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A stylized illustration of a cloud raining over a road. The cloud is white with a grey outline, and several grey raindrops are falling from it. Below the rain, a grey road with a white line curves away into the distance.

# The National Highway Runoff Data and Methodology Synthesis

Volume II – Project Documentation

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# PREFACE

Knowledge of the characteristics of highway runoff (concentrations and loads of constituents and the physical and chemical processes which produce this runoff) is important for decisionmakers, planners, and highway engineers to assess and mitigate possible adverse impacts of highway runoff on the Nation's receiving waters. In October 1996, the Federal Highway Administration and the U.S. Geological Survey began the National Highway Runoff Data and Methodology Synthesis to provide a catalog of the pertinent information available; to define the necessary documentation to determine if data are valid (useful for intended purposes), current, and technically supportable; and to evaluate available sources in terms of current and foreseeable information needs. This paper is one contribution to the National Highway Runoff Data and Methodology Synthesis. More information about this project is available on the World Wide Web at <http://ma.water.usgs.gov/fhwa/>

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# SI\* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS				APPROXIMATE CONVERSIONS FROM SI UNITS			
Symbol	When You Know	Multiply By	To Find	Symbol	When You Know	Multiply By	To Find
in ft yd mi	inches feet yards miles	25.4 0.305 0.914 1.61	millimeters meters kilometers	mm m km	millimeters meters kilometers	0.039 3.28 1.09 0.621	inches feet yards miles
<b>LENGTH</b>				<b>LENGTH</b>			
<b>AREA</b>				<b>AREA</b>			
in <sup>2</sup> ft <sup>2</sup> yd <sup>2</sup> ac mi <sup>2</sup>	square inches square feet square yards acres square miles	645.2 0.093 0.836 0.405 2.59	square millimeters square meters square meters hectares square kilometers	mm <sup>2</sup> m <sup>2</sup> m <sup>2</sup> ha km <sup>2</sup>	square millimeters square meters square meters hectares square kilometers	0.0016 10.764 1.195 2.47 0.386	square inches square feet square yards acres square miles
<b>VOLUME</b>				<b>VOLUME</b>			
fl oz gal ft <sup>3</sup> yd <sup>3</sup>	fluid ounces gallons cubic feet cubic yards	29.57 3.785 0.028 0.765	milliliters liters cubic meters cubic meters	mL L m <sup>3</sup> m <sup>3</sup>	milliliters liters cubic meters cubic meters	0.034 0.264 35.71 1.307	fluid ounces gallons cubic feet cubic yards
<b>MASS</b>				<b>MASS</b>			
oz lb T	ounces pounds short tons (2000 lb)	28.35 0.454 0.907	grams kilograms megagrams (or "metric ton")	g kg Mg (or "t")	grams kilograms megagrams (or "metric ton")	0.035 2.202 1.103	ounces pounds short tons (2000 lb)
<b>TEMPERATURE (exact)</b>				<b>TEMPERATURE (exact)</b>			
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C	Celsius temperature	1.8C + 32	Fahrenheit temperature
<b>ILLUMINATION</b>				<b>ILLUMINATION</b>			
fc fl	foot-candles foot-Lamberts	10.76 3.426	lux candela/m <sup>2</sup>	lx cd/m <sup>2</sup>	lux candela/m <sup>2</sup>	0.0929 0.2919	foot-candles foot-Lamberts
<b>FORCE and PRESSURE or STRESS</b>				<b>FORCE and PRESSURE or STRESS</b>			
lbf lbf/in <sup>2</sup>	poundforce poundforce per square inch	4.45 6.89	newtons kilopascals	N kPa	newtons kilopascals	0.225 0.145	poundforce poundforce per square inch

NOTE: Volumes greater than 1000 l shall be shown in m<sup>3</sup>.

\* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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CD-ROM  
(In back pocket)

Computer files to accompany The National Highway Runoff Data and Methodology Synthesis, Volume II—Project Documentation.



# National Highway Runoff Water-Quality Data and Methodology Synthesis, Volume II—Project Documentation

By Gregory E. Granato, Shannon G. Dionne, Cameron K. Tana, *and* Tara L. King

## Abstract

The National Highway Runoff Data and Methodology Synthesis (NDAMS) is designed to provide the information necessary to address highway-runoff water-quality concerns within acceptable data-quality objectives. A bibliography of more than 2,600 relevant references with more than 1,300 selected abstracts (or preia—an abstract written by someone other than the author, in this case NDAMS project personnel) is provided to establish a searchable electronic record of available reports to meet information needs. Results of the evaluation of available information from the 252 reports reviewed during the synthesis are provided as a stratified metadatabase within the bibliographic database. Metadata reviews of selected reports were completed and cataloged to indicate the quality of available data in terms of highway-runoff quality information needs for regional or national synthesis. These reviews rep-

resent a sample of about 10 percent of the more than 2,600 reports in the catalog, and about 50 percent of the number of reports that have a primary emphasis on highway runoff. A total of 234 highway-research sites are identified worldwide, and of these, 197 sites are representative of conditions in the conterminous United States. This report describes and documents methods used to catalog and evaluate published information relevant to the study of highway-runoff and to provide a catalog of metadata about the reports that were reviewed. Brief descriptions of the overall project, the database design, a catalog of available reports, the methods used for evaluation of available information, and a description of the project quality-assurance and quality-control program are included in this report. (Computer files that document the results of this synthesis are included on an accompanying computer disk).



## INTRODUCTION

Potential problems caused by water-quality contaminants from nonpoint sources such as urban runoff, atmospheric deposition, and highway runoff are addressed by a number of environmental laws, executive orders, and policies intended to protect water quality across the Nation. Laws, orders, and policies that pertain to the quality of highway runoff include the National Environmental Policy Act (NEPA), the Clean Water Act of 1972 and amendments, the National Pollutant Discharge Elimination System (NPDES), Nonpoint Source (NPS) Management Programs, the Intermodal Surface Transportation Efficiency Act (ISTEA), the Department of Transportation National Transportation Policy (NTP), the Coastal Zone Act Reauthorization Amendment (CZARA), and other legislation (Bank, 1993, 1996; Young and others, 1996; Granato, 1997). Therefore, the Federal Highway Administration and State transportation agencies have a responsibility to determine and minimize the effects of highway runoff on receiving waters while planning, designing, building, operating, and maintaining the Nation's highway infrastructure.

### Problem

Information that is valid (useful for intended purposes), current, and technically defensible is necessary to assess and predict pollutant loadings and impacts from highway stormwater runoff and to provide information to develop best management practices to mitigate the potential effects of runoff on the quality of receiving waters. State departments of transportation (DOTs), the Federal Highway Administration (FHWA), the U.S. Environmental Protection Agency (USEPA), the U.S. Geological Survey (USGS), and many universities have sponsored or conducted research on the water-quality of runoff and the potential ecological effects of runoff on receiving waters during the last 30 years. Information about the existence, availability and quality of these data can be hard to identify and (or) difficult to obtain without a catalog of available research. Also, knowledge about the availability of data is not commonly widespread within or among highway agencies.

The Transportation Research Board (TRB) has determined that development of a nationally accessible electronic database of information pertinent to the

study of highway-runoff quality is a primary highway-runoff research need (Transportation Research Board, 1996a, 1997). This database is needed to facilitate coordination of local, regional, and national studies and will reduce or eliminate the need for costly literature reviews at the beginning of each study. The database also will provide investigators with easy access to existing sources of information. Runoff-quality studies typically start with a literature search. Results of these efforts, however, are not usually recorded in an electronic format suitable for future use. A readily accessible archive of information and key data sets, including research results on highway-runoff quality, on the design and effectiveness of best management practices (BMPs), and on related issues, may provide much of the information, sources of data, and expertise necessary for valid and comparable data-collection programs (Transportation Research Board, 1996a, 1997). Currently there are no established national formats for the exchange of information and key data sets generated by the highway water-quality research community (Transportation Research Board, 1996a, 1997).

The FHWA, therefore, determined that it was necessary to identify available information in the literature that is relevant to the study of the characteristics and potential ecological effects of highway-runoff quality, and that it was necessary to evaluate this information in terms of its suitability for use in a regional and (or) national synthesis. The USGS, in cooperation with the FHWA, designed and implemented the National Highway Runoff Water-Quality Data and Methodology Synthesis (NDAMS) project to address these information needs. This synthesis catalogs and documents characteristics of published water-quality programs to evaluate the availability and applicability of the public data for addressing questions for a national evaluation of highway-runoff quality to meet current and future information needs (Granato and others, 1998). The many digital products from this study, which include the NDAMS database, are compiled on the accompanying compact disk read-only memory (CD-ROM).

### Purpose and Scope

This report provides an overview of the NDAMS program and database. The report includes a brief description of the overall project and database design, the catalog of available reports, the evaluation of

available information, and a description of the project quality-assurance and quality-control program. The effort to catalog available reports is described in terms of the literature search and the resulting bibliographic catalog of pertinent literature. The effort to evaluate available information is described by a brief overview of the report documentation-review process and the metadatabase of report-review information. Detailed information about the contents and use of the products on the CD-ROM is available on the disk. Details about the organization of the CD-ROM and the files it contains are described in a series of "readme" files on the CD-ROM, which are presented in both text and internet (html) format. Detailed information about the database design and database software is available in the NDAMS database user's manual (Granato and Tessler, 2001). Detailed information about database utilization is available in the NDAMS database user's manual (Granato and others, 2001). An overview of the report-review protocols is provided herein, but because the information necessary to explain the details of the report-review process is both complex and topical, the review protocols are defined in detail by Dionne and others (1999). Electronic versions of these three reports are included on the accompanying CD-ROM.

This report is Volume II in a three-volume series designed to document results of the NDAMS project. Volume I is a compilation of 10 reports that each represents a synthesis of different technical issues pertinent to the study of highway-runoff quality and the potential for effects on receiving waters and ecosystems. Volume III is an evaluation of the availability and documentation of published information for use in regional or national highway-runoff quality data synthesis. Volume III is an interpretation of the metadata recorded in the NDAMS database included on the CD-ROM accompanying Volume II (this report).

## Acknowledgments

Most of the reports cataloged and reviewed were obtained through the USGS Library in Reston, Virginia, either from USGS collections or by interlibrary loan. Therefore, the success of this literature search was largely due to the efforts of the USGS Library staff, especially Carmen O'Neill, whose tireless pursuit of many references through the interlibrary loan system was essential in locating many of the reports in the catalog. Thanks also are due to the USGS Volun-

teers for Science, including Crystal Poirier, Susan Granato, Jessica Snow, and others who volunteered their time to enter citations, abstracts, and other information into files used in the project web pages and ultimately in the NDAMS database.

## OVERVIEW OF THE PROJECT

Decisionmakers concerned with the quality and potential effects of highway runoff must evaluate information needs with respect to the data-quality objectives necessary to address any given problem (Granato and others, 1998). The report metadata can be used to evaluate and characterize available information in terms of different data quality objectives as applied to the characteristics of individual reports or to the entire population of report review metadata. This database, however, is primarily designed to assess how valid, current, complete, and technically defensible available information may be in terms of a regional or national synthesis. Knowledge of relevant information requirements may also be useful in the development of protocols and (or) the systematic documentation of data and other information for current and future runoff-quality studies.

The NDAMS program is designed to meet current needs by providing decision makers with the information necessary to address potential problems related to highway-runoff water quality. This synthesis consists of five interrelated products to provide necessary information with the perspective of acceptable data-quality objectives for a regional or national synthesis. The first product is a series of reports describing technical concerns that may affect how valid, current, comparable, and technically defensible the existing data may be for different aspects of runoff-quality research, which are included as Volume I of this series. The second product is the bibliography of relevant references (with selected abstracts or previas—previas are abstracts written by someone other than the author, in this case NDAMS project personnel) that provide a searchable electronic record of available reports. The third product is a stratified metadatabase within the bibliographic database on the accompanying CD-ROM that contains results of the report reviews. The database is referred to as a metadatabase because it contains information about available data sets rather than a record of the original data. The fourth product includes

a series of tools including the report-review protocols (Dionne and others, 1999), the geographic information system (GIS) coverages (Smieszek and Granato, 2000), the point-interpolation program PLACER (Granato, 1999), the Chemical-Help tool (Granato and others, 2000), and other tools on the enclosed CD-ROM. The fifth product is the final interpretive report (Volume III of this series), which evaluates the report-review metadata in terms of the information needs for a regional or national highway-runoff synthesis.

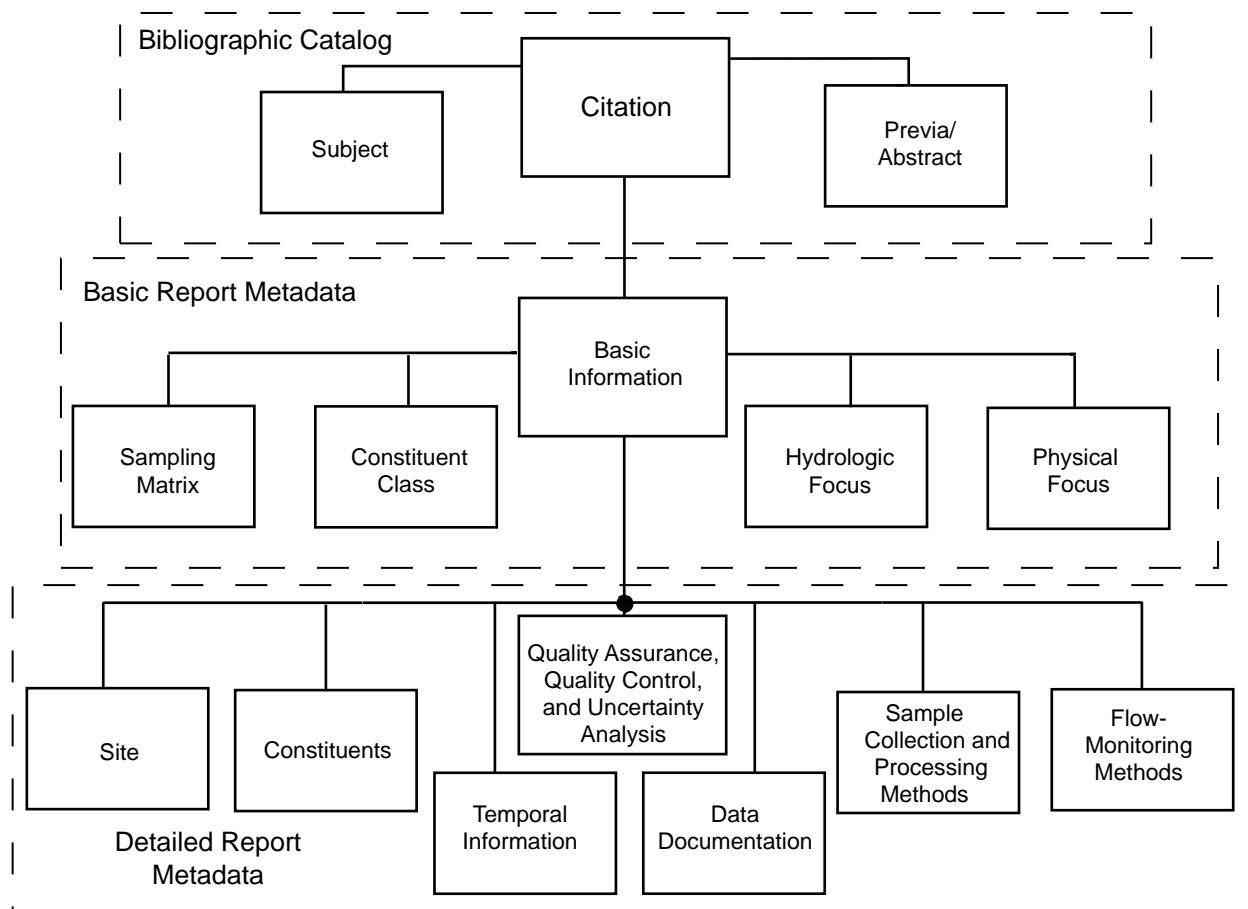
A team of subject-matter experts was assembled to examine technical issues associated with the collection, processing, interpretation, and documentation of data that would be valid, current, comparable, and technically defensible for individual studies and for subsequent regional and (or) national synthesis of highway-runoff data. Experts from within the USGS Water Resources and Biological Resources Disciplines combined their input with that from State and Federal environmental and transportation agencies to establish key issues and data-evaluation criteria based upon the current state-of-the-art at this time. They produced a series of reports (each concerning one aspect of highway runoff-quality investigations) that document data evaluation criteria that were used to produce the NDAMS program review sheets (Dionne and others, 1999). These reports document criteria for monitoring the quality of runoff including: basic information and data quality (Granato and others, 1998); precipitation and runoff flow (Church and others, 1999); the geochemistry of runoff (Bricker, 1999); sediments in runoff (Bent and others, 2001); trace elements in runoff (Breault and others, 2000); organic chemicals in runoff (Lopes and Dionne, 1998); the potential ecological effects of runoff (Buckler and Granato, 1999); monitoring atmospheric deposition (Colman and others, 2001); quality assurance and quality control (Jones, 1999); and interpreting runoff data using appropriate statistical techniques (Tasker and Granato, 2000).

A literature search was done to catalog literature relevant to the study of highway runoff. As reports were collected and citations were verified, pertinent information was entered into a computerized database. More than 2,600 reports and more than 1,300 abstracts or previas were cataloged in the bibliographic database

during the study. Abstracts are provided for almost all reports that do not have copyright restrictions, such as reports published by government agencies and journal articles about government sponsored research that are written by authors working for government agencies (U.S. Copyright Office, 2000). Previas were written for reports that were reviewed, which may have copyright restrictions, such as the reviewed journal articles. About 50 percent of the reports cataloged have an abstract or previa. The abstracts or previas included with the database are provided solely for the purposes of private study, scholarship, or research (U.S. Copyright Office, 2000). This database is available on the accompanying CD-ROM as the MS Access file "FHWA2001.mdb."

The data-evaluation criteria and the catalog of relevant literature were used as tools to select reports for the metadata review. Generally, publications presenting the results of highway-runoff water-quality investigations were selected for review in reverse chronological order. These reports were reviewed using the NDAMS program review sheets following methods described by Dionne and others (1999) to document metadata necessary to establish the published information as valid, current, and technically supportable (Granato and others, 1998).

During the project, 252 reports were reviewed and pertinent information was recorded as "basic report metadata" in the second level of the stratified metadata-base for each of these reports (fig. 1). Basic report information, the classes of chemical constituents sampled, the sampling matrixes, and the hydrologic and physical focus of each investigation were recorded in this "basic report metadata" component of the database. Published literature reviews and summary reports were included in the evaluation of available information in this level of the stratified metadata-base because they are often a valuable source of general information, they provide references for sources of detailed information, and they provide perspectives for the potential use of original data in regional or national synthesis efforts. Detailed information and metadata were not recorded for literature reviews and summary reports because these reports generally do not document enough details



**Figure 1.** Schematic diagram of the organization of the stratified metadatabase.

about the data-collection programs to evaluate the quality of information in the original interpretive studies that they summarize.

Reports that document details from runoff-quality investigations received a full data-quality evaluation. Metadata from 218 detailed reports were documented in all three levels of the stratified metadatabase (fig. 1). Detailed report metadata included documentation methods, temporal information, site location and characteristics, sample collection and processing methods, water-quality constituents of concern, flow monitoring methods, quality-assurance and quality-control methods, and uncertainty analyses. Metadata was recorded on the appropriate review sheet when subject information was clearly documented in the report being reviewed.

## OVERVIEW OF THE DATABASE DESIGN

All of the citations and the metadata collected during the project (from October 1996 through June 2001) are presented in a stratified metadatabase (fig. 1). The top layer is a catalog of bibliographic information for published literature that is available through interlibrary loan. The second layer catalogs general metadata for all the reviewed reports. The third layer catalogs detailed metadata for reports that document results of water-quality investigations.

The database is stratified because the top layer (the bibliographic catalog) contains information about all published reports that were available, the second layer contains general review information about all

published reports that were reviewed, and the third layer contains detailed review information about the reviewed reports that contain more comprehensive information (fig. 1). The bibliographic catalog is organized by a citation-identification number, author, year of publication, title, and publication information as well as major and minor subject categories that are used to classify the reports. The administrative citation-identification number is used throughout the relational database to identify all information in the database that is associated with any given report (Granato and Tessler, 2001). The top layer also includes a table of abstracts or previas. Basic information metadata for all the reports that were reviewed are recorded in several tables in the second layer. Basic report metadata include general information about the individual studies, the sampling matrix, the classification of monitored constituents, and the hydrologic and physical focus. Detailed report metadata for the reports that contain information that is more comprehensive are recorded in tables in the third layer. Detailed report metadata include information about monitoring sites; constituents measured; temporal information; quality assurance, quality control, and uncertainty; data documentation; sample collection and processing information; and flow-monitoring methods. Granato and Tessler (2001) provide detailed information about the data model and relational database design for highway runoff water-quality metadata.

Many issues were considered in choosing database software, including import and export capabilities in different formats, reasonable purchase price, prospects for continued availability, software capabilities, ease of use, and vendor support (Granato and Tessler, 2001). Microsoft (MS) Access was chosen from the several possible database systems because it best fit these design criteria and because it is the same software that is being used to support the FHWA ultra-urban best-management practices database (Cazenas, 1998; Shoemaker and others, 2000). The contents of the database are available as tab delimited ASCII files on the CD-ROM and may be converted from these files (or from the MS Access version) to another database or software product by users who may have different software requirements.

The relational database is fully documented in several files on the accompanying CD-ROM database. In the relational design, entries in all data tables link to a particular citation and each data table is focused on one aspect of the information collected in the literature

search and (or) the evaluation of available information. The database design includes 86 tables, including 29 data tables, 11 association tables, and 46 domain tables. Granato and Tessler (2001) implemented and documented the NDAMS relational database design using two MS Access files. The file "DBDESIGN.mdb" contains the database-design template. Complete documentation of the table names, table descriptions, and information about each of the 419 fields in the database are documented in the MS Access data dictionary file NDAMS\_DD.mdb. The file FHWA2001.mdb is the final populated version of the database that includes the tables, queries, forms, and reports necessary to implement the design with a user-friendly interface. The report by Granato and Tessler (2001) and other information about access to and use of the complete database also are available on the accompanying CD-ROM.

## CATALOG OF AVAILABLE INFORMATION

### Literature Search

The literature search was designed to catalog available published information relevant to the study of highway-runoff quality. The literature search included four components that were conducted in parallel, in a simultaneous and iterative process. These components included efforts to:

- Contact people in the State DOTs, the FHWA, the USEPA, the USGS, and other agencies and organizations who may have pertinent information;
- Search on-line electronic databases to identify reports of interest;
- Obtain copies of relevant reports to further the process; and
- Search through the bibliographies of these reports to find authors/researchers, organizations, and other reports relevant to the study of highway-runoff quality issues.

Many people throughout the United States were contacted to identify pertinent reports. USGS project staff mailed information-request letters and made follow-up phone calls to at least two people within each State DOT that were listed as environmental

specialists in the TRB's environmental professionals directory (Transportation Research Board, 1996b). The research-and-materials groups of many State DOTs were also contacted. Project staff also contacted stormwater professionals within the FHWA and the USEPA. Additionally, project staff contacted many people within the USGS, including professionals in the technical offices (Surface Water, Ground Water, and Water Quality); the USGS National Research Program (NRP); national thrust programs including the National Water-Quality Assessment Program (NAWQA), the National Stream Quality Assessment Network (NASQAN), the National Atmospheric Deposition Program (NADP); and the Water-Resources Division offices in all 50 states. Finally, project staff also contacted other State and local government agencies, such as the Virginia Transportation Research Council, the North Central Texas Council of Governments, and other groups that had done extensive stormwater runoff-quality investigations. Contacts with these groups were not only useful and instructive for this literature search but also supported the assumption that there were no readily available repositories of existing highway-runoff literature. In many cases, these contacts indicated that, institutional knowledge about highway-runoff studies that had been conducted was not persistent or pervasive, and studies that were more than about 5-years old were often forgotten.

Extensive searches of the bibliographies of published stormwater-runoff research reports proved to be the most valuable means for identifying existing information. This process, however, was the most labor-intensive part of the search. Each bibliography was read, and the title, publication outlet, or author was used to identify citations of potential interest. These citations were entered into a computer text file and then were checked against the original citation for data errors. Then the reports of interest were obtained through interlibrary loan or from the National Technical Information Service (NTIS). During this process, however, it was discovered that many bibliographies contain inaccurate or incomplete information, so that many reports (as cited in the published literature) were difficult or impossible to identify and obtain. Once a pertinent report was identified and obtained, the bibliography from that report was then used to extend the search in this iterative process.

Information from the bibliographies (such as key words—from titles of published reports, author's names, publications—such as conference proceedings,

and pertinent journals) also was used to guide electronic searches for available information. The electronic searches included services on the USGS internet/intranet (the USGS Library Catalog, the USGS Selected Water Resources Abstracts (SWRA), GeoRef, and FirstSearch); telnet (the Colorado Area Research Libraries—CARL, and Uncover); the internet (using many available search engines); and a search by the FHWA on the Transportation Research Information Service (TRIS). Each of these electronic sources provided some unique references, but no single source provided a substantial number of the reports recorded in the NDAMS catalog. These electronic sources were used to verify information in bibliographies published within stormwater-research reports (although they also contained a few errors and omissions) and to identify pertinent reports not included in available bibliographies. For example, when using an author's name to search the electronic databases, reports that were more current than those listed in published bibliographies could be identified. Ferreting out pertinent reports, however, was not a trivial effort. For example, a search using the keywords “atmospheric deposition” on one electronic on-line search database resulted in an available list of about 13,000 articles, most of which were probably not relevant to highway or urban runoff studies. In each search, different combinations and permutations of keywords were tried to optimize the search without missing important works.

Report acquisition was an important component of this literature search. Physical copies of the report were needed to:

- verify the bibliographic information collected from other reports and electronic sources,
- assess the relevance of a given report to the study objectives and the information needs of the highway-runoff research community,
- search the report's bibliography for other leads, and
- (when appropriate) provide the text for a metadata review.

The USGS library provided most of the reports inspected for the cataloging process either directly or through interlibrary loan. About 20 percent of the more than 2,600 reports cataloged were obtained directly from the author or from the organization sponsoring the report. A few reports were obtained from NTIS, but these reports were costly and the quality of the reproductions was generally poor and sometimes partially illegible. A few reports were available in various

electronic formats through the World Wide Web. These reports were easy to obtain. Electronic reports afforded ease of use by being searchable, by enabling pertinent references to be copied electronically without the labor and quality assurance necessary to retype bibliographic entries, and these reports could be reproduced as needed at the original resolution by printing the document.

## Bibliographic Catalog of Pertinent Literature

Results of the literature search were entered into a computerized bibliography to facilitate use for current and future stormwater-runoff studies. The catalog

of pertinent literature is organized by author, year of publication, title, and by citation information. Individual reports can be identified by these four characteristics or by an administrative citation identification number used throughout the database. Groups of similar reports may be identified by subject and (or) by publication outlet. All reports in the catalog are identified and organized by subject using a set of keywords. The primary (major topic) and secondary (minor topic) of each report is identified. These key words and their one-letter subject codes (listed in alphabetical order by code) are defined in table 1. For example, a report identified as BH would have a primary focus on BMPs, but also would contain information about the characteristics of highway runoff at the study site(s). Conversely,

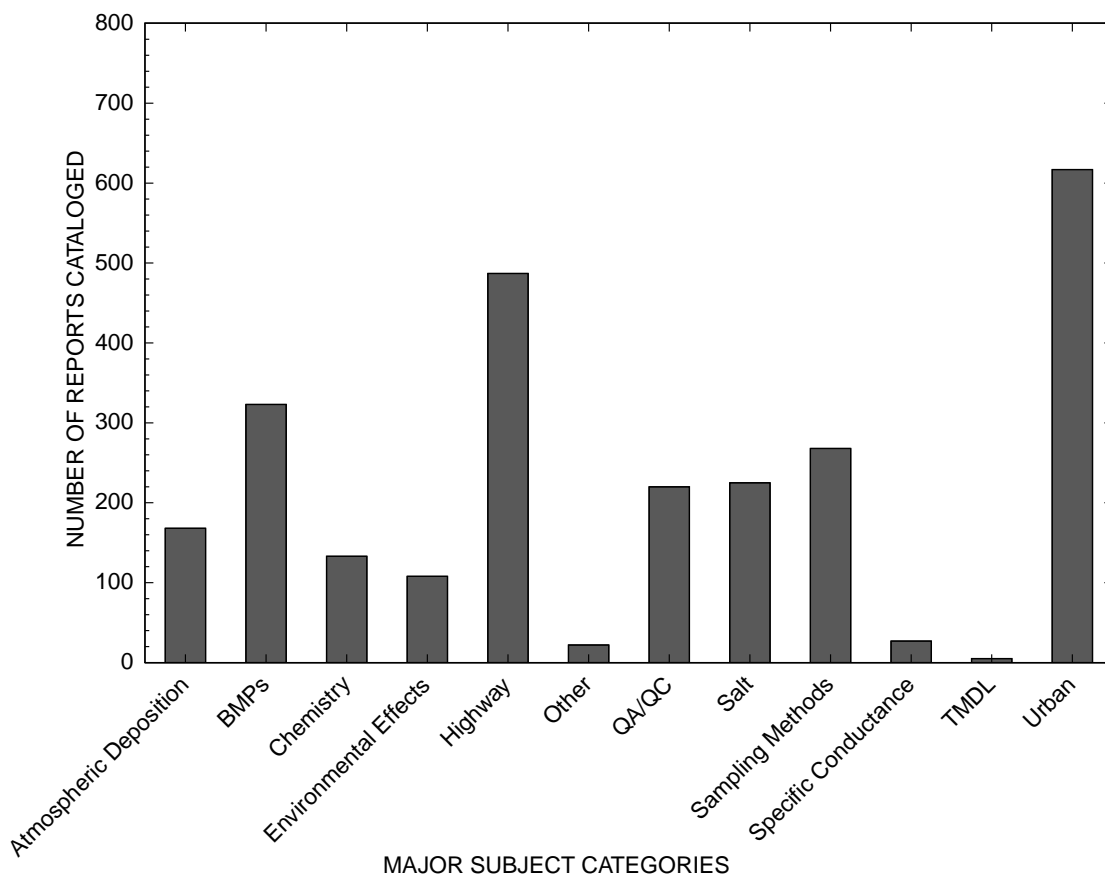
**Table 1.** Subject codes, key words and definitions used in the Federal Highway Administration water-quality metadatadase

Subject Code	Key Words	Definitions
A	Atmospheric Deposition	Reports focused on the quantity and quality of wet and dry deposition.
B	Best Management Practices (BMPs)	Reports focused on the design, maintenance, implementation, and effectiveness of structures or management practices designed to control the quantity and (or) quality of stormwater runoff.
C	Chemistry	Reports focused on chemical and physiochemical processes that affect or control the quality of stormwater runoff and (or) the bioavailability of contaminants in receiving waters.
G	Specific Conductance	Reports focused on the measurements and interpretation of specific conductance as an interpretive tool for characterizing the quality of stormwater runoff.
E	Environmental Effects	Reports focused on the effects of stormwater runoff on biota and ecosystems.
H	Highway	Reports focused on the quality and characteristics of highway runoff.
M	Sampling Methods	Reports focused on technical issues pertinent to representative and scientifically defensible sampling strategies and methods for collection, processing, and analysis of samples, measurements, and electronic data.
O	Other	Reports focused on other issues such as regulatory information pertinent to stormwater monitoring and management issues.
Q	Quality Assurance and Quality Control (QA/QC)	Reports focused on the methods necessary to document that data sets are accurate, precise, and technically supportable.
S	Salt/Deicing Chemicals	Reports focused on deicing chemicals, which are a major component in stormwater runoff in climates where deicing operations are deemed necessary for public safety.
T	Total Maximum Daily Loads (TMDL)	Reports focused on the emerging issue of total maximum daily loads of nonpoint sources to the Nation's watersheds.
U	Urban	Reports focused on the quality and characteristics or urban runoff.

a report identified as HB would primarily characterize highway runoff in the study area, but also would mention the use of or effectiveness of the BMP used to control the runoff. Reports having the same major and minor code do not have an appreciable secondary emphasis. Major and minor subject codes are derived from examination of the title, abstract, tables, figures, and conclusions of each report, and from a scan of the remainder of the report. The codes of some reports were changed upon closer examination in the metadata review process. Therefore, subject codes should be considered as guidelines rather than absolute definitions. Figure 2 indicates the number of reports cataloged by major subject. Reports with a primary or secondary emphasis on highway runoff, urban runoff, BMPs, and relevant atmospheric deposition make up about 60 percent of the catalog (fig. 2).

The reports also are classified using the publication outlet. The publication outlet may be used as a keyword to classify reports in the catalog and to facilitate the search for information. The publication outlet is the agency or organization publishing the document. The possible publication outlets are:

- State transportation agencies;
- other State agencies;
- the FHWA in conjunction with State transportation agencies;
- the FHWA;
- the U.S. Environmental Protection Agency (USEPA);
- the USGS;
- other federal agencies;
- the Transportation Research Board (TRB) and (or) the National Cooperative Highway Research Program (NCHRP);



**Figure 2.** Distribution of cataloged reports, by major subject categories.

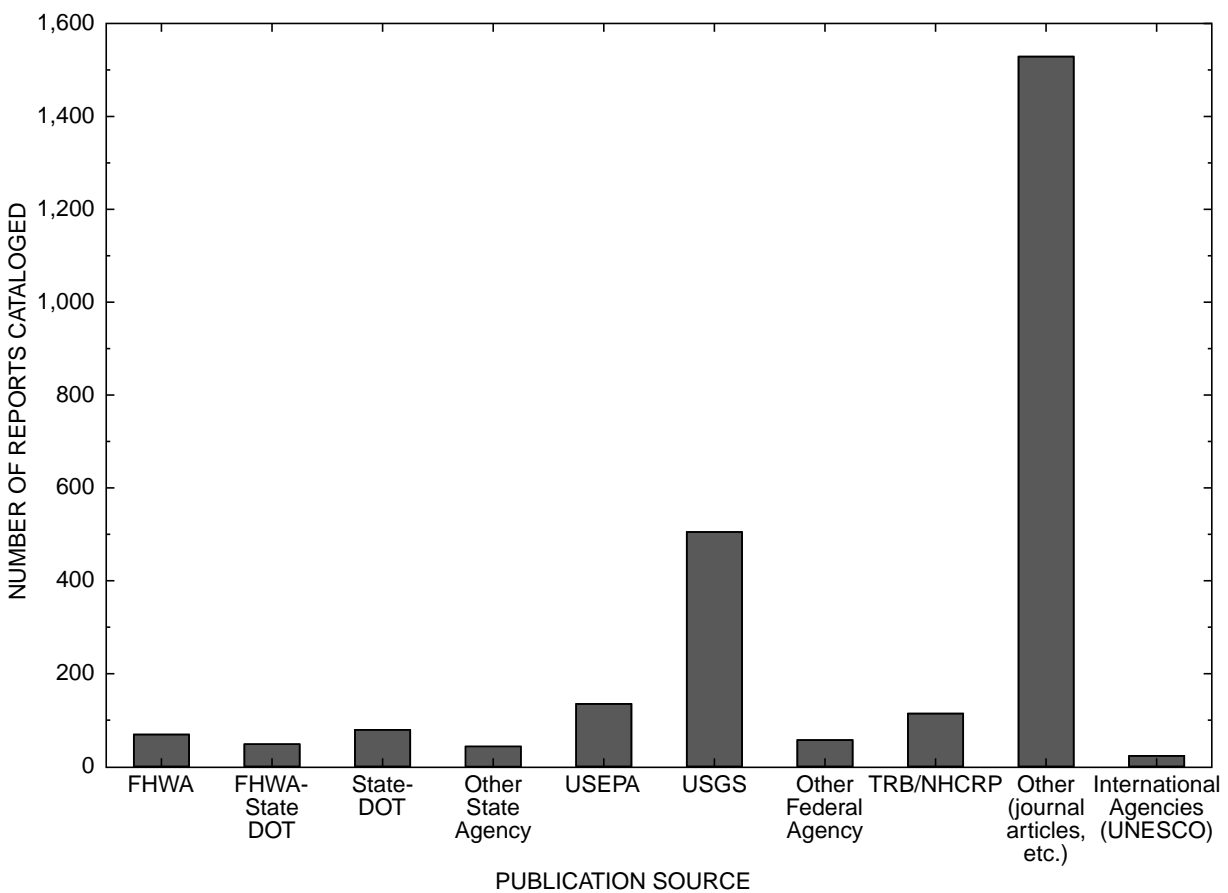


- foreign or international agencies such as the United Nations Educational, Scientific, and Cultural Organization (UNESCO); and
- other sources such as scientific journals, proceedings, or other publication outlets.

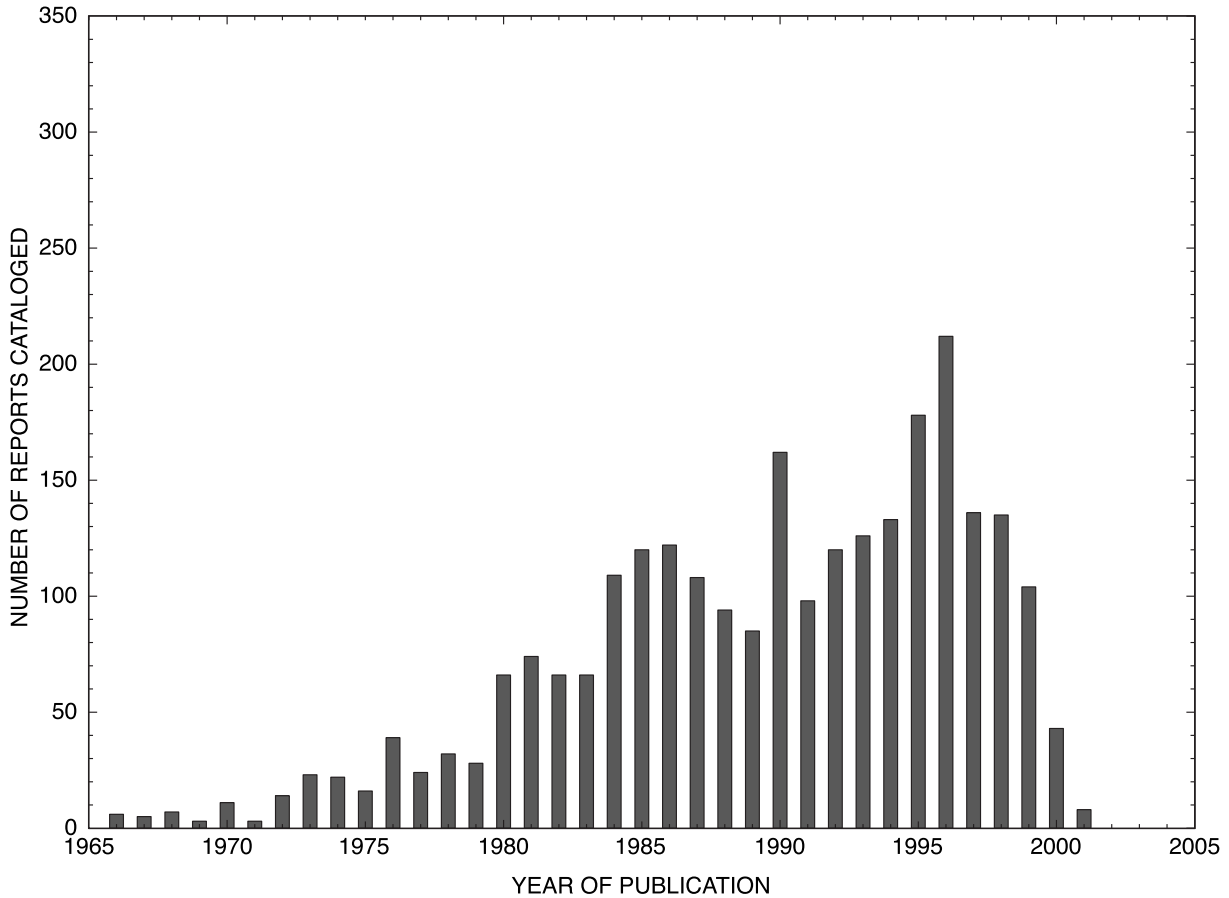
Reports published by State DOTs, the FHWA, the USEPA, the USGS, and transportation research organizations such as the TRB, and the NCHRP constitute about 36 percent of the catalog. Reports published in scientific, technical, or trade journals, or other sources such as conference proceedings constitute about 60 percent of the catalog (fig. 3). Many of

the reports classified as "other" also document research sponsored by State and Federal DOTs, the USGS, and environmental-regulatory organizations even though they are not official-agency-sponsored reports.

Reports in the database have publication dates that span from 1905 through 2001. Over 90 percent of the reports cataloged, however, were published during or after 1979, and about 55 percent of these reports were published during or after 1990 (fig. 4). The catalog of pertinent reports is extensive, but probably is not complete because of the difficulty in identifying and finding all the available sources.



**Figure 3.** Distribution of cataloged reports, by source of publication.



**Figure 4.** Distribution of cataloged reports, by year of publication.

## EVALUATION OF AVAILABLE INFORMATION

### Review Process

The report review process is designed to determine the technical merit of the existing literature in terms of current requirements for data documentation, data quality, quality assurance and quality control (QA/QC), and technical issues, which may affect the use of historical data (Granato and others, 1998; Dionne and others, 1999). The report review process is based on the NDAMS review sheet, which was

designed by the USGS with input from the FHWA, State transportation agencies, and the regulatory community. The review process was intended to catalog and assess the completeness and comparability of the documentation in published reports in terms of the data-quality objectives for a regional or national synthesis of highway-runoff data.

The NDAMS review sheet is divided into 12 major sections and 14 water-quality constituent group subsections (Dionne and others, 1999). The 12 numbered sections document (1) administrative review information, (2) investigation and report information, (3) temporal information, (4) location information

(5) water-quality monitoring information, (6) sample-handling methods, (7) constituent information, (8) sampling focus and matrix, (9) flow-monitoring methods, (10) field QA/QC, (11) laboratory QA/QC, and (12) uncertainty/error analysis.

Dionne and others (1999) describe the methods of the NDAMS report review and metadata documentation in detail and provide an overview of the approach and the QA/QC program used to implement the review process. A glossary of relevant terms, a copy of the report-review sheets, and report-review instructions are documented in detail within a series of three appendixes included within the review-methods report (Dionne and others, 1999). Therefore, the reviews are repeatable and the methods can be used by transportation research organizations to catalog new reports as they are published.

## Metadatabase of Report-Review Information

Results of the review process are entered as standardized metadata tables within the computerized bibliographic database to facilitate use for current and future stormwater-runoff investigations. The subset of reviews in the stratified metadatabase can be sorted or filtered by any of a number of different criteria to produce a bibliography of available literature containing information about a particular problem. For example, figure 5 shows the classification of reports that were reviewed (by major subject). Report reviews also may be classified by the source of publication (fig. 6) or year of publication (fig. 7).

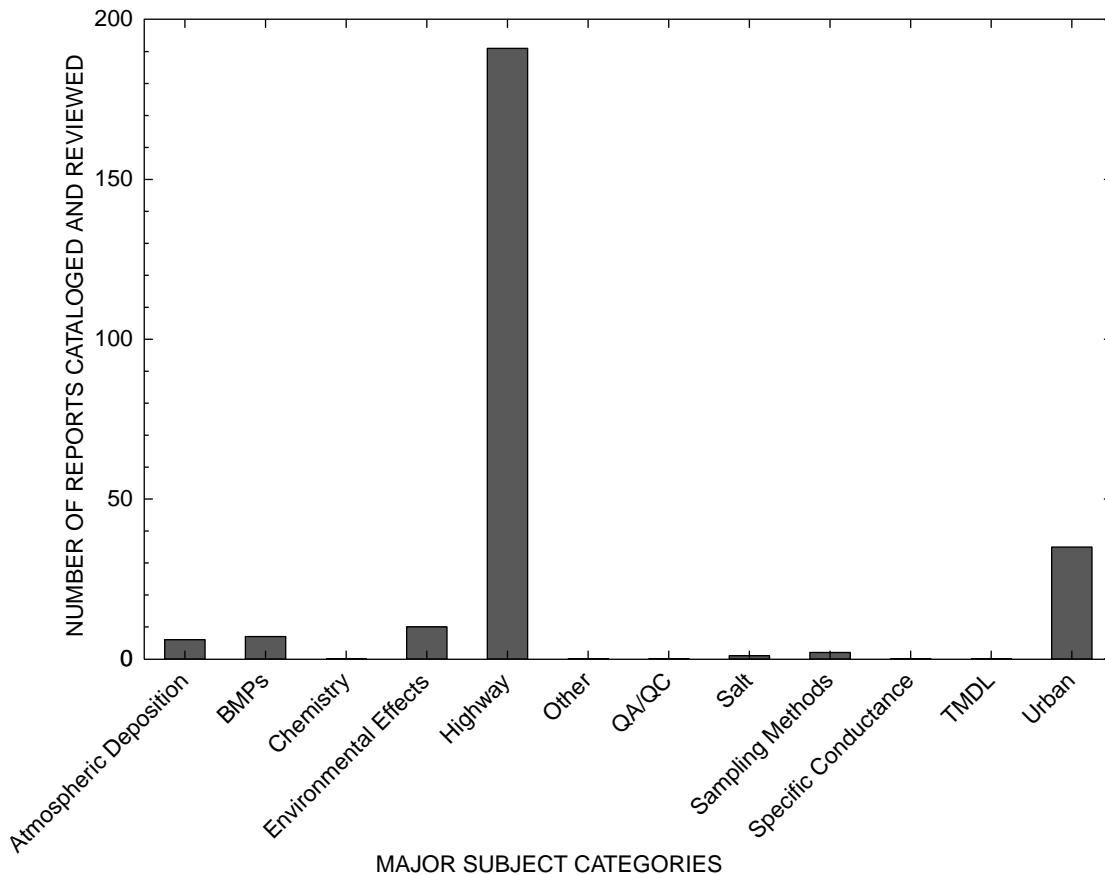
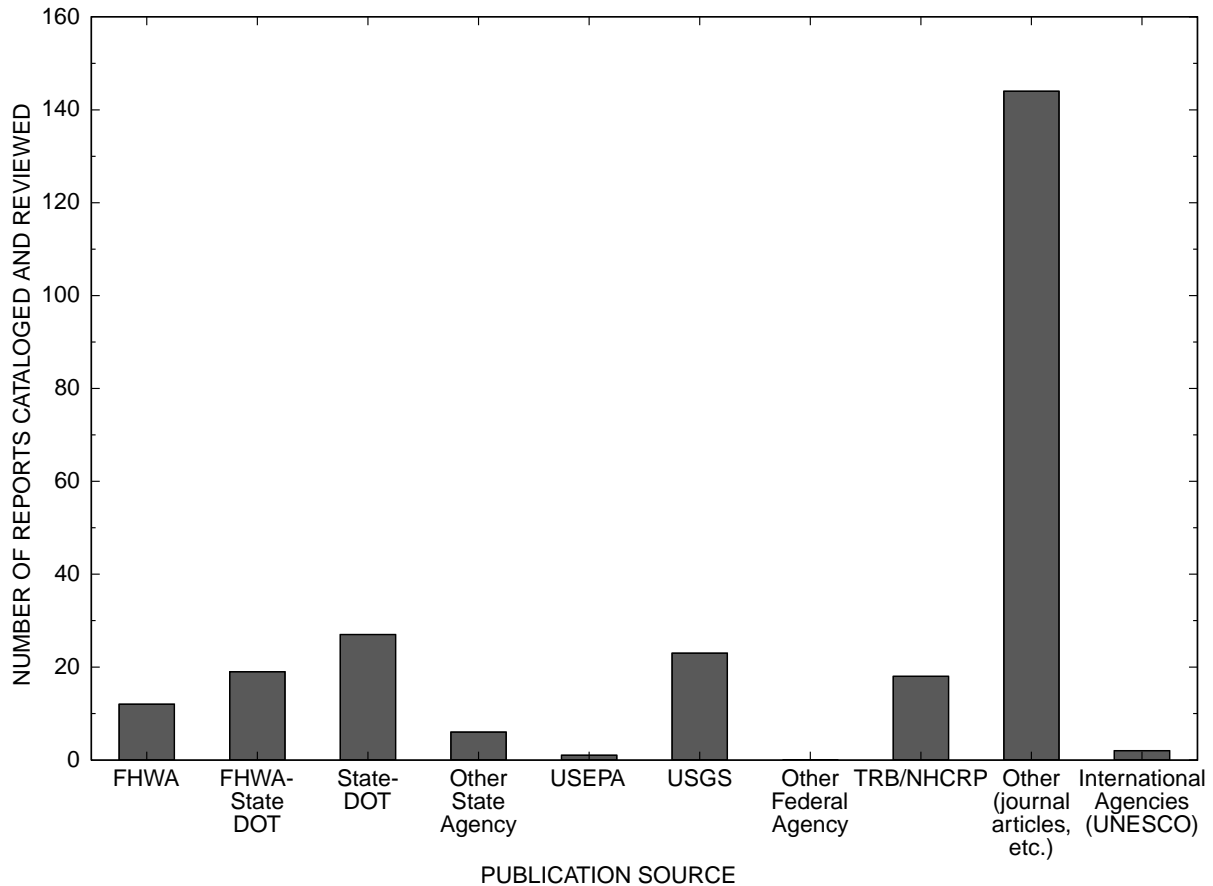


Figure 5. Distribution of reports cataloged and reviewed, by major subject categories.

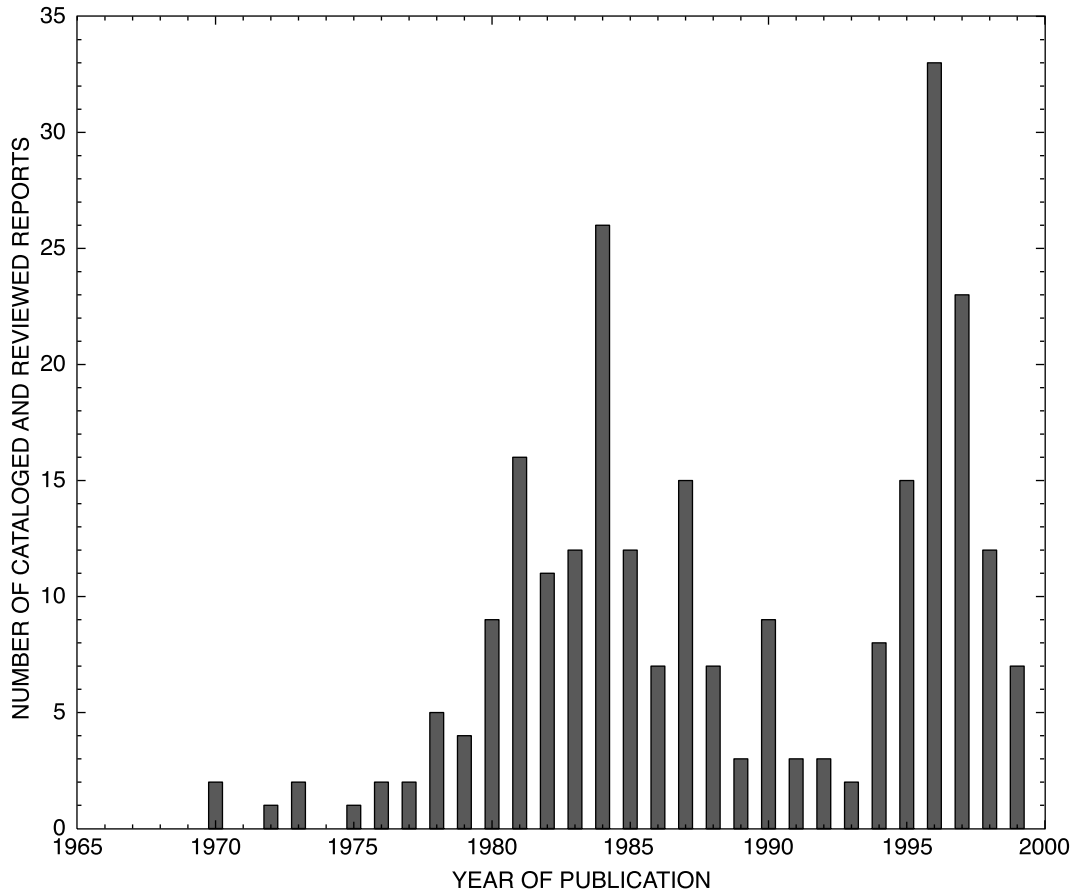


**Figure 6.** Distribution of reports cataloged and reviewed, by source of publication.

The metadatabase of report-review information is organized by citation number and by basic report information including the type of report and the types of data documented in each report. Review results may provide the metadata needed for an assessment of available-published information if the metadata are examined in terms of a particular research need and an appropriate set of data-quality objectives. The evaluation of available literature included reviews of 252 reports, including metadata from 34 review or summary reports and 218 detailed reports. The total number of reviews represents more than 50 percent of the total number of reports cataloged that are designated with "highway" as a primary subject (fig. 2). Some of the reviewed reports are not designated with

"highway" as a primary subject (fig. 5). Many of these reports, however, have a secondary subject category designated as "highway." Furthermore, many of the reports in figure 5 were reclassified from "highway" to one of the other major subject categories when the detailed review revealed that the emphasis of the report was not about highway-runoff quality.

Generally, reports were selected for review from among the population of highway-runoff reports in reverse chronological order (fig. 8). The publication dates of the population of reviewed reports, however, are not substantially different from the general population of highway-runoff reports because the report-review process was designed to focus on the results of highway-runoff quality data-collection efforts and

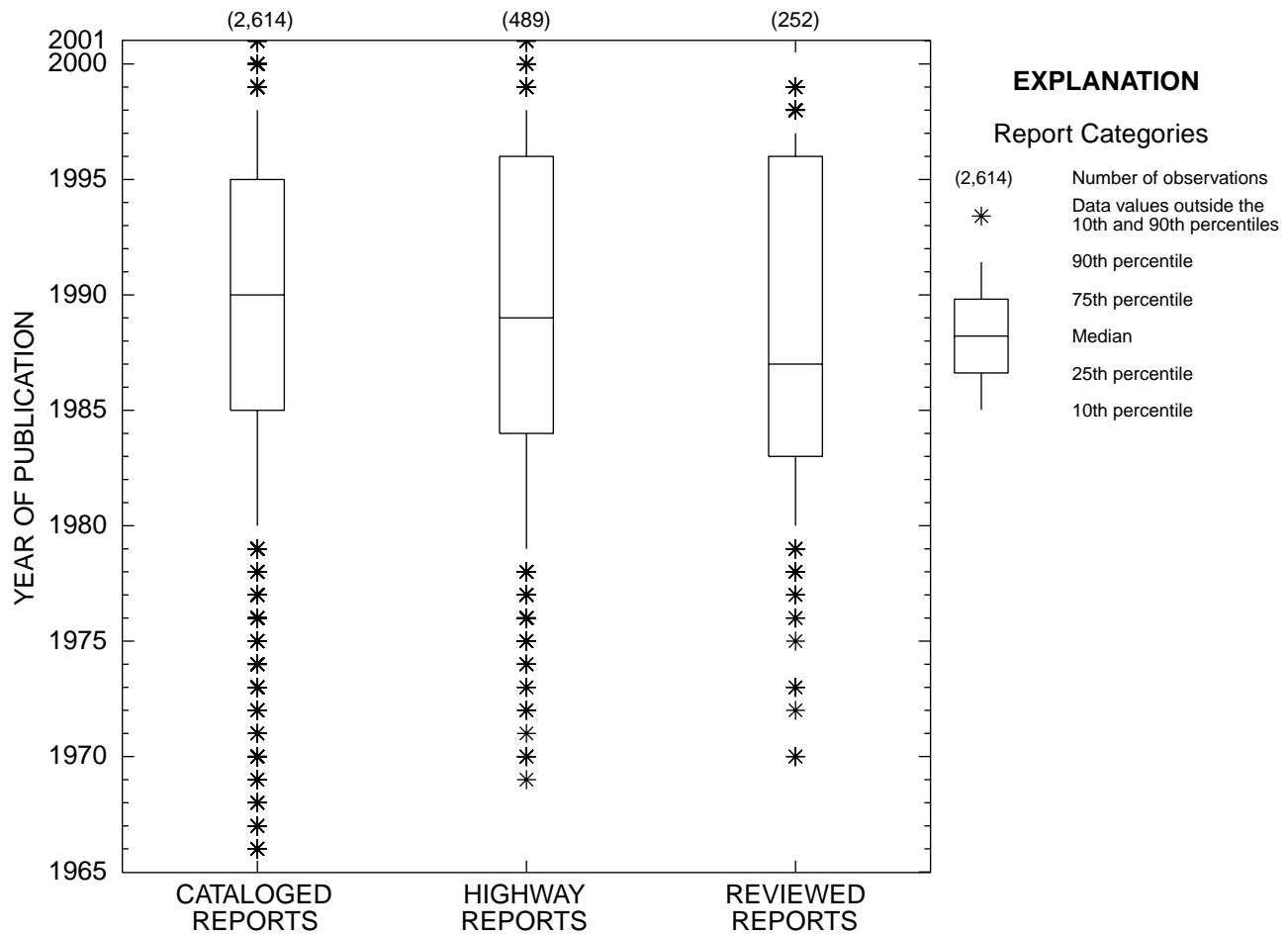


**Figure 7.** Distribution of reports cataloged and reviewed, by year of publication.

many recent "highway" reports have been manuals (such as the Washington State DOT highway runoff Manual, 1995), modeling studies (such as Driscoll and others, 1990a,b), and reviews (such as Young and others, 1996) that are based upon older data collected by the State DOTs and the FHWA. The medians and 90th percentiles of the year of publication for the reports (and "highway" reports) cataloged are slightly higher than for the reviewed reports because the review process was completed in early 2000, whereas the efforts to keep the bibliographic report current continued until publication of this document.

Other, more detailed information can also be used to classify information from different report

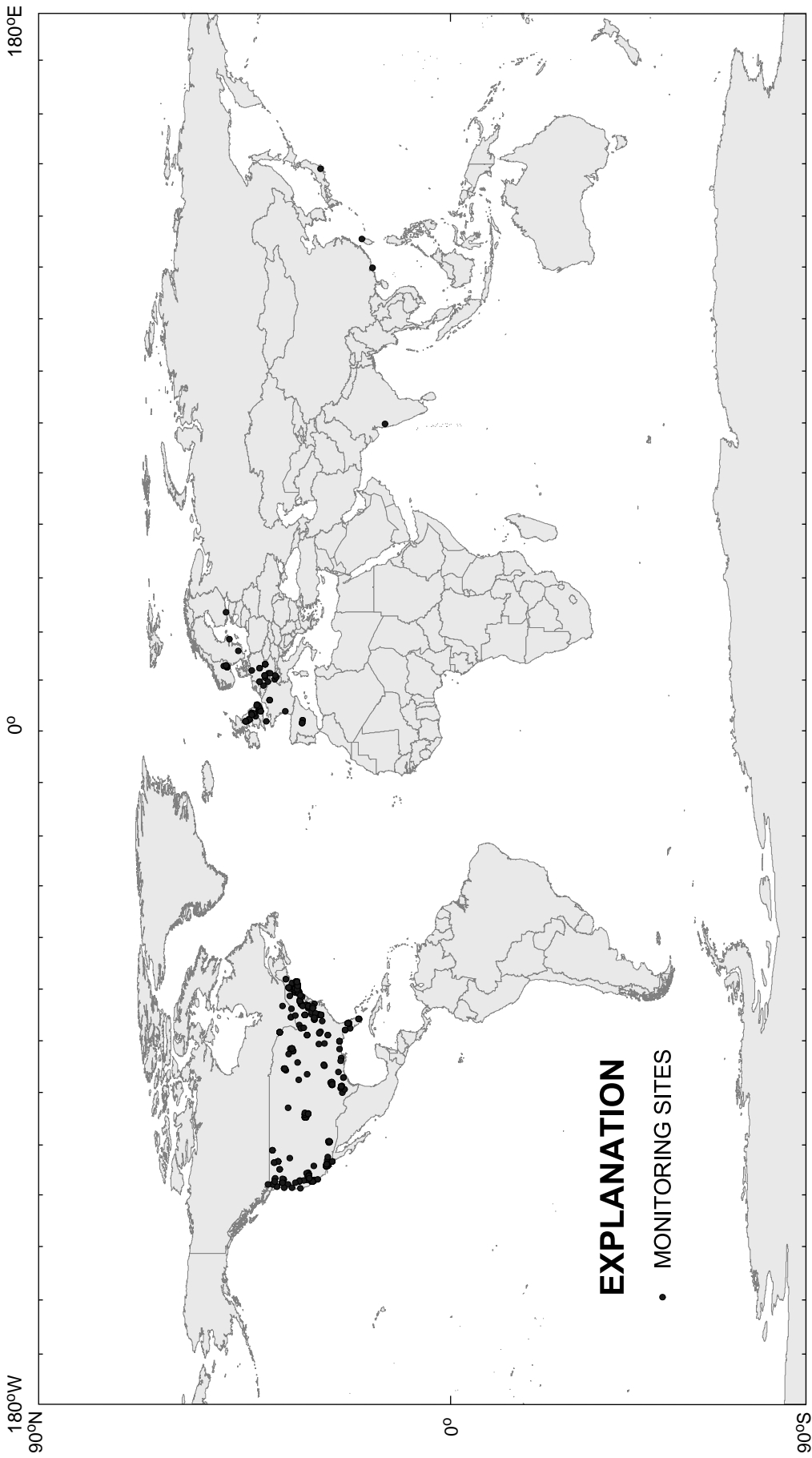
reviews by criteria that may be pertinent to highway runoff-quality research. For example, geographic information is necessary for interpretation of the results from runoff studies because a number of explanatory variables that would affect runoff quality and the potential effects on receiving waters and aquatic biota are specific to each study site. These site-specific variables vary with climate, geology, and anthropogenic influences, which are a function of the location of the study site (Granato and others, 1998; Smieszek and Granato, 2000; Tasker and Granato, 2000). Examination of the metadatabase for site information reveals that 994 study sites were cataloged in the review process. Of these sites, 537 have unique



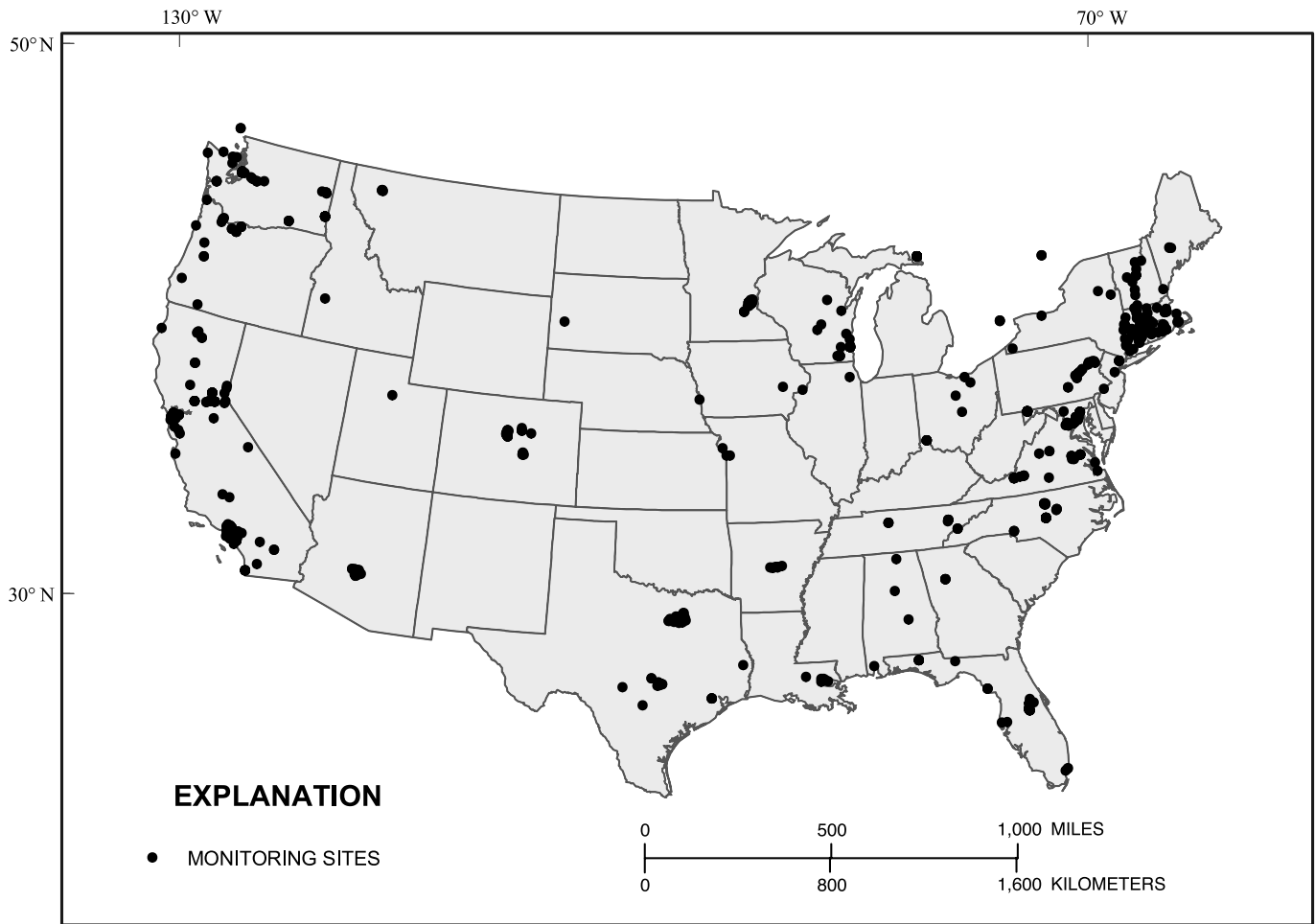
**Figure 8.** The year-of-publication for all cataloged reports, all cataloged reports with a highway classification, and all reviewed reports.

latitude and longitude coordinates worldwide (fig. 9). This data set includes 451 sites in the United States and southern Canada (fig. 10) that could be considered representative of sources and conditions in the conterminous United States (within a rectangle inscribed by latitudes 25 to 49 degrees north and 65 to 125 degrees west). Of the 537 unique study sites identified, there are 234 unique sites identified as highway sites worldwide and 197 of these highway sites can be identified as representative of conditions in the conterminous United States.

The location with the type of study sites is an example of the information that may be extracted from the database (Granato and others, 2001). The metadatabase is designed to be parallel with the review forms documented by Dionne and others (1999). Individual data tables in the database correspond to individual sections in the review forms (Granato and Tessler, 2001). The user interface provides detailed information about individual reviewed reports and summaries of the responses for the population of reviewed reports (Granato and others, 2001).



**Figure 9.** Distribution of study sites worldwide.



**Figure 10.** Distribution of study sites that could be considered as representative of sources and conditions for the conterminous United States.

## PROJECT QUALITY-ASSURANCE AND QUALITY-CONTROL PROGRAM

A quality-assurance and quality-control (QA/QC) program was implemented from the beginning of the NDAMS project to ensure that the existing information would be cataloged properly and the suitability of each reviewed report (and by inference the population of available literature) to meet highway-runoff information needs would be properly documented. Design and implementation of a QA/QC plan is necessary to achieve results that can be used to form valid management decisions (Jones, 1999). The NDAMS project QA/QC program was designed to ensure and document that:

- the project design was adequate to meet the stated goal,

- valid protocols were used to collect and interpret data, and
- these protocols were properly executed.

Each component of the project, including the literature search, report acquisition and inspection process, and the report-review development and implementation process, was addressed in the project QA/QC program.

The literature search included a number of QA/QC efforts. The process of identifying, recording, and documenting publications of interest enforced the QA/QC program because citations that were insufficiently or erroneously documented within the existing literature could not be located or verified in the library-loan process. The QA/QC program for collection of materials from USGS offices in all 50 States included use of standard format text files to record information



and use of the project web pages documenting storm-water activities as feedback mechanism that allowed USGS offices to check and update their entries using electronic mail (Granato and others, 1997). The QA/QC process for obtaining information from the State DOTs included contacting two or more people within each DOT, use of a standard contact form (to standardize and document responses), and follow-up phone calls to verify and standardize responses that were unclear or incomplete. The USGS library provided an independent quality check in the literature search and report acquisition process. The library verification process included identification and acquisition from the USGS library collection or identification in the NTIS database or the Online Computer Library Center (OCLC) database and acquisition through inter-library loan. Only the citations for which a physical copy could be located were included in the NDAMS database. This process ensures that all references are available to the public for research efforts.

The NDAMS database was designed to facilitate the QA/QC program. For example, two QA/QC data fields, denoting that the citation was (1) physically inspected and (2) verified when entered, were included in the design of the citations table. The citation identification number is an auto-number key to uniquely associate all the metadata in the database with a specific report in the bibliography. An auto-number key is a device within the Microsoft Access program that forces referential integrity in the database by ensuring that each citation has a unique identification number and that all other information in the database is properly referenced using this key (Granato and Tessler, 2001). The citation bibliography was also designed with association tables to establish standard choices for descriptor fields. The design and implementation of the database is described in the NDAMS database documentation and user's manual by Granato and others (2001), and Granato and Tessler (2001), respectively.

Each reference was verified by an independent inspection once it was entered into the database. The bibliographic database was also inspected several times throughout the project to detect editorial errors, inconsistencies, and duplicates. The largest sequential

citation identification number is larger than the actual number of citations in the database by 27 citations; therefore, the rate of duplicate citations that were detected and eliminated throughout the project was about one percent of the total. The information in the abstract field of the bibliographic database was also inspected for content, format, and the association with the appropriate reference.

The NDAMS project metadata review process and the associated QA/QC program is documented by Dionne and others (1999). The QA/QC program for the review process included the use of training, standard protocols, standard forms, supervisory and group evaluations of completed reviews, duplicate and replicate reviews, and other mechanisms to ensure that the metadata defining each report were collected and documented in a complete and consistent manner. The design of the metadatabase of report-review information, and the report-review metadata-entry QA/QC process complemented the QA/QC of the review process because the data-entry technician, and the person who checked the data-entry results would also examine the review for obvious errors and inconsistencies.

The design of the NDAMS project database was completed when the review process was about 75 percent complete. The experience and knowledge of the reviewers was used to translate the results of the review process using the NDAMS review sheets into standard responses that would lead to consistent and objective interpretations of available data in published reports. Whenever possible, narrative descriptions in the review sheets were condensed into yes/no questions (or yes/no variants which would include responses for "not applicable" or "unknown" where appropriate), standard multiple-choice questions, or extendable lists of appropriate responses. Information in the review sheets was converted to standard inputs in the database by using standard lists in domain tables to ensure that the data could be reliably and repeatably entered, and that information recorded in the database could be grouped and (or) classified for interpretation. For example, the reviews include information about sampling materials (such as equipment, bottles, and preservatives), but examination of the reviews indicates that

this information was not typically available, or was not described in a consistent manner among the reviewed reports. Therefore, the question regarding sampling materials was simplified to a "yes" or "no" response. Also, some information from the review forms was omitted when it was deemed that inclusion in the database would not add meaningful information. For example, although it is recognized that trained and professional sampling-teams are necessary to collect reliable stormwater-quality data in a consistent manner, it proved impossible to quantify this measure of data quality in an objective review of a published report, and therefore, this information was omitted from the database.

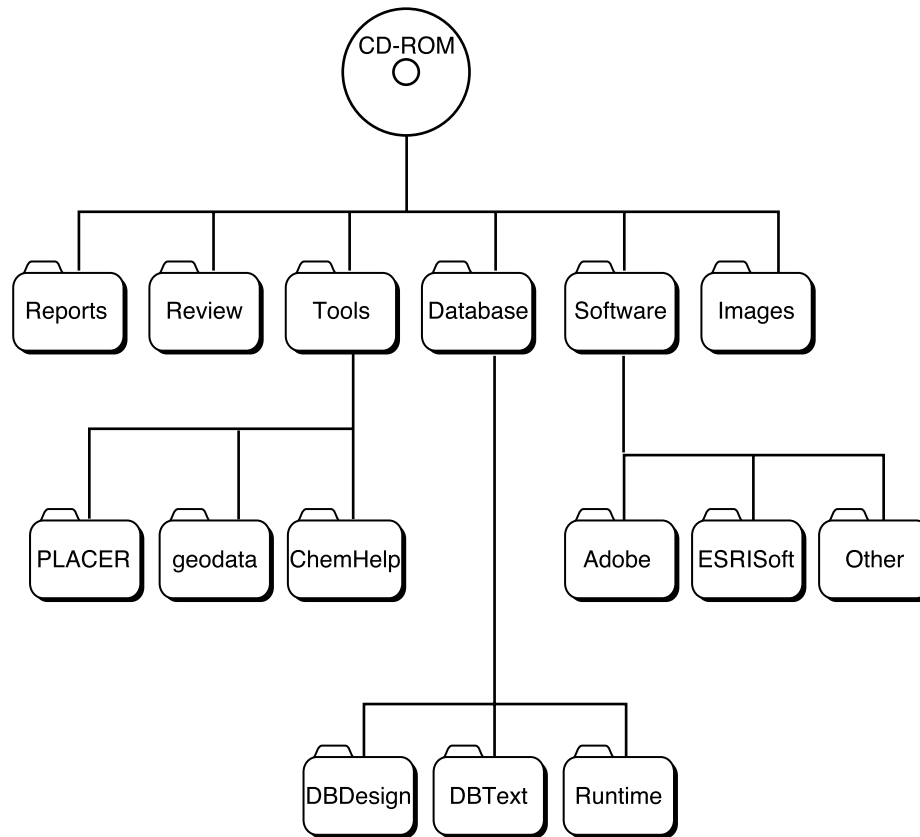
Standard forms were used for entering metadata in the data-entry process as part of the QA/QC design. The form-based interface was designed to facilitate data entry by integrating the data-entry process, using internal programming to establish default values, and controlling input so that the metadata recorded would be internally consistent. For example, if the basic report metadata indicates that flow measurements were not recorded for a given report, the electronic forms used to enter information about a flow-monitoring program are not available for data entry. During the data-entry process, every report review was given a complete and comprehensive quality-control check to ensure that metadata from reviews were entered into the database in a standard format.

## **CD-ROM DIRECTORY STRUCTURE**

The CD-ROM accompanying this report includes all the products produced by the NDAMS project in various electronic formats, information about use of the CD-ROM, and the royalty-free software necessary to use the computer files (fig. 11). The root directory contains computer files necessary to launch the html interface as well as the CD-ROM cover, the preface, the main menu (in text and html format), disclaimer information, license information, instructions for downloading files from disk, contact information for obtaining reports from the FHWA and the USGS,

and this report in electronic format. The technical reports in Volume I of this series are included in the "Reports" directory. The report describing the review methods (Dionne and others, 1999) is in the "Review" directory. Products that were developed to facilitate the review process including ChemicalHelp (Granato and others, 2000), PLACER (Granato, 1999), and the GIS files developed for use in the interpretive report (Smieszek and Granato, 2000) are available in the "Tools" directory. The "Database" directory contains the final database FHWA2001.mdb, the database users manual, database documentation files (in the "DBDesign" subdirectory), an installation package of the database for users without Microsoft Access (in the "Runtime" subdirectory), and tab delimited text files documenting the contents of the database (in the DBText subdirectory). Royalty-free versions of commercial software necessary to view the reports including the Adobe PDF reader (Adobe, 2001) and the ESRI ArcExplorer (ESRI, 2001) software (for viewing GIS files) are available in the "Software" directory in the "Adobe" and "ESRISoft" subdirectories, respectively. The "Images" directory contains the logos and other images used in the html web-page interface.

The CD-ROM is designed with a self-starting web-based interface. The CD-ROM is designed with a web-based interface to facilitate exploration of the disk and use of the contents therein from within a computing environment that is familiar to many computer users. The CD-ROM is designed for use in a Microsoft operating system environment, but the disk may be opened and explored using software designed for other operating systems. When the disk is inserted in a personal computer with a MS Windows operating system it will utilize the host computer's default web browser to launch the cover-page of the report. The user may then navigate through the various directories to find and use information of interest. The CD-ROM does not install any files on the user's computer unless the user decides to save files, install software, or implement the runtime version of the Microsoft Access database. The interface also includes copyright information, the federal software disclaimer, and instructions for saving files to disk.



**Figure 11.** The CD-ROM directory structure.

## SUMMARY

Highway engineers, planners, and decision-makers need valid, current, and technically defensible information about the quality and potential environmental effects of highway runoff. The National Highway Runoff Data and Methodology Synthesis (NDAMS) program is designed to provide a catalog of available runoff-quality studies and to provide information and metadata that can be used to evaluate the suitability of these studies in terms of the data-quality objectives that are applicable for local, regional, and (or) national interpretation of this data. A bibliography of relevant references (with selected abstracts) is provided to establish a searchable electronic record of available reports to meet information needs. A stratified metadatabase, within the bibliographic database, that contains results of the evaluation of available information from the 252 reports reviewed during the synthesis

is provided to indicate the quality of published data. This report describes and documents methods used to catalog and evaluate published information relevant to the study of highway-runoff quality. This report includes a brief description of the overall project and database design, the catalog of available reports, the evaluation of available information, and a description of project quality-assurance and quality-control program. All products from the study, including the catalog of metadata pertaining to the available published reports, are provided in electronic format on the accompanying CD-ROM.

The project coupled an intensive literature search with a metadata evaluation and documentation program. The literature search produced a database that contains more than 2,600 relevant bibliographic references and more than 1,300 abstracts (or previa). All reports were classified by major and minor topics using subject codes such as atmospheric deposition, best

management practices, highway runoff, or urban runoff. The reports were also classified by the publication outlet, such as the FHWA, the USEPA, or the USGS.

The evaluation of available literature included reviews of 252 reports (about 10 percent of the more than 2,600 reports in the catalog), including metadata from 34 literature review or summary reports, and 218 detailed reports. Reports with a primary emphasis on highway-runoff quality were selected for review in reverse chronological order. The reviews represent more than 50 percent of the number of reports designated with a primary emphasis on highway runoff. Among the 537 unique study sites identified, a total of 234 highway-research sites are identified world wide, and of these, 197 sites are representative of conditions in the conterminous United States.

The literature search and the report review process were conducted within the framework of a comprehensive quality-assurance and quality-control program. Efforts were made to verify that all citations in the database are complete, correct, and available to the public. The report-review process and the review metadata-entry process were designed to provide the complete, correct, and objective information needed to evaluate the available information necessary to address highway-runoff water-quality problems within acceptable data-quality objectives.

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