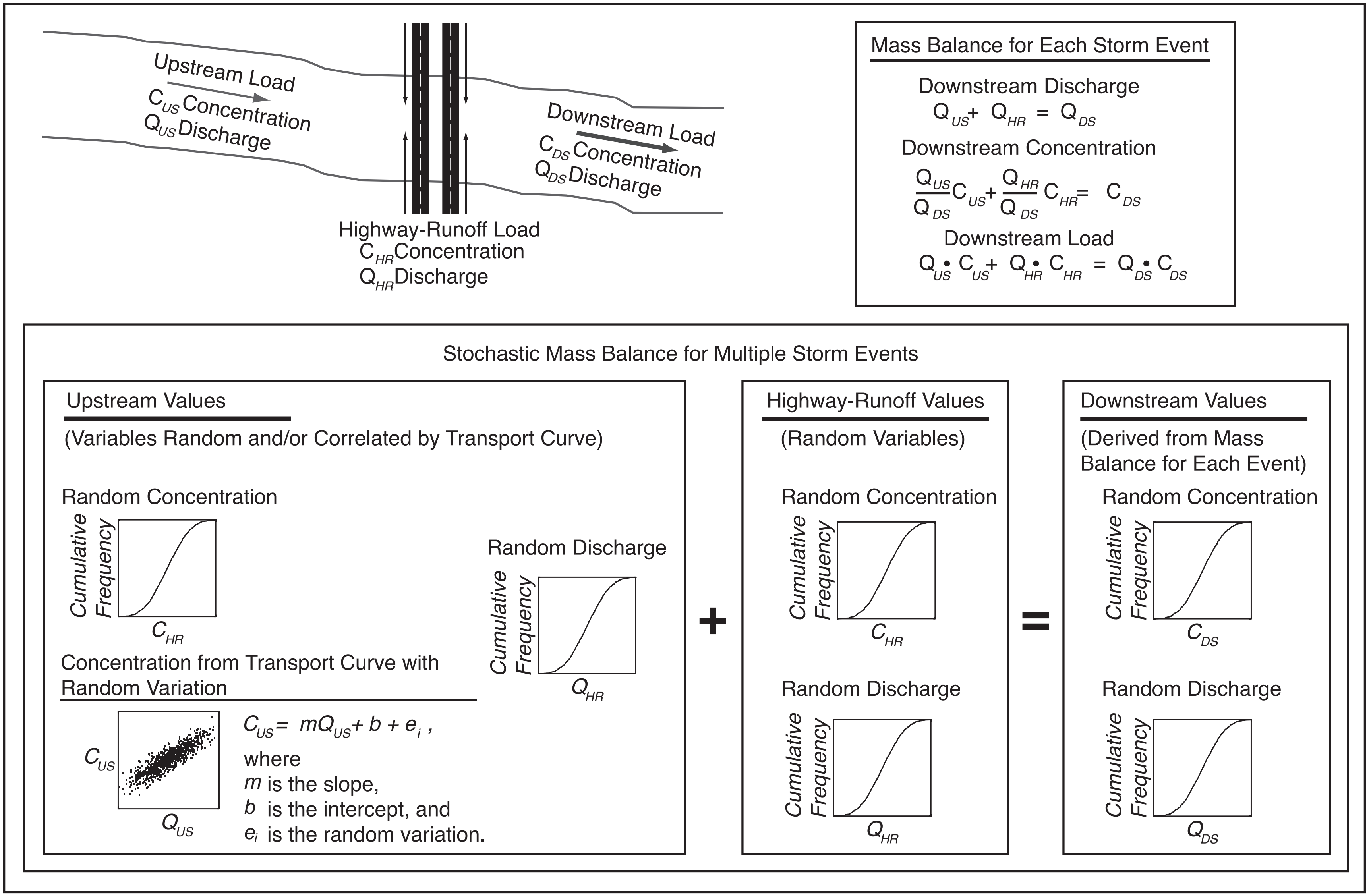

Figure 1. Schematic diagram showing the stochastic mass-balance approach for estimating discharge, concentration, and loads of water-quality constituents upstream of a highway outfall, from the highway, and downstream of a highway-runoff outfall. Upstream concentrations may be random, or may be related to discharge with a transport curve (with random white-noise quantified by an error term ei), highway runoff concentrations are commonly assumed to be random, and the downstream concentration is a function of the highway and upstream loads.

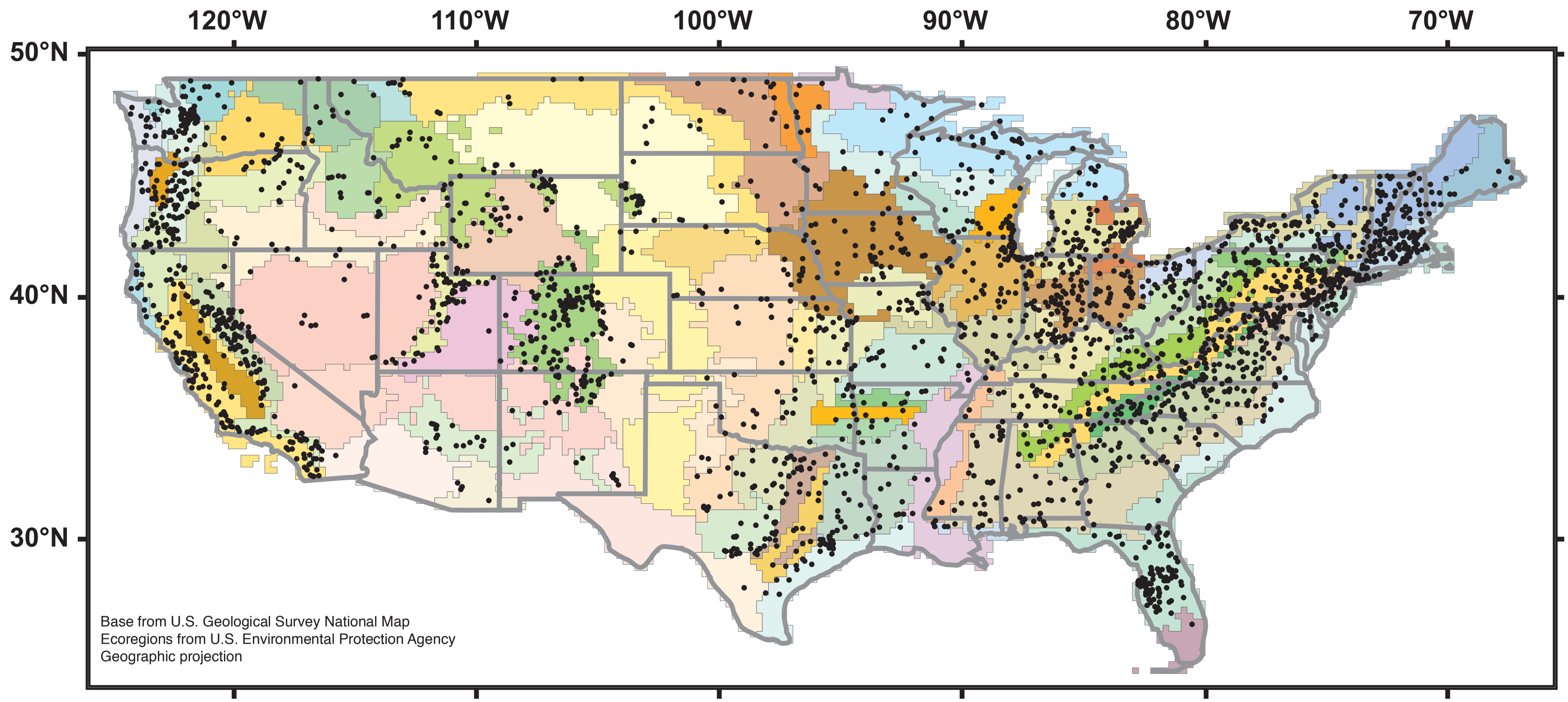

Figure 2. Spatial distribution of 2,783 selected U.S. Geological Survey streamflow-gaging stations (black dots) among U.S. Environmental Protection Agency (2003b) Level III ecoregions (colored polygons) that have been discretized to a 15-minute grid in the conterminous United States (geographic projection). The selected U.S. Geological Survey streamflow-gaging stations have at least 24 years of streamflow data collected during 1960–2003 with drainage areas between 10 and 500 square miles that are not listed as being at, near, or immediately below a dam.

Purpose and Scope

This report and the appendixes on the CD-ROM describe the implementation, use, and interpretation of results from five programs that were written for obtaining and analyzing streamflow data. This report provides an overview of the five programs included on this CD-ROM. The appendixes are the manuals for each program. These manuals describe the statistical and numerical methods used to implement each program. The manuals describe input and output file formats. The manuals also describe methods to install and use the programs. Each appendix is written as a self-contained software manual because each program may have many uses alone or in tandem with other programs on the CD-ROM.

Computer Programs for Obtaining and Analyzing Streamflow Data

Five computer programs were developed for obtaining and analyzing NWISWeb streamflow data. These computer programs were conceived and written to facilitate the analysis of daily mean streamflow data for planning-level water-quality analyses but also are useful for many other applications for streamflow data and statistics. These computer programs include:

1. Get National Water Information System Streamflow (Q) files (GNWISQ Version 1.0)—A program for individual or batch download of streamflow-gaging-station information and daily mean streamflow files;

2. Make Plotting Position file (MkPP Version 1.0)—A program for generating plotting positions and normal scores for daily mean streamflow files from the USGS NWISWeb site;

3. Streamflow Record-Extension Facilitator (SREF Version 1.0)—A program for extension or augmentation of available streamflow data by using long-term streamflow records at hydrologically similar sites.

4. Streamflow (Q) Statistics (QSTATS Version 1.0)—A program for calculating population statistics for streamflow data; and

5. Make U.S. Environmental Protection Agency DFLOW3 batch input files (MkDF Version 1.0)—A program to facilitate mass processing of daily mean streamflow files by the U.S. Environmental Protection Agency (2004a) DFLOW3 computer program for estimating design streamflows for use in water-quality standards and Total Maximum Daily Load (TMDL) waste-load allocations.

The computer programs are documented on the CD-ROM accompanying this report. Each of these Visual Basic programs has a graphical user interface that follows standard Microsoft Windows interface conventions.

The GNWISQ program was developed to facilitate the process for downloading streamflow-gaging-station information and daily mean streamflow data files from the USGS NWISWeb site. The GNWISQ program has an individual-file mode to retrieve information and data for one streamflow-gaging-station. The program also has a batch-file mode to retrieve information and data for multiple streamflow-gaging-stations. The program also has the capability to reformat the current (2006) NWISWeb text-file format to an earlier, more consistent, NWISWeb text-file format. The program provides error files to document any problems that may occur. The output from the GNWISQ program can be used to facilitate hydrologic-data analysis with multiple programs in individual or batch mode.

The MkPP program was developed to facilitate visual analysis of daily mean streamflow data. Hydrologic analysis of streamflow data may be improved by visual inspection of a probability plot or flow-duration curve of the data values. The program was designed to sort the data and provide a condensed file of the plotting positions, percentiles, normal frequency factors, Pearson Type III frequency factors, and associated data. The program reads daily-value data files that have been downloaded from the USGS NWISWeb site and reformatted to a common format with GNWISQ. The output file from the MkPP program can be used to facilitate rapid production of probability plots and flow-duration curves using simple spreadsheet or graphing software commonly available on most personal computers.

The SREF program was developed to provide an estimated long-term record of daily mean streamflows (record extension) or long-term estimates of streamflow statistics (record augmentation) at sites with limited data. SREF can be used to extend or augment limited data from a partial-record site or short-term streamflow-gaging-station by using data from a representative long-term continuous-record streamflow-gaging-station. Record extension and augmentation are based on the assumption that long-term streamflow records from hydrologically similar sites can be used to estimate values at a site of interest with limited data. The SREF program implements the maintenance of variance extension type 1 (MOVE.1) methods described by Hirsch (1982) and the maintenance of variance extension type 3 (MOVE.3) method described by Vogel and Stedinger (1985). The program also facilitates record extension with a single or multisegment regression model developed by use of the nonparametric Kendall-Theil Robust Line (KTRLine) program (Granato, 2006). The program provides graphical displays of the data, regression lines and residual statistics to facilitate the analytical process. The program outputs a file of paired data values and a file with regression statistics. The user may output files containing an estimated record of daily mean streamflow data and files containing estimates of selected long-term statistics for the site of interest.

The QSTATS program was developed to facilitate statistical analysis of daily mean streamflow data for one station or multiple stations. The program reads daily-value data files that have been downloaded from the USGS NWISWeb site and reformatted to a common format with GNWISQ. The program can be used to calculate the average, standard deviation, skew, and median of daily mean streamflow values in arithmetic and common logarithmic (Log10) space. The program provides the option to calculate probability weighted moments and L-moments in arithmetic and Log10 space. The program also calculates the total number of daily mean streamflow values, the number of gaps in the record (each of which may be one day to several decades long), and the fraction of zero flows recorded in the data file.

The MkDF program was developed to facilitate creation of batch input files for the U.S. Environmental Protection Agency (2004a) DFLOW3 program. The program reads daily-value data files that have been downloaded from the USGS NWISWeb site and reformatted to a common format with GNWISQ. The program was designed to create DFLOW input files automatically from a list of USGS streamflow-gaging station numbers because streamflow stations must be manually specified within the DFLOW3 interface. The DFLOW3 program was developed to calculate water-quality-design streamflow statistics. Low-flow statistics including the 1-day 3-year biological low flow (1B3) and the 4-day 3-year biological low flow (4B3) are known as water-quality-design streamflows because low-flow statistics represent a streamflow with a specified exceedance frequency that is used for setting water-quality criteria and TMDL waste-load allocations. These low-flow statistics may also be used with estimates of runoff from a watershed to estimate the potential for water-quality exceedances from stormwater runoff that occurs during low-flow periods.

Summary

Reliable, efficient, and repeatable methods are needed to access and process streamflow information and data because streamflow information is important for many planning and design activities including water-supply, habitat protection, bridge and culvert design, and water-quality assessments. The U.S. Geological Survey (USGS) in cooperation with the Federal Highway Administration developed five computer programs as part of the effort to develop the stochastic empirical loading and dilution model because streamflow information is especially critical for water-quality assessments. These computer programs were conceived and written to facilitate the analysis of daily mean streamflow data for planning-level water-quality analyses but also are useful for many other applications pertaining to streamflow data and statistics.

Streamflow data and information are available to the public on the USGS NWISWeb site, and these five computer programs were developed to facilitate streamflow data analysis. The GNWISQ program can be used to download files containing streamflow-gaging-station information and daily mean streamflow data from the NWISWeb site. The MkPP program can be used to produce statistics for visual analysis of daily mean streamflow data. The SREF program can be used to augment or extend limited data from a partial-record site or short-term streamflow-gaging station by using data from a representative long-term continuous-record streamflow-gaging station. The QSTATS can be used for statistical analysis of daily mean streamflow data. The MkDF program can be used to create batch input files for the U.S. Environmental Agency DFLOW3 program.

These five computer programs are documented on the CD-ROM accompanying this report. This report and the appendixes on the CD-ROM describe the implementation and use of the programs and the interpretation of results from the programs. The body of this report provides an overview of the five programs on this CD-ROM. The appendixes are the manuals for each program. These manuals describe the statistical and numerical methods used to implement each program, input-file formats, output-file formats, installation of the programs, and use of the programs. Each appendix is written as a self-contained manual because each program may have many uses alone or in tandem with other programs on the CD-ROM. Each of these Visual Basic programs has graphical user interface that follows standard Microsoft Windows interface conventions.

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