Identifying a Base Network of Federally Funded Streamgaging Stations

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Abstract

The U.S. Geological Survey (USGS) has completed a preliminary analysis to identify streamgaging stations needed in a base network that would satisfy five primary Federal goals for collecting streamflow information. The five goals are (1) determining streamflow at interstate and international borders and at locations mandated by court decrees, (2) determining the streamflow component of water budgets for the major river basins of the Nation, (3) providing real-time streamflow information to the U.S. National Weather Service to support flood-forecasting activities, (4) providing streamflow information at locations of monitoring stations included in USGS national water-quality networks, and (5) providing streamflow information necessary for regionalization of streamflow characteristics and assessing potential long-term trends in streamflow associated with changes in climate.

The analysis was done using a Geographic Information System. USGS headquarters staff made initial selections of stations that satisfied at least one of the five goals, and then staff in each of the 48 USGS district offices reviewed the selections, making suggestions for additions or changes based on detailed local knowledge of the streams in the area.

The analysis indicated that 4,242 streamgaging stations are needed in the base network to meet the 5 Federal goals for streamflow information. Of these, 2,692 stations (63.5 percent) are currently operated by the USGS, 277 stations (6.5 percent) are currently operated by other agencies, 865 (20.4 percent) are discontinued USGS stations that need to be reactivated, and 408 (9.6 percent) are locations where new stations are needed.

Introduction

Since 1889, the U.S. Geological Survey (USGS) has operated a network of streamgaging stations to continuously collect, document, and distribute accurate and timely streamflow information for the Nation. The streamgaging network is operated by the USGS from offices in every State using standardized data-collection, analysis, storage, and quality-assurance methods. This standardization enables the USGS to bring the capability of its nationally distributed staff to bear on challenging problems, such as responding to catastrophic floods, assessing national and regional streamflow conditions, and operating stations where there are unique streamflow conditions.

The streamgaging network is funded by the USGS and by more than 800 other Federal, State, and local agencies. Most network stations are funded through the Cooperative Water Program, in which the USGS shares the costs of station operation with one or more other agencies. Each station in the network is operated to achieve the Federal interests and the specific goals of the cooperating agencies. The network as a whole provides information to support flood forecasting and warning;

water-resource planning, development, management, and protection activities; design of water-related facilities and structures; conflict resolution, and scientific research. Population and economic expansion are increasing demands on the Nation's water resources, and these demands are causing the need for streamflow information to grow rapidly.

On December 11, 1998, the USGS delivered a report to the U.S. House of Representatives Subcommittee on Interior Appropriations, at its request, that examined how well the network was meeting Federal goals for streamflow data in the conterminous 48 States (U.S. Geological Survey, 1998). The report, hereafter referred to as the Report to Congress, identified five key goals: (1) water transfers at interstate and international border crossings, (2) water budgets, (3) flooding, (4) water quality, and (5) long-term trends. Other Federal needs were recognized, but they were not addressed in the report. Some of these needs include supporting Wild and Scenic Rivers, guiding the operation of large Federal reservoirs, managing critical habitat for endangered and threatened species, and defining hydrologic characteristics for designing federally funded structures, such as bridges and roads.

A network evaluation done for the Report to Congress identified the stations that met each of the Federal goals during each year since 1921, to determine how well the goals were met over time. Although attainment of the water-budget and water-quality goals has been stable for more than 40 years, substantial declines were found in the ability of the network to meet the flooding and long-term change goals, and a smaller decline was found in the interstate and international transfers goal. The report attributed the declines to static funding of the network while costs have been increasing, and to the decreasing USGS share as a percentage of total network funding. This decreasing Federal funding share has resulted in loss of stations that provide data to support the Federal goals of the network. These lost stations typically have significant local value, as well. Of greatest concern was the substantial loss of stations with long-term records on undeveloped streams. These stations are essential for analysis of streamflow and climatic trends, for definition of recurrence intervals of floods and droughts, and for transfer of that information to ungaged streams.

In response to concerns raised by the Report to Congress, the USGS has developed a plan for the National Streamflow Information Program (NSIP) (U.S. Geological Survey, 1999). The NSIP constitutes the vision of the USGS for meeting the streamflow information needs of the 21st century, and calls for (1) enhancements to the streamgaging infrastructure, (2) a new funding mechanism for the streamgaging network, (3) intensive data collection during floods and droughts, (4) ongoing regional and national assessments of streamflow characteristics and trends, and (5) improved capabilities for monitoring, processing, disseminating, and archiving current and historical streamflow information. During fiscal years 2000 and 2001, the USGS has received additional funding from Congress for the streamgaging network. Some of this additional funding is being used to implement parts of the NSIP plan.

Under the NSIP plan, a base network of streamgaging stations would be funded completely through Federal appropriations, thus eliminating reliance upon funding partners to keep the stations active. This base network would consist of the minimum number of stations needed to satisfy entirely the Federal goals for streamflow information. The NSIP plan recast the Federal goals somewhat. The plan added stations mandated by court decrees to the interstate and international transfers goal, it restricted the flooding goal to providing streamflow data for National Weather Service forecast locations, it added streamflow regionalization to the long-term trends goal, and it limited the water-quality goal to providing streamflow data for USGS water-quality network stations. Regionalization is the process of using the streamflow records for representative streamgaging stations to estimate streamflow characteristics for sites on ungaged streams. This report describes a preliminary analysis

that was done to identify stations that should be included in the base network for all 50 States and the Commonwealth of Puerto Rico.

Streamgaging-Station Data Base

The streamgaging-station data base used for this analysis included a total of 21,026 stations; 6,783 active USGS stations, 12,391 discontinued USGS stations, and 1,852 active stations operated by 53 other agencies and corporations. Information in the data base included operating agency, station identification number and name, location coordinates (latitude and longitude), USGS district and State in which the station is located, station status (active or discontinued), and whether or not real-time data are available at the stations.

USGS streamgaging stations were identified by retrievals from the National Water Information System (NWIS) data bases that store data separately for each of the 48 USGS district offices. A district office is operated within each State, except for Rhode Island, which is combined with Massachusetts; Vermont, which is combined with New Hampshire; and Delaware, which is combined with Maryland. Active stations were identified initially on the basis of availability of continuous data in the data bases during water year 1999 (Oct. 1, 1998 through Sept. 30, 1999) -- the latest complete year of record available when the analysis was begun -- and were verified by checking whether data for the stations were included in the 1999 Water Resources Data reports, which are published annually by each USGS District. District staff further verified the resulting active station list for each district, and updated it to reflect water year 2000 activities.

Staff from the USGS district offices and their cooperators were queried to identify other agencies and corporations that might be collecting continuous streamflow data. Other-agency information was also provided by members of the Streamgaging Task Force of the Advisory Committee on Water Information. All identified agencies and corporations were requested to provide a list of the stations they operate, along with other information necessary to complete the data base entries for their sites. Brief descriptions of quality-assurance procedures were also requested.

Other-agency stations were not considered in the Report to Congress. According to the subsequently developed NSIP plan; however, other-agency stations identified as meeting any of the Federal goals for streamflow information could be included as part of the National streamgaging network. Operators of these stations could be provided with Federal funding, if necessary, to bring their data-collection standards into compatibility with those of the USGS. A few agencies refused to comply with the request for information, and as a result, stations operated by those agencies were not considered in the analysis and cannot be considered for Federal funding under the NSIP.

The data base of stations included in the NSIP analysis can be obtained at http://water.usgs.gov/osw/programs/nsip/. Historical data for all USGS stations on the list and real-time data where it is available can be obtained from the NWIS-Web data base, which is available on the World Wide Web at http://water.usgs.gov/nwis.

Methods

The five Federal goals for the network were defined previously in the Report to Congress, and metrics were developed for each of the goals to determine levels of attainment over time. The definitions and metrics were modified somewhat for this analysis, and are described below.

The analysis was done using a Geographic Information System (GIS). As an initial step, each station in the data base was assigned to one of the 60,000 reaches in an enhanced version of the RF1

river-reach file GIS data layer of the U.S. Environmental Protection Agency (1994), which corresponds to all streams shown on 1:500,000-scale USGS topographic maps. Smith and others (1997) enhanced the RF1 reach file to include several new attributes that facilitate analysis of the goals, including estimated drainage area, reach length, and an attribute that allows for determining what reaches are upstream and downstream from other reaches. Alexander and others (1999) further enhanced the reach file to ensure the hydrologic integrity of the digital reach traces and to quantify the time of travel of flow in river reaches and reservoirs.

About 30 percent of the stations in the data base were on small streams that do not appear in the RF1 data layer. These stations were assigned to the RF1 reach to which the small stream drained. An additional attribute was added to the data base to reflect whether the stations were actually on the reach to which they were assigned or on a tributary reach not included in the RF1 data layer. The imprecise assignment of the off-reach stations had no effect on the analysis for transfers of water at interstate and international border crossings, the water budget, or the water-quality goals because these goals require stations on relatively large streams that are included in the RF1. The effects on the flooding and the long-term changes goals are discussed below.

Locations of streamgaging stations operated by the USGS and by other agencies were compared on digital maps created using the GIS to other geospatial information that described where stations were needed to meet each of the goals. USGS headquarters staff made the initial station selections and marked the selected stations on the digital maps with special colors and symbols. The digital maps with the selections and instructions for reviewing them were sent to the USGS district offices, where staff from the district offices reviewed the selections for their operational areas and either verified them or made alternate selections based on more detailed local knowledge, and on discussions with cooperators. The district offices were also asked to suggest locations for new stations where the goals could not be met by active or discontinued stations. USGS headquarters staff compiled the information returned from the district offices and resolved any conflicts to obtain the final lists of stations that meet each of the goals. Priorities for selecting the base network stations were (1) current USGS stations, (2) recently discontinued USGS stations that would not require full reconstruction, (3) stations operated by other agencies, (4) long-discontinued USGS stations that would require full reconstruction, and (5) new stations.

Border Crossings, Compacts, and Decrees

In the Report to Congress, the interstate and international transfers goal measured “the ability of the network to provide accepted, neutral data for States to use in the allocation of interstate waters.” These data are needed to compute amounts of water transferred across State and international borders. The metric for border crossings requires that stations be operated on all reaches that have a drainage area of at least 500 square miles at State and international border crossings. For this analysis, the requirement for operating stations at all locations mandated by treaties, interstate compacts, and court decrees was added to the goal. USGS district staff identified these locations through a literature search and through discussions with cooperators.

The analysis for this goal was done using the GIS by plotting the RF1 data layer, the data layer of streamgaging-station locations, and a data layer of State and international boundaries (Negri, 1994). Reaches with drainage areas equal to or greater than 500 square miles that intersect a border were identified and highlighted on the digital map. Locations of stations required by treaties, compacts, and decrees were also highlighted on the map. Locations of all USGS and other-agency stations were then

compared to the highlighted locations on the map to select active, discontinued, or new stations to meet the goal.

Water Budgets

Knowledge of the outflows of major river basins is required for forming national water policies and planning. Seaber and others (1987) defined drainage boundaries for the 352 major river basins in the United States and designated the major basins as accounting units (AU's) with 6-digit hydrologic unit codes. AU's in Hawaii and Puerto Rico correspond to the entire areas of the major islands. To satisfy the water-budget goal, the contribution of streamflow should be accounted for from each AU to the next downstream AU or to coastal waters or the Great Lakes.

The metric is to gage as much of the area of each AU as possible. For AU's drained by a single major river, 90 to 110 percent of the drainage area of the AU should be gaged. For coastal AU's drained by more than one major river, and for some inland basins with no outlet, the terminal end of the largest river should be gaged. If the drainage area for these stations is less than 50 percent of the drainage basin, then a second station may be added.

The RF1 streams, the AU boundaries (Watermolen, 1999), the State lines, and the streamgaging-station locations were plotted on a digital map to analyze this goal. The station that was on the major river that drains each AU and that was closest to the terminal end of the AU was selected as meeting the goal. If the drainage areas for these stations constituted less than 90 percent of the AU and a gaged tributary entered below the highlighted station and above the terminus of the AU, then the tributary station was also selected.

In coastal AU's with more than one major river draining them and in inland AU's with no outlets, the farthest downstream stations on the largest rivers were selected. If those stations accounted for less than 50 percent of the drainage areas of the AU's, the station with the next largest drainage area on a different river in the AU was selected as well. In some of these AU's, less than 50 percent of the drainage areas will be gaged in the Federal network.

Flooding

The goal is to provide critical streamflow information for populations at risk from flooding. Long-term data are needed to design structures, such as dams, roads, and bridges, that need to remain operational during large floods, and to develop flood inundation maps for setting flood-insurance rates and for zoning. Real-time data are needed for flood forecasting and for emergency-management decisions.

Two metrics were used to assess this goal in the Report to Congress. The first metric related to stations needed to serve the population at risk from flooding. The second metric related to stations needed to support the flood-forecasting functions of the U.S. National Weather Service (NWS). Only the second metric was assessed for this analysis.

The NWS provided a list, along with the latitudes and longitudes, of 3,328 service locations in the conterminous 48 United States at which it provides flood forecasts. Of these, 279 service locations were on reservoirs; they were eliminated from the analysis because stations at these locations were assumed to record water level only. About two-thirds of the non-reservoir service locations coincide with active USGS streamgaging stations. Service locations outside the conterminous 48 United States were not available at the time of the analysis. The metric is to provide real-time data for each of the service locations at which the NWS needs streamflow data to calibrate and operate forecast models.

The list of 3,049 non-reservoir service locations was used to create a digital data layer for assessing the flooding goal. Each service location was related to a stream reach in the RF1 data layer by specifying the RF1 reach number as an attribute in the service location data layer. Of the non-reservoir service locations, 222 were on small streams not included in the RF1 data layer. These service locations were assigned to the RF1 stream to which the small stream drained, and an attribute was set to indicate that the stations were actually located off the reach.

The data layers for the RF1 streams, the streamgaging-station locations, and the service locations provided by the NWS were plotted on digital maps to assess the metric. Active streamgaging stations that provide data relevant to the NWS service locations were selected. Service locations on the RF1 reaches were matched to streamgaging stations on the same reaches. Service locations not on RF1 reaches were matched to streamgaging stations by comparing the names of the service locations to the names of the streamgaging stations.

Where no active stations met the NWS needs for data, discontinued or new stations were selected on the basis of priorities indicated by the NWS for the Real-Time Hazards Initiative of the USGS. The goal of the Initiative, which is described on the World Wide Web at http://water.usgs.gov/hazards_initiative/, is to enhance the ability of the USGS to meet the NWS forecast needs. For the Initiative, the USGS asked each of the NWS River Forecast Centers to prioritize locations where reactivated or new stations were needed to meet their forecasting needs. The U.S. Congress provided additional funding for the Initiative during Federal fiscal years 2000 and 2001.

Water Quality

This goal seeks to provide streamflow information for the three national USGS water-quality networks: Hydrologic Benchmark (HBM) stations, National Stream Water Quality Accounting Network (NASQAN) stations, and National Water Quality Assessment Low-Intensity Phase (NAWQA LIP) stations. The HBM network consists of 63 stations, the NASQAN network consists of 40 stations, and the NAWQA LIP network consists of 107 stations. Each of the networks is designed to fulfill different national needs for water-quality information. The networks are described on the World Wide Web at http://water.usgs.gov/nasqan/. The metric for the water-quality goal is that an active streamgaging station should provide streamflow data for every water-quality station in each of the networks.

Lists of the stations in the three networks, along with their latitudes and longitudes, were combined and used to create a digital data layer of the network station locations. This data layer was plotted using the GIS along with data layers for the RF1 streams and the streamgaging-station locations to create digital maps for assessing the metric. Active streamgaging stations were required to be on the same reaches as the water-quality network stations to be selected.

Regionalization and Long-term Trends

Long-term streamgaging stations are needed for determining streamflow characteristics, such as the 100-year flood and the 7-day, 10-year low flow, which are used by water-resources planning and regulatory agencies throughout the Nation. Regionalization techniques use information from long-term streamgaging stations that are minimally affected by human influences to estimate streamflow characteristics for sites on ungaged streams. Stations that are suitable for regionalization are also suitable for assessing trends in streamflow in response to climatic change. The goal is to operate a

streamgaging network that enables, on a nationwide basis, regionalization of streamflow characteristics and assessments of trends in streamflow.

This goal was analyzed differently in the conterminous United States than in Alaska, Hawaii, and Puerto Rico. In the conterminous United States, the metric was to operate a representative streamgaging station in each of the 802 eco-AU's in the Nation. Eco-AU's are geographic areas of at least 100 square miles defined by intersecting the 352 AU's (Watermolen, 1999) with the 76 ecoregions of the conterminous United States (Omernick, 1987). Representative stations are those that are minimally affected by human influences and that have drainage areas that are at least 80 percent within a single eco-AU, as opposed to stations on streams that simply flow through the eco-AU.

In Alaska, the metric was to operate a representative streamgaging station in each of the 20 ecological regions defined by Gallant and others (1995). Limiting the network for this goal to one station in each ecological region rather than to one station in each eco-AU was necessary because the cost of operating streamgaging stations in Alaska is prohibitive and the population served is small. Operating a station in each eco-AU would have required establishing more than 80 new Alaskan stations at an annual cost of about $50,000 per station to operate. The average annual cost for operating stations in the conterminous United States is currently about $12,000. In Hawaii and Puerto Rico, a windward and a leeward station was selected for each major island.

Data layers for the streamgaging-station locations, for the RF1 streams, and for the eco-AU's were plotted in the GIS to assess the goal. A single station was selected to represent each eco-AU (each AU in Alaska). In making the selections, stations included in the Hydroclimatic Data Network (HCDN) (Slack and others, 1993) were given preference if their drainage areas were entirely or nearly within the eco-AU. HCDN stations meet strictly defined criteria for measurement accuracy and record length, and are as unaffected by diversions, dams, or other human influences as possible. Active stations were given preference over discontinued stations, longer record lengths were given preference over shorter record lengths, and larger drainage areas were given preference over smaller drainage areas. USGS district personnel were relied on heavily for making the selections because of their local knowledge of any possible effects of human influences on the streamflow records for individual stations.

Active and discontinued stations were selected to represent eco-AU's whether the stations were located on or off RF1 reaches. For eco-AU's that required establishment of new streamgaging stations, the RF1 reaches on which new stations should be located were selected.

Results

On the basis of the above analysis, the USGS needs to operate 4,242 streamgaging stations to fully satisfy the 5 Federal goals for streamflow information. The number of active USGS stations, active other-agency stations, reactivated USGS stations, and new stations needed to fully satisfy each of the five goals are shown in table 1. Also shown in table 1 are the combined totals of stations needed and the percentages of attainment by active USGS and other-agency stations. The sum of the total stations shown in table 1 for each of the goals is 5,003 stations; however, because 764 of the stations satisfy 2 or more goals, only 4,242 stations are needed in the network. In addition, 46 of the 214 stations needed to fulfill the obligations of compacts and decrees were also needed to account for transfers of water at border crossings, thus reducing the number of stations needed to satisfy this combined goal from 530 to 484 stations.

Of the 4,242 stations, 2,692 (63.5 percent) are currently operated by the USGS, 277 (6.5 percent) are currently operated by other agencies, 865 are discontinued USGS stations that will need to

be reactivated (20.4 percent), and 408 are new stations that will need to be established (9.6 percent). The number of active USGS stations, active other-agency stations, reactivated USGS stations, and new stations needed in each State to complete the base network are shown in table 2.

Lists of stations identified by this preliminary analysis have been compiled for each State, and can be viewed on the World Wide Web at http://water.usgs.gov/osw/programs/nsip/. The lists include the station name and identification number for all active and discontinued stations, as well as latitude, longitude, RF1 stream reach number, and goals met for all stations. The lists are subject to change as a result of further refinement in the analysis process and availability of new information. When finalized, the lists will be useful to develop a detailed implementation plan for completing the base network. The plan will include cost estimates for reactivating and installing new stations, annual operation costs, and a timetable for implementation. Interested individuals and agencies are encouraged to review the lists and to provide comments by mail to the U.S. Geological Survey, Office of Surface Water, 12201 Sunrise Valley Drive, Reston, VA 02192, or by telephone at (703) 648-5301.

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Table 1. Stations needed to fully satisfy each of the five Federal goals for streamflow information and percent achieved by currently active stations.

Goal	Active USGS	Active other agency	Inactive USGS	New	Total Stations	Percent of goal achieved
1. Border crossings, compacts, and decrees	397	14	56	17	484	84.9
2. Water budgets	337	23	63	12	435	82.8
3. Flooding	1,928	234	582	305	3,049	70.9
4. Water quality[1]	209	0	0	0	209	100
5. Long-term changes	527	16	208	75	826	65.7
Combined[2]	2,692	277	865	408	4,242	70.0

[1]Analysis for this goal included only stations in the 48 contiguous United States.

[2]Values shown in this row do not equal the sums of the preceding rows because many stations fulfill mulitiple goals.

Table 2. Stations needed in each State to complete the base network of Federally funded streamgaging stations.

State Name	Active USGS	Active other agency	Inactive USGS	New	Total Stations
Alabama	38	8	15	7	68
Alaska	21	0	20	14	55
Arizona	56	1	14	12	83
Arkansas	43	28	21	8	100
California	110	23	51	16	200
Colorado	100	32	43	1	176
Connecticut	9	2	1	1	13
Delaware	4	0	0	0	4
Florida	62	2	7	5	76
Georgia	55	1	13	13	82
Hawaii	12	0	0	0	12
Idaho	67	1	14	12	94
Illinois	86	4	13	12	115
Indiana	56	0	5	9	70
Iowa	80	4	13	19	116
Kansas	110	0	30	21	161
Kentucky	38	5	26	7	76
Louisiana	42	24	5	5	76
Maine	19	1	4	1	25
Maryland	17	0	0	1	18
Massachusetts	18	0	1	3	22
Michigan	57	0	28	12	97
Minnesota	47	9	23	15	94
Mississippi	49	6	11	8	74
Missouri	62	10	22	19	113
Montana	85	3	28	4	120
Nebraska	54	12	40	9	115
Nevada	20	0	8	0	28
New Hampshire	7	1	9	1	18
New Jersey	29	0	0	1	30
New Mexico	79	2	18	7	106
New York	64	8	21	3	96
North Carolina	58	4	7	15	84
North Dakota	45	2	12	8	67
Ohio	44	2	15	3	64
Oklahoma	80	4	20	15	119
Oregon	85	8	34	7	134
Pennsylvania	106	2	9	5	122
Puerto Rico	9	0	0	0	9
Rhode Island	2	0	0	0	2
South Carolina	29	1	5	7	42
South Dakota	39	3	10	4	56
Tennessee	25	15	21	1	62
Texas	244	12	106	50	412
Utah	69	0	31	8	108
Vermont	4	0	9	1	14
Virginia	42	12	14	3	71
Washington	75	11	9	11	106
West Virginia	33	3	11	7	54
Wisconsin	45	2	10	9	66
Wyoming	62	9	38	8	117
TOTALS	2,692	277	865	408	4,242