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U.S. Geological Survey (USGS) Streamgaging Network: Overview and Issues for Congress

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SUMMARY

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Anna E. Normand
Analyst in Natural Resources Policy

U.S. Geological Survey (USGS) Streamgaging Network: Overview and Issues for Congress

Streamgages are fixed structures at streams, rivers, lakes, and reservoirs that measure water level and related streamflow—the amount of water flowing through a water body over time. The U.S. Geological Survey (USGS) in the Department of the Interior operates streamgages in every state, the District of Columbia, and the territories of Puerto Rico and Guam. The USGS Streamgaging Network encompasses 10,300 streamgages, which record water levels or streamflow for at least a portion of the year. Approximately 8,200 of these streamgages measure streamflow year round as part of the National Streamflow Network. The USGS also deploys temporary rapid deployment gages to measure water levels during storm events, and select streamgages measure water quality.

Streamgages provide foundational information for diverse applications that affect a variety of constituents. The USGS disseminates streamgage data free to the public and responds to over 670 million requests annually. Direct users of streamgage data include a variety of agencies at all levels of government, private companies, scientific institutions, and recreationists. Data from streamgages inform real-time decisionmaking and long-term planning on issues such as water management and energy development, infrastructure design, water compacts, water science research, flood mapping and forecasting, water quality, ecosystem management, and recreational safety.

Congress has provided the USGS with authority and appropriations to conduct surveys of streamflow since establishing the first hydrological survey in 1889. Many streamgages are operated cooperatively with nonfederal partners, who approach the USGS and sign joint-funding agreements to share the cost of streamgages and data collection. The USGS Cooperative Matching Funds (CMF) Program provides up to a 50% match with tribal, regional, state, and local partners, as authorized by 43 U.S.C. §50. The average nonfederal cost-share contribution has increased from 50% in the early 1990s to 63% in FY2018. In the early 2000s, the USGS designated federal priority streamgage (FPS) locations based on five identified national needs. The SECURE Water Act of 2009 (Title IX, Subtitle F, of P.L. 111-11) directed the USGS to operate by FY2019 no less than 4,700 federally funded streamgages. In FY2018, 3,640 of the 4,760 FPSs designated by the USGS were operational, with 52% of their funding from the USGS.

Congressional appropriations and agreements with 1,400 nonfederal partners funded USGS streamgages at $189.5 million in FY2018. The USGS share included $24.7 million for FPSs and $29.8 million for cooperative streamgages through CMF. A dozen other federal agencies provided $40.7 million. Nonfederal partners, mostly affiliated with CMF, provided $94.3 million. In FY2019, Congress appropriated level funding for FPS and CMF streamgages. Congress directed an additional $8.5 million to pilot a Next Generation Integrated Water Observing System (NextGen), establishing dense networks of streamgages in representative watersheds in order to model streamflow in analogous watersheds. The President's budget request for FY2020 does not include NextGen system funding and would reduce CMF for streamgages by $250,000.

The USGS uses appropriated funding to develop and maintain the USGS Streamgaging Network. The USGS and numerous stakeholders have raised funding considerations including user needs, priorities of partners, federal coverage, infrastructure repair, disaster response, inflation, and technological advances. Some stakeholders advocate for maintaining or expanding the network. Others may argue that Congress should consider reducing the network in order to prioritize other activities and that other entities operate streamgages tailored to localized needs. Congress might also consider whether to invest in streamgage restoration and new technologies.

Congress may consider outlining the future direction for the USGS Streamgaging Network through oversight or legislation. As the USGS faces a deadline by the SECURE Water Act of 2009 to operate no less than 4,700 FPSs by FY2019, Congress directed the USGS through appropriations legislation to invest in the NextGen system. Congress may consider such policy options as pursuing both the FPS mandate and the NextGen system simultaneously, amending the SECURE Water Act of 2009, and the relative emphasis of the NextGen system.

Contents

Introduction 1
What Is a Streamgage? 2
Streamgage Uses 5
Examples of Streamgage Uses 6
Network Structure 9
Cooperative Matching Funds Program 10
Federal Priority Streamgages 12
Network Funding 13
USGS Funding Trends 16
Issues for Congress 17
Funding Considerations 17
Addressing the Size of the Network 17
Restoration of Streamgages 20
Modernizing the USGS Streamgaging Network 21
Balancing Policy Options 24
Pursuing Both the FPS Mandate and the NextGen System 24
Amending the SECURE Water Act of 2009 24
Replacing the FPS Network with NextGen System 25

Figures

Figure 1. USGS Streamgaging Network Structure and Number of Streamgages 1
Figure 2. Diagram of a Streamgage Measuring Stream Stage Height 3
Figure 3. Discharge Graph Capturing Streamflow during Hurricane Florence 4
Figure 4. Number of National Streamflow Network Streamgages in U.S. States and Territories in 2018 10
Figure 5. Number of USGS Streamgages and Policy Changes over Time 12
Figure 6. FY2018 Funding for the USGS Streamgaging Network 14
Figure 7. USGS Funding for the Streamgaging Network 17
Figure 8. Map of the Planned Next Generation Integrated Water Observing System (NextGen) Pilot in the Delaware River Basin 23

Tables

Table 1. FY2018 Funding and Streamgages Supported by Other Federal Agencies 15

Contacts

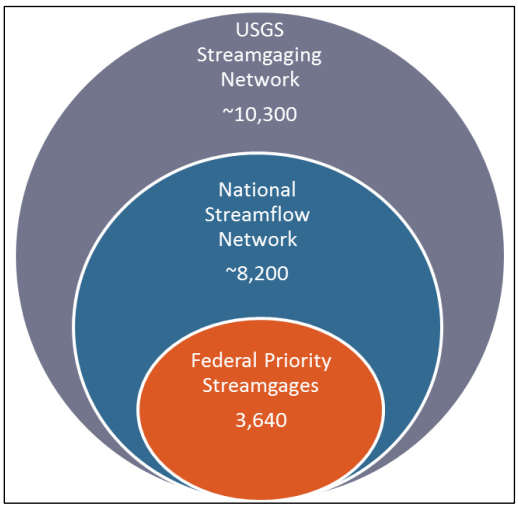
Author Information 25

Introduction

Streamgages measure water level and related streamflow at streams, rivers, lakes, and reservoirs across the country. Streamgages provide foundational information for diverse applications that affect a variety of constituents. Congress has supported a national streamgage program for 130 years.[1] These streamgages operate in every state, the District of Columbia, and the territories of Puerto Rico and Guam; therefore, national streamgage operations garner interest from many Members of Congress. Data from streamgages informs real-time decisionmaking and long-term planning on issues such as hazard preparations and response, infrastructure design, water use allocations, ecosystem management, and recreation.[2] Direct users of streamgage data include a variety of agencies from all levels of government, utility companies, consulting firms, scientific institutions, and recreationists.[3]

Streamgages are operated across the globe with national programs in North America, Europe, Australia, and Brazil, among others.[4] In the United States, the U.S. Geological Survey (USGS), the Department of the Interior's (DOI's) lead scientific agency, manages the USGS Streamgaging Network (**Figure 1**). The network encompasses 10,300 streamgages that record water height or streamflow for at least a portion of the year. Approximately 8,200 of these streamgages measure streamflow year-round and are part of the National Streamflow Network. This subnetwork includes 3,640 Federal Priority Streamgages (FPSs), which Congress and the USGS designated as national priorities (see section on "Federal Priority Streamgages"). Some entities, such as state governments, operate their own streamgages separate from the USGS Streamgaging Network.[5]

Figure 1. USGS Streamgaging Network Structure and Number of Streamgages



Source: CRS with data from USGS Groundwater and Streamflow Information Program.

Notes: The number of streamgages are in parentheses. The National Streamflow Network is a subset of the USGS Streamgaging Network, and FPSs are a subset of the National Streamflow Network.

Congressional appropriations and agreements with approximately 1,400 nonfederal partners funded the USGS Streamgaging Network at

[1] Congress has provided the U.S. Geological Survey (USGS) with the authority and appropriations to conduct surveys of streamflow since establishing the first hydrological survey in 1889. 28 Stat. 910 funded the first irrigation survey to be conducted by the USGS.

[2] National Hydrologic Warning Council (NHWC), *Benefits of USGS Streamgaging Program*, 2006, at https://water.usgs.gov/osw/pubs/nhwc_report.pdf. Hereinafter NHWC, Benefits of USGS Streamgaging Program.

[3] The Coalition Supporting the USGS National Water Monitoring Network, for example, which represents an array of stakeholders (local agencies, river compact commissions, environmental nonprofits, professional societies, and recreational groups), frequently advocates for USGS streamgage funding.

[4] Albert Ruhi, Mathis L. Messager, and Julian D. Olden, "Tracking the Pulse of the Earth's Fresh Waters," *Nature Sustainability*, vol. 1, no. 4 (2018), p. 199. Hereinafter Ruhi, Earth's Fresh Waters.

[5] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, December

$189.5 million in FY2018.[6] Some streamgages are funded solely through congressional appropriations for the USGS and other federal agencies, such as the U.S. Army Corps of Engineers (USACE), Bureau of Reclamation (Reclamation), and Department of Defense (DOD). Much of the USGS Streamgaging Network is funded cooperatively. Interested parties sign funding agreements with the USGS to share the cost of streamgages and data collection.[7] The USGS Cooperative Matching Funds Program (CMF) provides up to a 50% match with tribal, regional, state, and local partners (see section on "Cooperative Matching Funds Program").[8] Other federal agencies, nonfederal governments, and nongovernmental entities may provide reimbursable funding for streamgages in the USGS Streamgaging Network without contributed funds from the USGS.[9]

Evolving federal policies and user needs from diverse stakeholders have shaped the size, organization, and function of the USGS streamgage program. This report provides an overview of federal streamgages by describing the function of a streamgage, the data available from streamgage measurements, and the uses of streamgage information. The report also outlines the structure and funding of the USGS Streamgaging Network and discusses potential issues for Congress, such as funding priorities and the future structure of the nation's streamgage network.

What Is a Streamgage?

A streamgage's primary purpose is to collect data on water levels and streamflow (the amount of water flowing through a river or stream over time).[10] Streamgages *estimate* streamflow based on (1) continuous measurements of stage height (the height of the water surface) and (2) periodic measurements of streamflow, or discharge, in the channel and floodplains.[11] USGS measurements are used to create rating curves, in order to convert continuously measured stage heights into estimates of streamflow.[12] Selected streamgages may provide additional measurements, such as measurements of water quality (see box on "Supergages").

Streamgages house instruments to measure, store, and transmit stream stage height (**Figure 2**).[13] Stage height is usually transmitted every hour, or more frequently at 5 to 15 minute intervals for

17, 2018.

[6] The appropriations bill for Interior, Environment, and Related Agencies funds the USGS share of the USGS Streamgaging Network under the Groundwater and Streamflow Information Program. Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, February 19, 2019.

[7] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, April 9, 2019.

[8] 43 U.S.C. §50. "The share of the United States Geological Survey in any topographic mapping or water resources data collection and investigations carried on in cooperation with any State or municipality shall not exceed 50 per centum of the cost thereof."

[9] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, November 15, 2018.

[10] This section describes the basics of streamgaging specific to the USGS operations of continuously measuring streamflow. A little over 2,000 streamgages in the USGS Streamgaging Network only record water level or operate less than year-round.

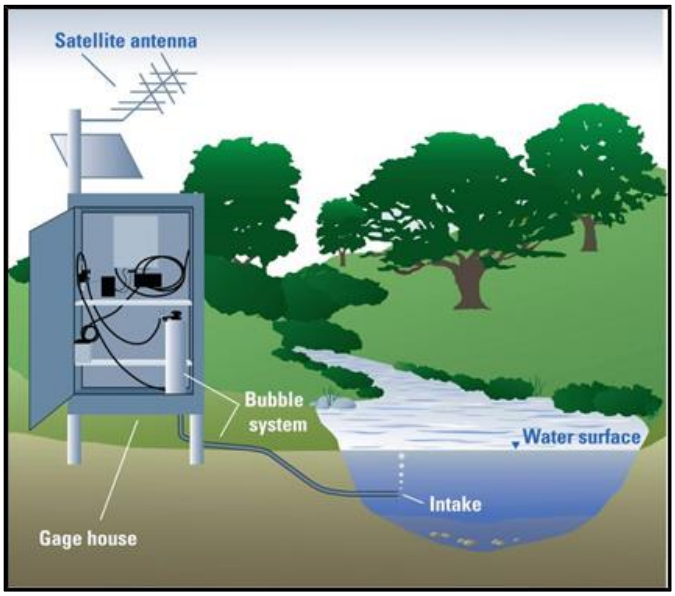
[11] Stephen Blanchard, *Recent Improvements to the U.S. Geological Survey from the National Streamflow Information Program*, USGS, FS 2007-3080, 2007, at http://pubs.usgs.gov/fs/2007/3080/index.html.

[12] Rating curves are relationships between stage height and streamflow. The USGS develops rating curves using streamflow measurements over range of stage heights.

[13] Vernon Sauer and Phil Turnipseed, *Stage Measurement at Gaging Stations*, U.S. Geological Survey Techniques and Methods Book 3, Chapter A7, 2010, at https://pubs.usgs.gov/tm/tm3-a7/.

emergency or priority streamgages.[14] Most streamgages transmit data by satellite to USGS computers; the data then are provided online to the public.[15] Numerous streamgages also have cameras that capture and transmit photos of streamflow conditions.[16]

Figure 2. Diagram of a Streamgage Measuring Stream Stage Height



Source: Dee Lurry, *How Does a U.S. Geological Survey Streamgage Work?* USGS, FS 2011-3001, 2011, at https://pubs.usgs.gov/fs/2011/3001/pdf/fs2011-3001.pdf.

Notes: This figure depicts a streamgage measuring stage height with a bubble system, but streamgages also may measure stage height using other technology.

Periodic streamflow measurements require USGS personnel to measure discharge at various sections across the stream.[17] Streamflow measurements are made every six to eight weeks to capture a range of stage heights and streamflows, especially at high and low stage heights. Repeated measurements allow scientists to capture changes to the channel from vegetation growth, sedimentation, or erosion, which can affect the relationship between stage height and streamflow.

The USGS National Water Information System (NWIS) receives and converts all stream height data from USGS streamgages into streamflow estimates.[18] An example of streamgage data from

[14] J. Michael Norris, *From the River to You: USGS Real-Time Streamflow Information*, USGS, FS 2007-3043, 2007, at https://pubs.usgs.gov/fs/2007/3043/.

[15] Streamgages are increasingly employing cellular and radio telemetry as an additional way to transmit and serve data online. Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, February 19, 2019.

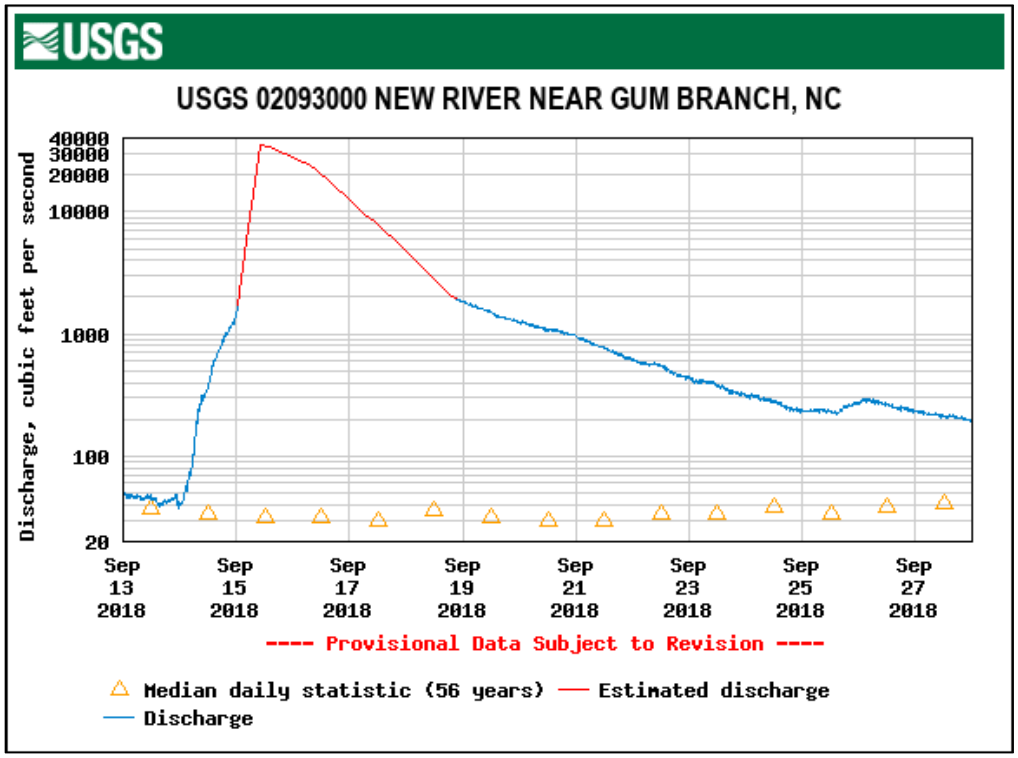
[16] An example of a streamgage camera can be accessed at https://txdata.usgs.gov/ASI/site.html?SiteNumber=08170950.

[17] Phil Turnipseed and Vernon Sauer, *Discharge Measurements at Gaging Stations*, U.S. Geological Survey Techniques and Methods Book 3, Chapter A8, 2010, at https://pubs.usgs.gov/tm/tm3-a8/.

[18] The USGS Surface-Water Data for the Nation, National Water Information System: Web Interface houses streamgage data at https://waterdata.usgs.gov/nwis. Users may select various USGS monitoring sites across the United States to access streamflow and other field measurements using USGS National Water Information System: Mapper at https://maps.waterdata.usgs.gov.

NWIS is shown in **Figure 3** for a site capturing peak streamflow during a hurricane event. The free and publicly accessible data are frequently accessed online or by request to users.[19] For example, the agency responded to over 670 million requests for streamflow and water level information in 2018.[20] The NWIS website is the main repository for current and historical streamflow data, in addition to other water information. Tools such as WaterWatch summarize the current conditions of the nation's streams and watersheds through maps, graphs, and tables by comparing real-time streamflow conditions to historic streamflow from streamgages with records of 30 years or more.[21]

Figure 3. Discharge Graph Capturing Streamflow during Hurricane Florence



Source: USGS, Water Data for North Carolina, at https://waterdata.usgs.gov/nc/nwis.

Notes: The discharge graph is derived from one of 18 streamgages recording new peak streamflows during Hurricane Florence. Because stage height measurements were record-breaking, previous rating curves could not provide accurate discharge from September 15 to September 19, 2018; thus, discharge was estimated in red.

[19] Users can send an email or text to receive instant information about a specific streamgage with USGS WaterNow (accessible at https://water.usgs.gov/waternow), or they can sign up to receive alerts about stream conditions with USGS WaterAlert (accessible at https://maps.waterdata.usgs.gov/wateralert). Other partnership applications using Geographic Information System (GIS) interfaces include StreamStats (accessible at https://streamstats.usgs.gov), and TX Water on the Go and TX Water Dashboard (accessible at https://waterdata.usgs.gov/tx/nwis/rt).

[20] USGS, Budget Justifications and Performance Information: Fiscal Year 2020, pp. 84-85, at https://edit.doi.gov/sites/doi.gov/files/uploads/fy2020_usgs_budget_justification.pdf. Hereinafter USGS, FY2020 Budget.

[21] USGS WaterWatch is accessible at https://waterwatch.usgs.gov.

Streamgage Uses

The USGS Streamgaging Network provides streamflow information to assist during natural and man-made disasters, such as flooding and drought, and to inform economic and statutory water management decisions, such as the allocation of water supplies for irrigation. Individual streamgages in the network also can serve multiple uses. For example, a streamgage intentionally established for the purpose of reservoir management may provide data to inform water quality standards, habitat assessments, and recreational activities.[22] Additionally, the value of a single streamgage is enhanced by the operation of the entire network, particularly for research, modeling, and forecasting.

Streamgages were first established in the United States to inform water use and infrastructure planning—applications that benefit from continuous, long-term hydrologic records (see box on "Evolution of Streamgage Uses").[23] Long and continuous periods of data are used to construct baselines for water conditions and to identify deviations in the amount and timing of streamflow caused by changes in land use, water use, and climate.[24] Some stakeholders contend that the value of streamflow records increases over time, with at least 20 years of continuous coverage needed for many applications.[25]

Evolution of Streamgage Uses

A decade after the establishment of the U.S. Geological Survey (USGS) in 1879, Congress directed the USGS to conduct a hydrographic survey to measure streamflow of arid basins in the West. The survey was to investigate sites for reservoirs and other hydraulic works for the dual purpose of water storage for irrigation and flood prevention. The first station was on the Rio Grande in New Mexico. Since 1895, Congress has provided annual appropriations for streamgage surveys.

By 1900, there were 163 streamgages, mostly located in the West and operated for the purposes of monitoring water use and availability for irrigation. An expansion of the streamgage program began in the 20th century. The early drivers for expansion were the need of streamgage information to enhance water withdrawal and use, navigation, hydropower production, construction of military and transportation infrastructure, and flood risk and mitigation. Toward the end of the 20th century, water quality monitoring, regulations of streamflow for wildlife and fisheries habitat, and recreational decisionmaking further underpinned the need for streamflow information.

In the 21st century, these streamgage applications remain pertinent with the addition of more novel focuses: integration of groundwater-surface water interactions; forecasting the effects of hazards, especially in areas without streamgages; and modeling human interaction and prediction of water resources with increased land use, population gains, and climate change.

Technological advances allowing access to streamflow information in real time have expanded the uses of streamgages. Real-time forecasting and operational decisionmaking are used in many

[22] NHWC, Benefits of USGS Streamgaging Program.

[23] Kenneth Wahl, Wilbert Thomas, and Robert Hirsch, *Overview of the Stream-gaging Program*, USGS, Circular 1123, Reston, VA, 1995, at https://pubs.usgs.gov/circ/circ1123/overview.html. Hereinafter Wahl, USGS Circular 1123.

[24] Eric J. Evenson et al., *Continuing Progress Toward a National Assessment of Water Availability and Use*, Department of the Interior (DOI), Circular 1440, 2018, p. 23, at https://pubs.usgs.gov/circ/1440/circ1440.pdf. Hereinafter Evenson, DOI National Water Assessment.

[25] Personal correspondence between CRS and the Interstate Council on Water Policy, November 16, 2018. John Schaake, Qingyun Duan, and Michael Smith, et al., "Criteria to Select Basins for Hydologic Model Development and Testing," 15th Conference on Hydrology, American Meteorological Society, Long Beach, CA, 2000, at https://www.nws.noaa.gov/oh/hrl/papers/ams/ams_2000_1.8.pdf.

applications of streamflow data.[26] Web and phone applications also have facilitated increased public use of water information.[27]

Examples of Streamgage Uses

Streamgage data is used for a wide range of applications, including supporting activities of federal agencies. There are also a variety of streamgages tailored for specific purposes. The following is a noncomprehensive selection of streamgage uses to illustrate the scope of applications.

Water Management and Energy Development. USACE, Reclamation, and various state and local water management agencies use streamgages to inform the design and operation of thousands of water management projects across the nation.[28] Timely streamflow information helps water managers make daily operational decisions as they balance water requirements for municipal, industrial, and agricultural uses. Energy production and mineral extraction operations also rely on continuous streamflow measurements to comply with environmental, water quality, or temperature requirements.[29] For example, the Federal Energy Regulatory Commission (FERC) requires hydropower companies to support USGS streamflow and water-level monitoring as part of their FERC licensing process.[30]

Infrastructure Design. Transportation agencies use streamflow data to develop regional flow frequency curves for the design of bridges and culverts, stream stability measures, and analysis of bridge scour—the leading cause of bridge failure.[31] Without adequate information, some observers contend that engineers may overdesign structures, resulting in greater costs, or may not make proper allowances for floods, compromising public safety.[32]

Interstate and International Water Rights. Federal streamgages are used to collect streamflow information at U.S. borders and between states.[33] Streamgage data informs interstate compacts, Supreme Court decrees, and international treaties (e.g., under the purview of the International Boundary and Water Commission and the International Joint Commission).

Water Science Research. Many federal agencies depend on consistent, long-term data from streamgages to conduct water research and modeling (e.g., USACE, National Oceanic and Atmospheric Administration [NOAA], Environmental Protection Agency [EPA], DOI, U.S. Department of Agriculture [USDA], and National Aeronautic and Space Administration [NASA]).[34] To monitor climate trends and ecological patterns, the USGS distinguishes a subset of

[26] NHWC, Benefits of USGS Streamgaging Program.

[27] USGS, *Budget Justifications and Performance Information, Fiscal Year 2017*, J - Water Resources, at https://edit.doi.gov/sites/doi.gov/files/uploads/FY2017_USGS_Budget_Justification.pdf. Hereinafter USGS, FY2017 Budget.

[28] NHWC, Benefits of USGS Streamgaging Program.

[29] Wahl, USGS Circular 1123.

[30] The Federal Energy Regulatory Commission (FERC) licenses the construction and operation of nonfederal hydropower project pursuant to the Federal Power Act of 1935, 16 U.S.C. §797(a)(c).

[31] Bridge scour is the removal of sediment from the base of bridge structures. NHWC, Benefits of USGS Streamgaging Program, p. 8.

[32] NHWC, Benefits of USGS Streamgaging Program, p. 8.

[33] NHWC, Benefits of USGS Streamgaging Program, p. 12.

[34] Advances in satellite observations also depend on streamgages to calibrate stream discharge models. National Academies of Sciences, Engineering, and Medicine (NASEM), *Future Water Priorities for the Nation: Directions for the U.S. Geological Survey Water Mission Area*, Washington, DC, 2018, pp. 8 and 66, at https://doi.org/10.17226/

streamgages that are largely unaffected by development to serve as benchmarks for natural conditions.[35]

National Water Model

The National Oceanic and Atmospheric Administration's National Weather Service, in partnership with other agencies, launched the National Water Model in 2016. The National Water Model forecasts streamflow over the continental United States in near real time. The model assimilates real-time observations from over 7,000 USGS streamgages in addition to inputs of precipitation and land-surface properties. The model provides streamflow forecasts with 18-hour, 10-day, and 30-day lead times at 2.7 million streams and rivers across the nation. In addition to high flows and flooding, the model also captures low flows and drought conditions. Future iterations of the model could improve forecasts for stream reaches influenced by tides and reservoir operations.[36] The National Water Model builds off of the U.S. Geological Survey (USGS) National Hydrologic Model, which couples precipitation, surface water, and groundwater interactions.[37]

Source: National Oceanic and Atmospheric Administration (NOAA), *National Water Model: Improving NOAA's Water Prediction Services*, 2016, at http://water.noaa.gov/documents/wrn-national-water-model.pdf.

Flood Mapping. The Federal Emergency Management Agency (FEMA) uses floodplain maps to establish flood risk zones and requires flood insurance through the National Flood Insurance Program (NFIP) for properties with a 1% annual chance of flooding.[38] Long-term streamflow records are used to determine 1% annual chance flood flows and to develop water surface profiles to map areas at risk of flooding. The USGS often works with FEMA to produce new inundation maps after streamgages record new streamflow peaks from weather events such as hurricanes.[39]

Emergency Forecasting and Response. Streamgages inform flood forecasting and emergency response to protect lives and property.[40] Real-time data from more than 3,600 streamgages allow NOAA's National Weather Service (NWS) river forecasters to model watershed response, project future streamflows, forecast monthly to seasonal water availability, and issue appropriate flood watches and warnings (see box on "National Water Model").[41] Flood warnings provide lead time for emergency response agencies, such as FEMA, to take effective action in advance of rising waters.[42] In addition, the USDA National Resource Conservation Service (NRCS) uses

25134. Hereinafter NASEM, Future Water Priorities for the Nation.

[35] These are referred to as *sentinel basins*, according to the National Research Council (NRC), *Assessing the National Streamflow Information Program*, pp. 57-59, at https://doi.org/10.17226/10967. Hereinafter NRC, Assessing the NSIP.

[36] Brian Cosgrove et al., "NOAA's National Water Model: An Update on Model Activities and Related Initiatives," American Geophysical Union, Washington, DC, 2018.

[37] NASEM, Future Water Priorities for the Nation, pp. 62-64.

[38] 41 U.S.C. §§4011 et seq. See CRS Report R44593, *Introduction to the National Flood Insurance Program (NFIP)*, by Diane P. Horn and Baird Webel. Because the 1% annual exceedance probability flood has a 1 in 100 chance of being equaled or exceeded in any one year and an average recurrence interval of 100 years, it often is referred to as the *100-year flood*. Robert R. Holmes, "The 100-Year Flood - It's All About Chance," USGS, at https://water.usgs.gov/edu/100yearflood-basic.html.

[39] Kara Watson et al., Characterization of Peak Streamflows and Flood Inundation of Selected Areas in Southeastern Texas and Southwestern Louisiana from the August and September 2017 Flood Resulting from Hurricane Harvey, USGS, Scientific Investigations Report 2018–5070, 2018, at https://doi.org/10.3133/sir20185070.

[40] William J. Carswell and Vicki Lukas, *The 3D Elevation Program – Flood Risk Management*, USGS, FS 2017-3081, 2018, at https://doi.org/10.3133/fs20173081.

[41] The Secretary of Commerce is charged with flood warning and reporting on river conditions pursuant to the National Weather Service Modernization Act of 1890, 15 U.S.C. §313 et seq.

[42] National Hydrologic Warning Council, *Flood Management Benefits of USGS Streamgaging Program*, 2006, pp. 25-33, at https://water.usgs.gov/osw/pubs/Flood_Management_benefits_complete.pdf.

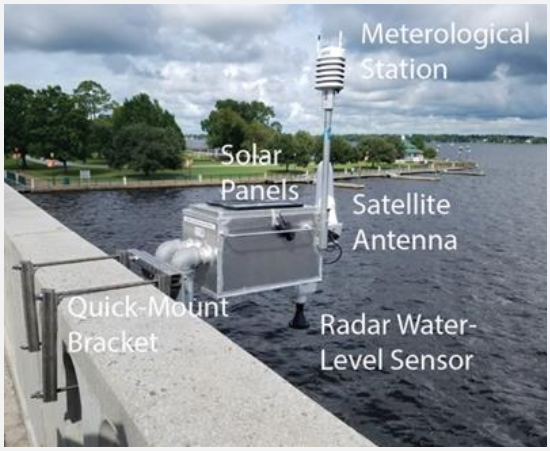
streamgages to forecast flows for water supply, drought management and response, hydroelectric production, irrigation, and navigation in western states.[43]

Rapid Deployment Gages

Rapid deployment gages (RDGs) are temporarily fixed on structures above streams and rivers (such as bridges) in emergencies to add stage height data when a streamgage does not exist or is damaged. Water-stage height and meteorological conditions are transmitted every six minutes. The U.S. Geological Survey (USGS) Flood Event Viewer provides a website where streamgage and RDG data can be seen in real time for large flood events. In 2018, the USGS had 132 RDGs and deployed 33 during Hurricane Florence.

Source: USGS, *Rapid Deployment Gages*, at https://water.usgs.gov/floods/resources/rdg, and *Flood Event Viewer*, at https://stn.wim.usgs.gov/FEV.

Notes: This fixed design can also be used for permanent streamgages.



Water Quality. Streamflow data is important for measuring water quality and developing water quality standards for sediments, pathogens, metals, nutrients (e.g., nitrogen and phosphorus), and organic compounds (e.g., pesticides). At select streamgages, the USGS also operates instruments recording water quality data (see box on "Supergages"). Section 303(d) of the Clean Water Act requires states to develop total maximum daily load (TMDL) management plans for water bodies determined to be water quality impaired by one or more pollutants.[44] When determining TMDL levels for specific pollutants, agencies may consider historic streamflow data, along with other factors, in their evaluations. Agencies may use current flow conditions when determining the proper release of wastewater to ensure compliance with TMDL standards and National Discharge Elimination System permitting.[45]

Supergages

Supergages are a small subset of streamgages (just over 420) that collect data in addition to streamflow by using water quality monitoring equipment. Supergages monitor continuous streamflow in addition to either (1) a combination of physical parameters, such as temperature, conductance, pH, dissolved oxygen, turbidity, or dissolved organic matter, or (2) one or more measurements of nitrate, phosphorus, suspended sediment, chlorophyll, or cyanobacteria data. The information from supergages is used for decisionmaking regarding drinking water, water treatment, regulatory programs, recreation, public safety, and ecosystem health.

Ecosystem Management and Species. Some water users and resource agencies use streamflow data to meet the flow requirements needed to protect endangered or threatened fish and wildlife under the Endangered Species Act (16 U.S.C. §1531 et seq.). Natural resource agencies, such as the U.S. Fish and Wildlife Service (FWS), collect streamflow data to understand how threatened and endangered species respond to flow variations.[46] The USGS operates streamgages to monitor ecosystem restoration progress, such as restoration of the Chesapeake Bay watershed.[47]

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[43] NRC, Assessing the NSIP, pp. 4 and 55.

[44] A TMDL is both a quantitative assessment of pollution sources and pollutant reductions needed to restore and protect U.S. waters and a planning process for attaining water quality standards.

[45] NHWC, Benefits of USGS Streamgaging Program, p. 11.

[46] NHWC, Benefits of USGS Streamgaging Program, p. 10.

[47] Scott Phillips et al., *U.S. Geological Survey Chesapeake Science Strategy, 2015-2025—Informing Ecosystem*

Next Generation Water Observing System (NextGen)

The U.S. Geological Survey (USGS) has initiated a Next Generation Integrated Water Observing System (NextGen) "to provide high-fidelity, real-time data on water quantity and quality necessary to support modern water prediction and decision support systems for water emergencies and daily water operations." The USGS plans to develop dense networks of streamgages in medium-sized watersheds (each approximately 15,000 square miles) representative of larger water-resource regions. The USGS would also make modest enhancements to the existing streamgage network. Fully implemented, the NextGen system would provide quantitative information on streamflow, snowpack, loss of water to the atmosphere, soil moisture, water quality, groundwater, and water usage. The USGS contends that a suite of highly monitored watersheds, in combination with an enhanced streamgage network and other relevant data sets, can better inform advanced models (e.g., the National Water Model) and water information and forecasts. In an effort to assess this approach, the USGS started a multiyear NextGen system pilot project in the Delaware River Basin in FY2018. The USGS plans to install 17 new streamgages and modernize 28 streamgages in the basin; the streamgages will be equipped with two-way communication for remote operation and troubleshooting, cell and satellite transmission redundancy, real-time water temperature monitoring, and webcams and water quality sensors at select sites. The USGS anticipates expanding the concept to approximately a dozen representative basins.

Source: USGS, *Next Generation Water Observing System: Delaware River Basin*, 2018, at https://www.usgs.gov/mission-areas/water-resources/science/next-generation-water-observing-system-delaware-river-basin.

Recreation. Real-time streamgage data can help individuals and tourism businesses assess stream conditions for recreational outings.[48] USGS data can be used to decide if conditions are suitable for recreational activities such as fishing, boating, and rafting. The USGS also partners with the National Park Service (NPS) to provide water science and data to help manage parks and to enhance interpretive programs.

Network Structure

The USGS Streamgaging Network is part of the Groundwater and Streamflow Information Program under the USGS Water Resources mission area.[49] The President's budget request for FY2020 proposes a restructuring of the mission area to create a Water Observing Systems Program that would combine the USGS Streamgaging Network and other water observation programs.[50] The primary operators of streamgages are the regional and state USGS Water Science Centers, which maintain hydrologic data collection and conduct water research in the region.[51]

Approximately 8,200 of the 10,300 USGS streamgages measure year-round streamflow (National Streamflow Network; see **Figure 4**), with the rest only measuring stage height or measuring streamflow on a seasonal basis. USGS streamgages are also differentiated based on cooperative funding (CMF) and federal interest (FPSs).

Management of America's Largest Estuary, USGS, Open-File Report 2015–1162, 2015, at https://doi.org/10.3133/ofr20151162.

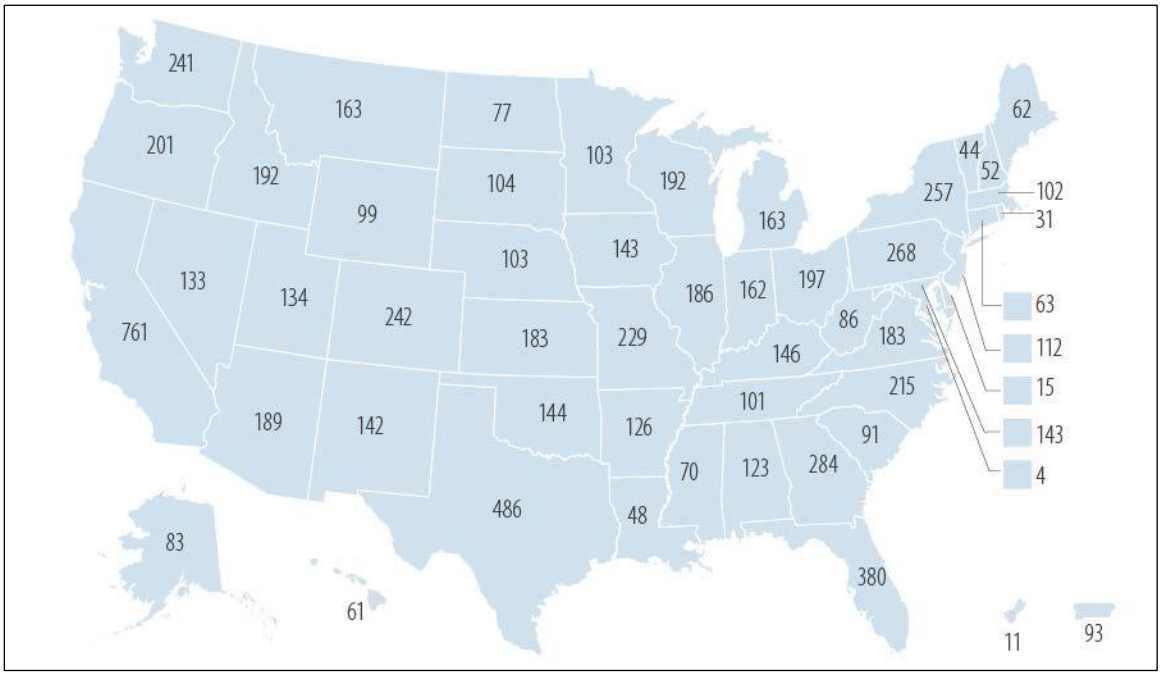
[48] NHWC, Benefits of USGS Streamgaging Program, p. 14.

[49] USGS, *Budget Justifications and Performance Information: Fiscal Year 2019*, pp. 79-93, at https://edit.doi.gov/sites/doi.gov/files/uploads/fy2019_usgs_budget_justification.pdf.

[50] The budget justification states that the restructuring of the Water Resource Mission Area would align program operations. In particular, the proposed Water Observing Systems Program would house all water observational networks—both water quantity and quality. USGS, FY2020 Budget, pp. 14-15.

[51] A list of USGS Water Science Centers can be found at https://www.usgs.gov/science/mission-areas/water/centers.

Figure 4. Number of National Streamflow Network Streamgages in U.S. States and Territories in 2018



Source: CRS with data from USGS Groundwater and Streamflow Information Program.

Notes: Streamgages in the National Streamflow Network measure streamflow year round. Streamgages that measure stage height only or operate seasonally are not included in this figure.

Cooperative Matching Funds Program

Much of the streamgaging program has been cooperative in nature as interested parties sign funding agreements to share the cost of streamgages and data collection.[52] Through CMF, the USGS funds up to a 50% match with tribal, regional, state, and local partners.[53] In 2018, CMF supported 5,345 streamgages (52% of the USGS Streamgaging Network).

The first cooperative agreement began in 1895 with the Kansas Board of Irrigation Survey and Experiment (now known as the Division of Water Resources of the Kansas Department of Agriculture).[54] Funds from cooperative entities steadily increased in the early 20th century.[55] Congress passed legislation in 1928 stipulating that the USGS can share up to 50% of the costs for water resources investigations carried out in cooperation with tribes, states, and municipalities (see **Figure 5**).[56] In 2016, this Federal-State Cooperative Water Program was renamed the

[52] U.S. Government Accountability Office, *Environmental Information, Status of Federal Data Programs that Support Ecological Indicators*, 05-376, 2005, pp. 164-174, https://www.gao.gov/new.items/d05376.pdf. Hereinafter GAO, Federal Data Programs.

[53] 43 U.S.C. §50. "The share of the United States Geological Survey in any topographic mapping or water resources data collection and investigations carried on in cooperation with any State or municipality shall not exceed 50 per centum of the cost thereof."

[54] Wahl, USGS Circular 1123.

[55] Mary Rabbitt, *A Brief History of the U.S. Geological Survey*, USGS, DOI 10.3133/70039204, Washington, DC, 1975.

[56] P.L. 70-100.

Cooperative Matching Funds Program (CMF), which provides cooperative funding for programs across the USGS Water Mission Area.[57]

To participate in the CMF, potential partners approach the USGS to discuss the need for a specific streamgage. The USGS determines its feasibility based on available funds and program priorities. If the USGS deems establishing the streamgage is feasible, the USGS and cooperator sign a joint funding agreement (JFA), which is a standard agreement that specifies how much each party will contribute to funding the streamgage and the payment schedule for the cooperator.[58] These agreements span five years or less. During the agreement, the cost-share generally remains the same, but there is flexibility to alter the cost-share on an annual basis for multi-year agreements. Once a streamgage is operating, if a partner can no longer contribute funds, the USGS seeks to work with other partners that use the streamgage to augment funding. The USGS provides a website identifying streamgages that are in danger of being discontinued or converted to a reduced level of service due to lack of funding.[59] The website also identifies streamgages that have been discontinued or are being supported by a new funding source.

Approximately 3,700 of the 10,300 USGS streamgages (36%) are funded by nonfederal and federal partners without matching funds from the USGS (i.e., not with CMF). Nonfederal partners sign JFAs, and federal partners share interagency agreements with the USGS (except USACE which uses a military interdepartmental purchase request).[60] These gages are part of the USGS Streamgaging Network and are operated in accordance with the quality control and public access standards created by the USGS, with the agency assuming liability responsibility for the streamgages.

Public and private entities may also elect to own and operate streamgages tailored to their specific needs and not affiliated with the USGS. These independent streamgages may differ in various ways compared to streamgages in the USGS Streamgaging Network (e.g., capital and operating costs, operating periods, measurement capabilities, and data standards and platforms).[61]

[57] USGS, *Budget Justifications and Performance Information, Fiscal Year 2016*, J - Water Resources, https://www.doi.gov/sites/doi.gov/files/migrated/budget/appropriations/2016/upload/FY2016_USGS_Greenbook.pdf. Hereinafter USGS, FY2016 Budget.

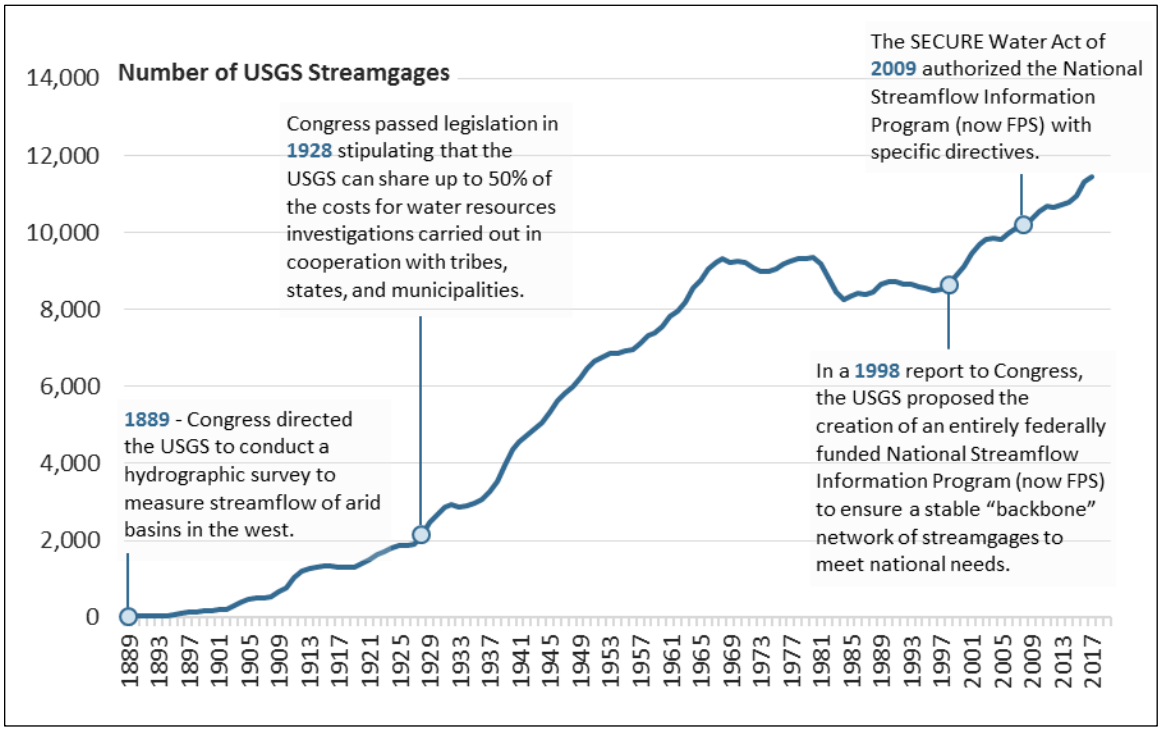
[58] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, April 9, 2019.

[59] Discontinued, threatened, or revived streamgages can be explored through an interactive map at https://water.usgs.gov/networks/fundingstability.

[60] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, April 9, 2019.

[61] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, December 17, 2018.

Figure 5. Number of USGS Streamgages and Policy Changes over Time



Source: CRS, with data from USGS Groundwater and Streamflow Information Program.

Notes: This historic length-of-record dataset considered any USGS streamgage to be active in a given year if it computed at least one daily value in that year. This dataset also includes streamgages in all surface-water bodies, not just streams and lakes (i.e., wetlands, estuaries, drainage ditches, etc.). Therefore, the total streamgages in this dataset include more than those in the USGS Streamgaging Network.

Federal Priority Streamgages

The SECURE Water Act of 2009 (Title IX, Subtitle F of P.L. 111-11) directs the USGS to operate a reliable set of federally funded streamgages. The law requires the USGS to fund no fewer than 4,700 sites complete with flood-hardened infrastructure, water quality sensors, and modernized telemetry by FY2019. Originally titled the National Streamflow Information Program (NSIP), the USGS now designates these streamgages as FPSs.[62] Out of the 4,760 FPS locations identified by the USGS, 3,640 sites were operational in 2018.[63] In FY2018, the USGS share of funding was $24.7 million for FPSs.

The idea of a federally sustained set of streamgages arose in the late 20th century when audits revealed the number of streamgages declining after peaking in the 1970s (see decrease in **Figure 5**).[64] In a 1998 report to Congress, the USGS stated that the streamgage program was in decline

[62] USGS, FY2016 Budget.

[63] When the USGS proposed FPS locations in the early 2000s, many sites were already operational. NRC, Assessing the NSIP, p. 1. Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, February 19, 2019.

[64] For example, see Wahl, USGS Circular 1123. In 1998, the House Committee on Appropriations stated in report language accompanying H.R. 4193 from the 105th Congress: "the Committee has noted the steady decline in the number of streamgaging stations in the past decade, while the need for streamflow data for flood forecasting and long-term water management uses continues to grow."

because of an absolute loss of streamgages, especially those with a long record, and asserted that the loss was due to partners discontinuing funding. Partners also had developed different needs for streamflow information.[65] The USGS proposed the creation of an entirely federally funded NSIP to ensure a stable "backbone" network of streamgages to meet national needs.[66] The USGS used five national needs to determine the number and location of these streamgage sites:[67]

1. Meeting legal and treaty obligations on interstate and international waters.
2. Forecasting flow for NWS and NRCS.
3. Measuring river basin outflows to calculate regional water balances.
4. Monitoring benchmark watersheds for long-term trends in natural flows.
5. Measuring flow for water quality needs.

The original design included 4,300 active, previously discontinued, or proposed streamgage locations.[68] The proposed program was to be fully federally funded, conduct intense data collection during floods and droughts, provide regional and national assessments of streamflow characteristics, enhance information delivery, and conduct methods development and research.[69]

The SECURE Water Act of 2009 authorized the NSIP to conform to the USGS plan as reviewed by the National Research Council.[70] The law required the program to fund no fewer than 4,700 sites by FY2019. The law also directed the program to determine the relationship between long-term streamflow dynamics and climate change, to incorporate principals of adaptive management to assess program objectives, and to integrate data collection activities of other federal agencies (i.e., NOAA's National Drought Information System) and appropriate state water resource agencies.

Network Funding

In FY2018, congressional appropriations and nonfederal partners provided $189.5 million for the USGS Streamgaging Network (**Figure 6**).[71] The USGS share included $24.7 million for FPSs and $29.8 million for CMF. Other federal agencies provided $40.7 million (**Table 1**). Nonfederal partners, mostly affiliated with the CMF program, provided $94.3 million.

[65] USGS, *A New Evaluation of the USGS Streamgaging Network: A Report to Congress*, 1998, at https://water.usgs.gov/streamgaging/report.pdf.

[66] USGS, Streamflow Information for the Next Century - A Plan for the National Streamflow Information Program of the U.S. Geological Survey, 1999, OFR 99-456, at https://pubs.usgs.gov/of/1999/ofr99456/.

[67] Federal Priority Streamgages designated by specific national priorities may be visualized with an interactive map at https://water.usgs.gov/nsip/fps.

[68] The number of FPS locations changes over time based on network analyses. In 2018, 4,760 locations met the criteria FPS designation. Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, April 9, 2019.

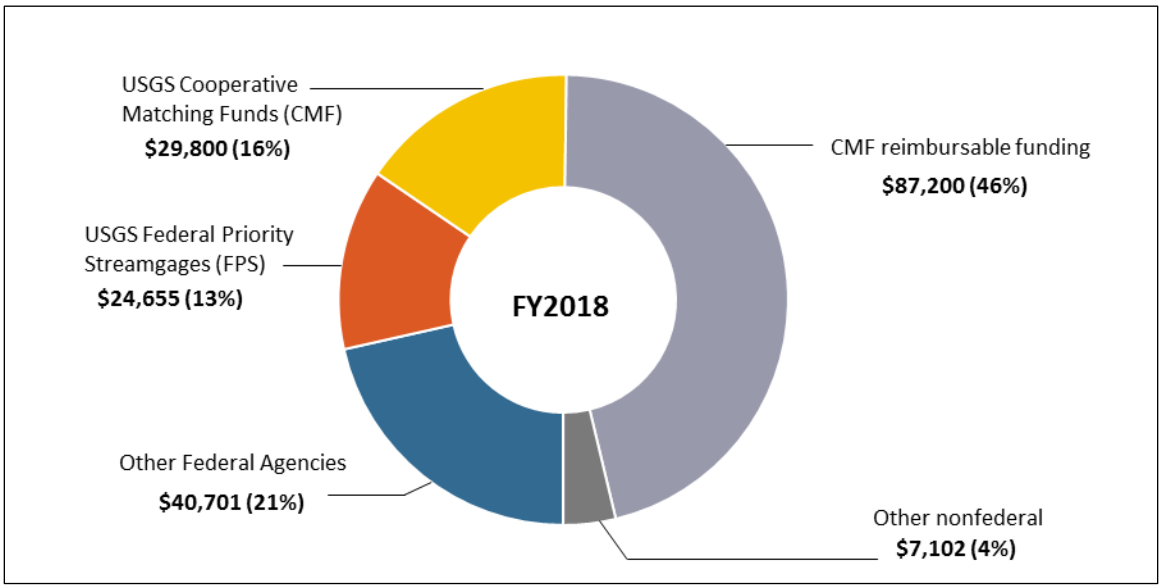
[69] NRC, Assessing the NSIP, p. 2.

[70] Omnibus Public Land Management Act of 2009 (Title IX, Subtitle F of P.L. 111-11). NRC, Assessing the NSIP.

[71] Total funding for the USGS Streamgaging Network is determined at the end of the fiscal year after accounting for contributions from cooperative partners. Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, February 19, 2019.

Figure 6. FY2018 Funding for the USGS Streamgaging Network

(in thousands of dollars)



Source: CRS, with data from USGS Groundwater and Streamflow Information Program.

Notes: Other nonfederal funding includes commercial businesses, nonprofit organizations, or power companies requiring streamflow data as part of their FERC licensing process.

The appropriations bill for the Interior, Environment, and Related Agencies funds the USGS share of the USGS Streamgaging Network. Funding for streamgages is included in the Groundwater and Streamflow Information Program under the USGS Water Resources Mission Area. The line item includes funding for the streamgage network and groundwater monitoring activities, as well as other activities. Congress provided $74.2 million in FY2018 and $82.7 million in FY2019 for the Groundwater and Streamflow Information Program. While maintaining level funding for FPS and CMF streamgages in FY2019, Congress directed increased funding of $8.5 million for the deployment and operation of NextGen water observing equipment.[72]

Approximate Cost of USGS Streamgages

Capitol cost for equipment and installation:

- $25,000 - $40,000 for a standard streamgage depending on the site conditions.
- $35,000 - $110,000 for a supergage depending on sensors and the site conditions.
- $15,000 for RDGs.

Annual costs for operation and maintenance:

- $16,500 - $30,000 for continuous streamflow measurements with a standard streamgage depending on site conditions. Costs decrease by half if measuring stream stage height only and proportionally if measuring seasonally.
- $25,100 and $134,000 for supergages depending on site conditions and the type and number of sensors.
- $3,500 per event for RDGs.

The President's budget request for FY2020 proposes creating a new Water Observing Systems Program combining the Groundwater and Streamflow Information Program and elements of the National Water Quality program focused on observations of surface water and groundwater.[73] The

[72] Division E of H.Rept. 116-9 accompanying P.L. 116-6.

[73] USGS, FY2020 Budget, pp. 14-15.

President's FY2020 budget requests $105.1 million for the proposed program, a decrease of $7.5 million compared to $112.5 million of FY2018 funding for a similar structure.[74] The budget request would maintain funding for active FPS locations and provide no funding for the NextGen system. For CMF, the request proposes a decrease of $500,000 for Tribal Water, which would result in a loss of $250,000 for CMF streamgages, and a decrease of $717,000 for Urban Waters Federal Partnership, which would reduce water quality monitoring at select streamgages.[75]

Other federal agencies contribute to whole or partial funding of streamgages for agency purposes (**Table 1**). Since FY2012, funding from other federal agencies has doubled from $19.9 million to $40.7 million in nominal dollars. This increase may be due to meeting inflation and other streamgage cost increases; to new needs for monitoring data with existing cooperators (e.g., USACE in the Savannah and Jacksonville Harbor expansion projects); and to the introduction of additional funding partners (e.g., the EPA) that are supporting new streamgages.[76]

Table 1. FY2018 Funding and Streamgages Supported by Other Federal Agencies

Agency	Funding	Streamgages
USACE	$28,209,955	1,950
Reclamation	$5,335,145	335
DOD (not civil)	$1,315,357	83
EPA	$1,198,073	97
Department of State	$1,093,164	61
Bureau of Land Management	$944,112	55
NPS	$647,864	45
FWS	$408,161	20
DOE	$473,240	27
Tennessee Valley Authority	$446,942	35
USDA	$462,235	34
Bureau of Indian Affairs	$123,811	10

Source: CRS, with data from USGS Groundwater and Streamflow Information Program.

Notes: Department of State funding included 60 streamgages for the International Joint Commission (Canadian border) and one streamgage for the International Boundary and Water Commission (Mexican border). USDA funding included streamgages from NRCS and the Forest Survey.

Nonfederal partners funded approximately half the costs of the USGS Streamgaging Network from FY2012 to FY2018.[77] Cooperative partners include tribal, regional, state, and local agencies related to natural resources, water management, environmental quality, transportation, and regional and city planning. Irrigation districts, riverkeeper partnerships, and utility agencies and

[74] USGS, FY2020 Budget, pp. 82-83.

[75] Email correspondence with Office of Congressional Affairs, USGS, March 22, 2019.

[76] The Environmental Protection Agency (EPA) is supporting ecosystem restoration initiatives in the Great Lakes, Chesapeake Bay, and the Sacramento and San Joaquin Rivers Delta (Bay-Delta) in California. Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, February 19, 2019.

[77] Nonfederal partners have provided 50%-57% of funding for the USGS Streamgaging Network over the period of FY2012 to FY2018. Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, February 19, 2019.

companies also fund the program. Contributions by nongovernmental partners to streamgages are very limited (1% in FY2018) and are not eligible for cost-sharing through the USGS CMF program.[78]

USGS Funding Trends

From FY2003 to FY2019, USGS funding for FPS streamgages increased from $11.7 million to $24.7 million (in 2018 dollars; **Figure 7**).[79] However, USGS funding has not met the SECURE Water Act of 2009 mandate for an entirely federally funded suite of not fewer than 4,700 streamgage sites. In FY2018, 35% of FPSs were funded solely by the USGS FPS program funds.[80] The USGS must rely on other federal agencies or nonfederal partners to fund the rest of the FPSs: 27% were funded by a combination of USGS CMF and partner funds, 24% were funded by a combination of other federal agencies and nonfederal partners, and 14% were funded solely by other federal agencies (not the USGS).

USGS funding for CMF has remained relatively level, ranging from $27.5 million to $30.7 million (in 2018 dollars) over 15 years, aside from a drop in FY2007 (**Figure 7**).[81] For the entire USGS Streamgaging Network, the nonfederal cost-share contribution has increased from near 50% in the early 1990s to an average of about 63% in FY2018.[82] With CMF appropriations remaining level, and demand for streamgages from stakeholders rising, the USGS cost-share available has declined. Cost-share commitments for long-term streamgages are generally renewed at consistent percentages, but JFAs for newer streamgages may include less contribution from the USGS.[83] Increasingly, the USGS may opt to only provide matching funds for installation and operation in the first year, with the agreement that the partner provides full funding in subsequent years.[84]

[78] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, February 19, 2019.

[79] Ibid.

[80] Ibid.

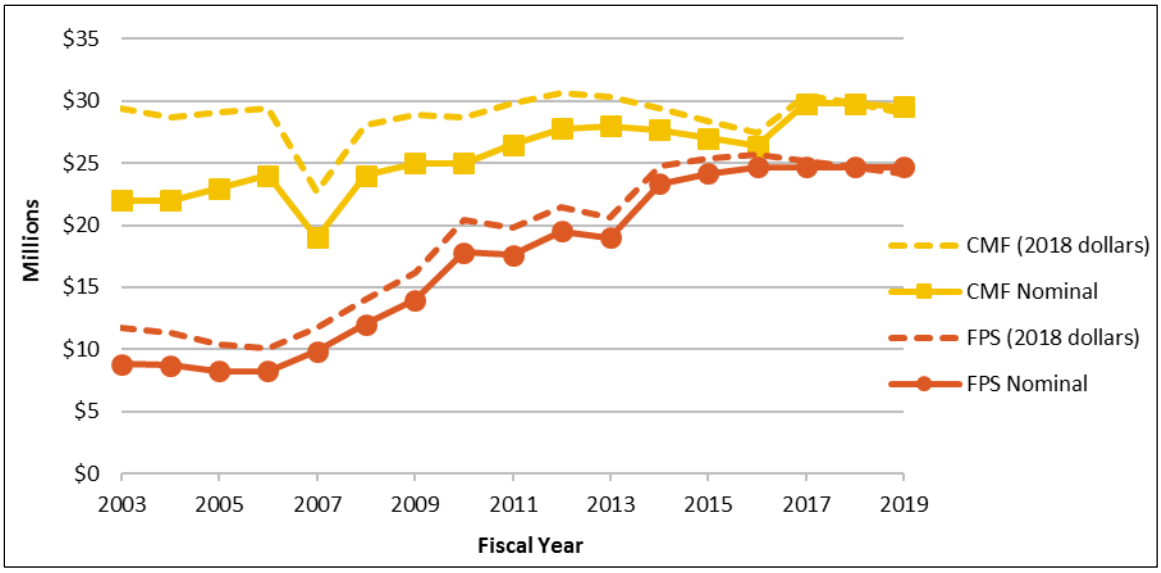
[81] Ibid.

[82] Ibid.

[83] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, December 17, 2018.

[84] Ibid.

Figure 7. USGS Funding for the Streamgaging Network



Source: CRS with data from USGS Groundwater and Streamflow Information Program.

Notes: Adjusted for inflation using the Office of Management and Budget (OMB) Gross Domestic Product (GDP) Chained Price Index (CPI) deflators for FY2018 dollars, presented in the OMB *FY2020 Budget of the United States Government*, Historical Tables, Table 10.1.

Issues for Congress

Congress may consider funding levels and policy priorities for the USGS Streamgaging Network. Congressional appropriations may affect the size of the network and the design of streamgages. Congress may provide direction regarding the policy priorities when considering the mandates of the SECURE Water Act of 2009 and initiating the NextGen system.

Funding Considerations

Congress determines the amount of federal funding for the USGS Streamgaging Network and may direct its allocation to FPS, CMF, and other initiatives. The USGS and numerous stakeholders have raised funding considerations including user needs, priorities of partners, federal coverage, infrastructure repair, disaster response, inflation, and technological advances.[85] Congress may consider whether to maintain, decrease, or expand the network, and whether to invest in streamgage restoration and modernization.

Addressing the Size of the Network

The USGS uses appropriated funding to develop and maintain the USGS Streamgaging Network. While some stakeholders advocate for maintaining or expanding the network, others may argue that Congress should consider reducing the network in order to prioritize other activities.

[85] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, November 15, 2018. NASEM, Future Water Priorities for the Nation, Questionnaire for USGS Water Science Centers; and Coalition Supporting the USGS National Water Monitoring Network.

Maintaining the Network

Congress may provide funding to maintain existing streamgages. The Administration continues to request funding for the Groundwater and Streamflow Information Program, which funds the USGS Streamgaging Network. The FY2020 budget request states that "one of the highest goals of the USGS is to maintain long-term stability of a 'Federal needs backbone network' for long-term tracking and forecasting/modeling of streamflow conditions."[86] Some stakeholders may advocate to maintain the current network as it provides hydrologic information for diverse applications (see section on "Streamgage Uses").[87] The FY2020 budget requests FPS funding at FY2019 enacted levels. If inflation increases costs, level funding may not fully maintain the current operations of FPSs. In addition, 71% of the network, including some FPSs, are funded by other federal and nonfederal partners, which makes those streamgages potentially vulnerable for discontinuation. According to the Government Accountability Office, maintaining streamgages through partners can be a challenge due to both the changing priorities and financial limitations of the partners.[88]

Reducing the Network Size

Congress may consider reducing the network, either for FPSs, cooperative streamgages, or both. The USGS has discontinued some streamgages because of other funding priorities or because cooperators decided to no longer fund them and alternative funding was not available for the operating costs. Closures may affect individual streamgages or a collection of streamgages.[89] The Administration requested reductions for the Groundwater and Streamflow Information Program in FY2018, FY2019, and FY2020 compared to previous congressional appropriations.[90] For FY2018, the Administration requested a decrease of $742,000 for the Groundwater and Streamflow Information Program, which the budget justification said would diminish the USGS's ability to execute its core activities including strengthening the national streamgaging and groundwater monitoring networks. For FY2019, the proposed reduction included a decrease of $160,000 for U.S.-Canada Transboundary Streamgages. The FY2019 and FY2020 requests proposed a decrease for Tribal Water CMF, which would result in a loss of CMF funding for select streamgages. Congress did not make these cuts in FY2018 and FY2019, and is considering appropriations for FY2020.

Reducing the USGS Streamgaging Network could alleviate federal spending on streamgages and allow other entities to operate streamgages tailored to their needs. On the other hand, discontinuing currently operational streamgages may result loss of data acquisition,

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[86] USGS, FY2020 Budget, p. 84.

[87] NHWC, Benefits of USGS Streamgaging Program.

[88] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, November 15, 2018; NASEM, Future Water Priorities for the Nation, Questionnaire for USGS Water Science Centers; and GAO, Federal Data Programs, pp. 164-174.

[89] For example, in 2017 the Missouri Department of Natural Resources decided to eliminate funding for 49 streamgages cooperatively operated with the USGS. The USGS continued six of these streamgages with new cooperators. After record-breaking floods across the southern half of Missouri, the state decided to continue the funding. Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, March 5, 2019; Will Schmitt, "Officials agree to fund most of Missouri's threatened stream gauges," *Springfield News-Leader*, June 13, 2017, at https://www.news-leader.com/story/news/politics/2017/06/13/officials-agree-fund-most-missouris-threatened-stream-gauges/387602001/.

[90] USGS budget request information is available at https://www.usgs.gov/about/organization/science-support/budget/budget-fiscal-year.

discontinuation of long-term datasets, and decreased coverage in some basins. Some stakeholders have proposed that entities with specific needs build and operate their own streamgages separate from the USGS network.[91] Some states, such as California and Oregon, already operate their own streamgaging networks.[92] This approach may contain some challenges (e.g., the data may be of higher or lower quality, the data be restricted for public use, or the host may use different standards). However, if individual streamgages were operated at the same level of quality as USGS streamgages, the USGS could incorporate such data into the NWIS network.[93] Some also argue that disparate data sets could be available on a shared platform with USGS streamgages; such a platform could include information on methods of collection, quality, and accuracy.[94]

Network Expansion

Congress may increase funding to expand the network, which could include establishing the remaining locations for FPS, providing more funds for cooperative streamgages, or pursuing new initiatives like the NextGen system.

Congress mandated completion of a national network of no less than 4,700 streamgages in the SECURE Water Act of 2009. At the close of FY2018, 3,640 of the 4,760 FPSs designated by the USGS were operational, with 52% of their funding coming from the USGS.[95] The USGS estimates that $125 million in additional funding each year would be needed to complete the network; however, an average of only about $25 million (in 2018 dollars) was appropriated annually for FPSs between FY2014 and FY2019.[96] While some stakeholders have advocated for Congress to provide full appropriations for FPSs to meet the mandate based on network needs,[97] Congress may consider other funding priorities (e.g., the NextGen system). Congress may also consider if other federal agencies and nonfederal cooperative partners could provide more funding for FPSs. These entities may not be interested in financing some of the designated streamgages in the FPS network, particularly those in isolated river basins with little anthropogenic activity.[98]

Some stakeholders advocate for more federal funding to expand the cooperative part of the network, which addresses more localized needs.[99] Some may argue against more federal funding for cooperative streamgages as it lacks a direct statutory mandate (unlike FPSs). Others have proposed increasing nontraditional funding sources for streamgages.[100] They suggest that businesses, homeowner associations, non-for-profit organizations, academic institutions, and

[91] Meeting of Water Science and Technology Board, National Academies of Sciences, Engineering, and Medicine, Washington, DC, November 29, 2018.

[92] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, December 17, 2018.

[93] Meeting of Water Science and Technology Board, National Academies of Sciences, Engineering, and Medicine, Washington, DC, November 29, 2018.

[94] Ibid.

[95] USGS funding refers to the FPS and CMF funding directed towards FPS streamgages. Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, February 19, 2019.

[96] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, December 17, 2018.

[97] The Coalition Supporting the USGS National Water Monitoring Network, representing an array of stakeholders, frequently advocates for full implementation for the National Streamflow Network.

[98] NRC, Assessing the NSIP, pp. 93-94.

[99] ICWP, Support for USGS Streamgages.

[100] Ruhi, Earth's Fresh Waters, p. 198.

other nontraditional entities could provide funding for streamgaging; therefore, increasing the amount of nonfederal investment. Contributions by nongovernmental partners to streamgages are currently relatively limited (1% in FY2018) and are not eligible for federal matching funds.[101] Congress could potentially encourage wider participation by nontraditional partners through such means as authorizing cooperative matching opportunities for public-private partnerships. Traditional stakeholders may oppose making matching funds available to entities not currently eligible, which could result in more competition for limited funds.

Congress increased the Groundwater and Streamflow Information Program appropriations by $1.5 million in FY2018 and $8.5 million in FY2019. These increases were directed to streamgages for the NextGen system (see section on "NextGen System"). Congress may consider expanding the network through the NextGen system based on results from the pilot project. Increases solely directed to the NextGen system may intensify funding constraints for FPSs and CMF streamgages.

Restoration of Streamgages

Streamgages are vulnerable to hazards if not properly hardened.[102] The SECURE Water Act directed the USGS to ensure all FPSs were flood hardened by FY2019. According to the USGS, structural restoration is usually funded because of emergencies; for example, disaster supplemental appropriations may provide funds for hardening streamgages, or funds are diverted from operational budgets to repair affected streamgages.[103] The 2017 hurricane season resulted in damage to more than 100 streamgages. In response, Congress provided $4.6 million in the Bipartisan Budget Act of 2018 to repair, replace, and restore these streamgages and recover their data, and for hydrologists to reconstruct stream channel measurements.[104] When the USGS does not receive disaster supplemental funding from Congress, the agency is not reimbursed for funding it redirects in order to provide around-the-clock monitoring during the events and equipment repair during and after the events.[105] Some stakeholders have advocated for Congress to provide funds specifically for strengthening and restoring infrastructure, especially to withstand natural disasters.[106] These stakeholders estimate that $238 million is needed to update half of the streamgages in the network to enable them to withstand major flood events and to meet new data transmitting requirements.[107] Under budget constraints, increases in congressional appropriations are often prioritized to maintain or expand the network instead of restoration.

[101] Taxable entities are not eligible for cooperative matching funds authorized by 43 U.S.C. §50.

[102] Structure hardening refers to structural improvements so that streamgages can withstand major flood events. Personal correspondence between CRS and the Interstate Council on Water Policy, November 16, 2018.

[103] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, November 15, 2018.

[104] P.L. 115-123 included disaster appropriations to the USGS for the surveys, investigations, and research. Within the amount for streamgages, $200,000 was for streamgages in Texas, $500,000 was for streamgages in Florida, and $3.9 million was for streamgage repairs, replacement, and data restoration in Puerto Rico. Email between CRS and the Groundwater and Streamflow Information Program, USGS, February 19, 2019.

[105] USGS, FY2017 Budget. Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, November 15, 2018.

[106] ICWP, Support for USGS Streamgages.

[107] Ibid.

Modernizing the USGS Streamgaging Network

Congress might consider investments in new technologies for the USGS Streamgaging Network. While regarded as reliable, many of the current streamgage operations are based on labor-intensive and more expensive techniques.[108] Some stakeholders suggest that investing in modern technological and computational capabilities could provide enhanced streamflow information with reduced costs.[109] Others raise that these approaches may not provide the quality and consistency of data expected of USGS streamgages and may reduce funds available for existing operations.[110]

Telemetry and Information Infrastructure

The SECURE Water Act of 2009 directed the USGS to equip all FPSs with modernized telemetry systems by FY2019. According to stakeholders, the current U.S. streamgage telemetry and information infrastructure may be vulnerable to failure, and the existing data collection platforms and computer networks might eventually be inefficient for real-time and detailed data.[111] In September 2018, an error in telemetry equipment resulted in an outage of 11% of the network. The USGS stated that redundancy in telemetry using cellular signals or camera streaming could have alleviated the problem, which affected the network for weeks.[112] The IMAGES Act of 2018 (H.R. 4905) introduced in the 115th Congress would have directed FEMA to work with USGS to modernize hardware and increase the speed of data transmittal, but the legislation did not specify funding amounts. Some stakeholders have suggested a figure of $112 million as the amount needed to upgrade the enterprise data management systems, information technology infrastructure, and real-time data delivery capabilities.[113] Past increases of appropriations for streamgages have prioritized continued operation and network expansion over technological improvements.[114] To mitigate costs for such upgrades, federal science agencies are considering cloud computing that could also benefit cloud providers if other users develop applications on the cloud network using the data already hosted there.[115] The FY2020 budget request for the USGS outlines enhancement and modernization of NWIS with a centralized platform meeting the

[108] Personal correspondence between CRS and the NASEM Committee Chair of Future Water Resource Needs for the Nation: Water Science and Research at the U.S. Geological Survey, November 19, 2018.

[109] NASEM, Future Water Priorities for the Nation.

[110] Personal correspondence between CRS and the Interstate Council on Water Policy, November 16, 2018. Personal correspondence between CRS and the NASEM Committee Chair of Future Water Resource Needs for the Nation: Water Science and Research at the U.S. Geological Survey, November 19, 2018.

[111] Personal correspondence between CRS and the Interstate Council on Water Policy, November 16, 2018. Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, November 15, 2018.

[112] USGS, "Working to Restore Streamgages," press release, 2018, https://www.usgs.gov/news/usgs-working-restore-streamgages.

[113] ICWP, Support for USGS Streamgages.

[114] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, December 17, 2018.

[115] According to National Institute of Standards and Technology (NIST), cloud computing is "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." The NOAA Big Data Project (BDP) was created to explore the potential benefits of storing copies of key observations and model outputs in the cloud to allow computing directly on the data without requiring further distribution. NOAA suggests that such an approach could help form new lines of business and economic growth while making NOAA's data more easily accessible to the American public. Find more information at https://www.noaa.gov/big-data-project.

Federal Cloud First Computing Strategy.[116] Some argue that Congress should fund alternative data infrastructure to ensure capacity and reliability of increased data while reducing the cost, though others may argue these strategies are not ready for full implementation.[117]

NextGen System

The USGS suggests that modern models and computational methods to estimate streamflow in ungaged or sparsely gaged basins may provide an alternative approach to conventional streamgaging.[118] These methods require more observational data, particularly for reference river basins, than that provided by the current streamgage network. In an effort to assess this approach, the USGS initiated a NextGen system pilot project in the Delaware River Basin with $1.5 million in FY2018 (**Figure 8**),[119] and the Consolidated Appropriations Act, 2019 (P.L. 116-6) provided $8.5 million for the NextGen system.[120] Reports accompanying FY2019 Interior appropriations bills by the House and Senate in the 115th Congress addressed the NextGen system.[121] The Senate committee report encouraged the USGS to have a cost-effective strategy for the NextGen system (S.Rept. 115-276), and the House committee report directed the USGS to provide the committee with a report on the NextGen system, explaining the limitations of the current water monitoring system, the enhancements and modernization needed, and costs to implement the system over a 10-year period and operate and maintain the system (H.Rept. 115-765). The USGS says the funding will allow further the NextGen system implementation in the Delaware River Basin; continued progress in modernizing USGS data infrastructure; and the selection of the next basin.[122] Advances by the NextGen system to estimate streamflow at ungagged locations based on modeling of highly measured reference basins could also result in reduced need for streamgages, lower costs, and expansion of coverage of streamflow data.[123] Others may suggest that modeling streamflow may not provide adequate data as physical measurements, and initiating the NextGen system may result in decreased funding available for traditional operations.[124]

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[116] According to https://cloud.cio.gov/, the Federal Cloud Computing Strategy is a long-term, high-level strategy to drive cloud adoption in federal agencies.

[117] "U.S. Group on Earth Observations (USGEO) Town Hall," American Geophysical Union Fall Meeting, Washington, DC, December 12, 2018.

[118] Evenson, DOI National Water Assessment, p. 23.

[119] USGS, *Next Generation Water Observing System: Delaware River Basin*, 2018, at https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/atoms/files/USGS_NextGen_DRB_BriefingSheet_v7.pdf.

[120] Division E of H.Rept. 116-9.

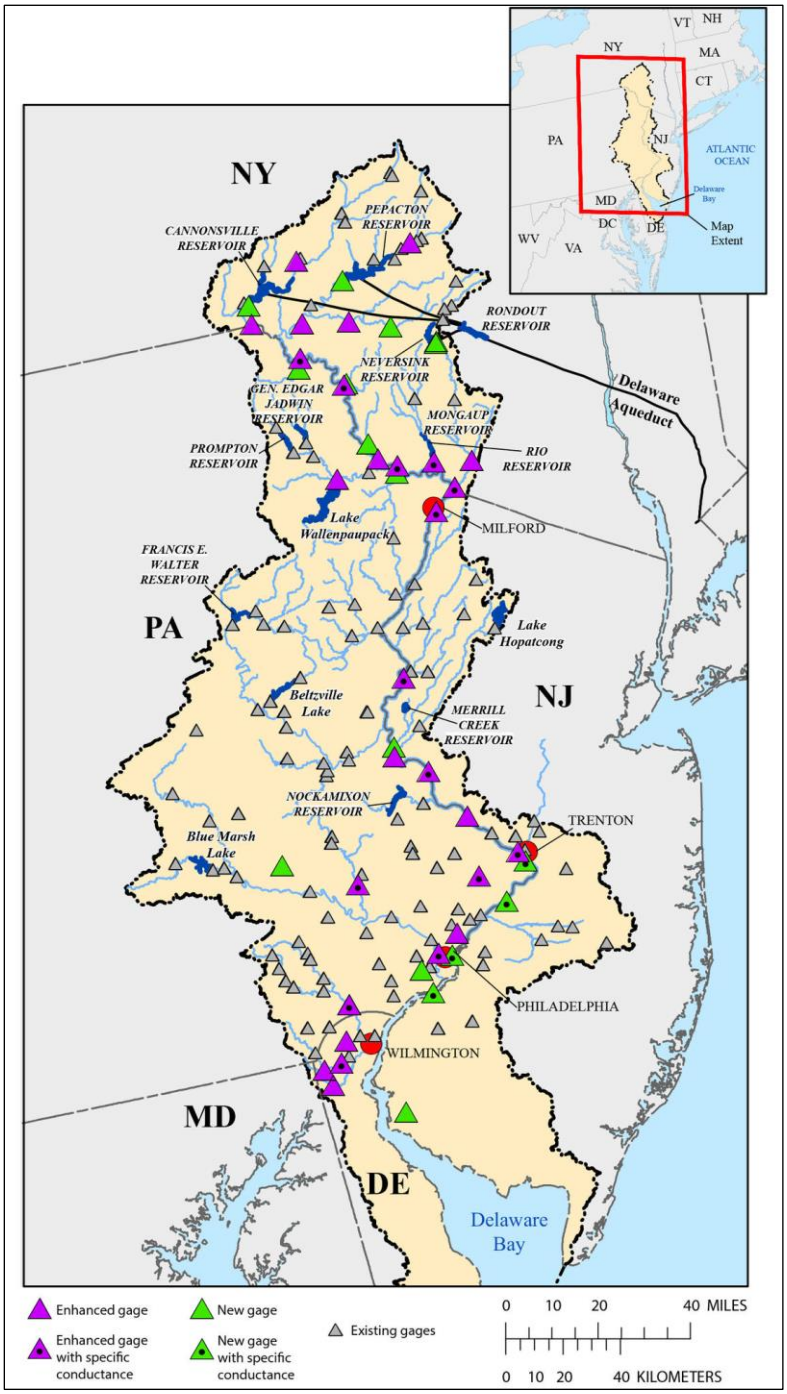
[121] The joint explanatory statement (H.Rept. 116-9) accompanying the Consolidated Appropriations Act, 2019 (H.J.Res. 31) enacted in the 116th Congress stated that language contained in H.Rept. 115-765 and S.Rept. 115-276 providing guidance and reporting requirements carried the same emphasis as the language included in the joint explanatory statement and should be complied with unless specifically addressed to the contrary. S.Rept. 115-276 accompanied S. 3073 and H.Rept. 115-765 accompanied H.R. 6147.

[122] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, February 19, 2019.

[123] Evenson, DOI National Water Assessment, p. 23.

[124] Personal correspondence between CRS and the Interstate Council on Water Policy, November 16, 2018. Personal correspondence between CRS and the NASEM Committee Chair of Future Water Resource Needs for the Nation: Water Science and Research at the U.S. Geological Survey, November 19, 2018.

Figure 8. Map of the Planned Next Generation Integrated Water Observing System (NextGen) Pilot in the Delaware River Basin



Source: USGS, *Next Generation Water Observing System: Delaware River Basin*, 2018, at https://www.usgs.gov/mission-areas/water-resources/science/next-generation-water-observing-system-delaware-river.

Notes: Base funding to support the NextGen system increased from $1.5 million in FY2018 to $8.5 million in FY2019, which will allow for implementation in the Delaware River Basin, among other activities.

Innovation

Congress may also consider directing the USGS to pursue innovative observation technologies: satellite-based or airborne platforms, ultrasound sensors for river stage-height measurement, radar technology for stream velocity, and autonomous vehicles for Light Detection and Ranging (LIDAR) and other types of remote sensing.[125] The USGS is currently evaluating combining cameras and radars with advanced imagery analysis and installing these combined technologies on drone platforms to collect streamflow in difficult or inaccessible areas.[126] Data coverage could also potentially increase with high-density sensing and sensor networks that use miniaturization, artificial intelligence, and economy of scale. Statistical advances to estimate streamflow at locations without streamgages could also result in reduced need for streamgages.[127] Some suggest that such technologies may eventually satisfy streamflow information needs at lower cost, while others caution that advanced technologies may not provide as robust and reliable data as traditional methods.[128]

Balancing Policy Options

Congress may consider outlining the future direction for the USGS Streamgaging Network through oversight or legislation. At the close of FY2018, 3,640 of the 4,760 FPS locations designated by the USGS were operational, with 52% of their funding coming from the USGS.[129] As the USGS faces a deadline by the SECURE Water Act of 2009 to operate no less than 4,700 FPSs by FY2019, Congress directed the USGS through appropriations legislation to invest in the NextGen system. Congress may consider pursuing both the FPS mandate and the NextGen system, amending the SECURE Water Act of 2009 to facilitate completion of FPSs, or replacing the FPS mandate with the Next Gen system.

Pursuing Both the FPS Mandate and the NextGen System

Congress may consider pursuing both FPS coverage and the NextGen system. This approach could allow the USGS to meet the SECURE Water Act mandate while fully exploring new methods to obtain streamflow information. Financial constraints may limit this approach and pursuing both initiatives simultaneously may result in duplication of resources and coverage.

Amending the SECURE Water Act of 2009

Congress may consider revising the SECURE Water Act of 2009 to facilitate completion of FPSs (i.e., extending the deadline for FPSs, reassessing the program goals, and changing the number of FPSs). Extending the mandate may provide more time to complete the FPS network. Some suggest that the national interests have evolved and the national goals and FPS locations should

[125] Future Water Priorities for the Nation, pp. 8 and 66.

[126] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, February 19, 2019.

[127] Evenson, DOI National Water Assessment, p. 23.

[128] Personal correspondence between CRS and the Interstate Council on Water Policy, November 16, 2018. Personal correspondence between CRS and the NASEM Committee Chair of Future Water Resource Needs for the Nation: Water Science and Research at the U.S. Geological Survey, November 19, 2018.

[129] USGS funding refers to the FPS and CMF funding directed towards FPS streamgages. Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, February 19, 2019.

be reassessed.[130] For example, monitoring streamflow for ecological purposes was not considered in the original design but has become an increased priority.[131] The SECURE Water Act of 2009 directed the USGS to incorporate principles of adaptive management by conducting period reviews of the FPSs to assess whether the law's objectives were being adequately addressed. An analysis of the network could reveal whether some currently funded FPS sites are no longer in the national interest and funding could be reallocated to complete other sites. Changes in the national goals may also result in the discontinuation of long-term streamgages or the need for new streamgages, and coverage may increase or decrease in various river basins.

Replacing the FPS Network with NextGen System

Congress may consider replacing FPSs with the NextGen system by authorizing the NextGen system as a pilot program or broader program. For example, the Weather Research and Forecasting Innovation Act of 2017 (P.L. 115-25) required NOAA to conduct a pilot program for commercial weather data. The act stipulated program criteria, authorization of appropriations, reporting requirements, and future directs for NOAA based on the success of the pilot program.[132] Congress could provide similar mandates in legislation including which basins are chosen for NextGen system improvements and whether the basins are determined by an external study, the Administration, or Congress.[133] While some acknowledge new streamgaging approaches are forthcoming, others may suggest that modeling streamflow may not provide as adequate data compared to traditional streamgages and altering the network design may result in loss of coverage at specific sites or across basins.[134]

Author Information

Anna E. Normand
Analyst in Natural Resources Policy

[130] The National Research Council's 2004 analysis of the program recommended periodically reevaluating the network to ensure that it meets anticipated future needs for streamflow information. NRC, Assessing the NSIP, pp. 66-67. In 2005, the Government Accountability Office stated that a cost-benefit analysis could point to changes in the design or operation of the program that could enhance the level of benefits the program provides, and recommended that the analysis be performed by an independent external organization. GAO, Federal Data Programs, 164-174.

[131] Personal correspondence between CRS and the Groundwater and Streamflow Information Program, USGS, December 17, 2018.

[132] CRS Report R44838, *The Weather Research and Forecasting Innovation Act of 2017: Congressional Direction to NOAA in P.L. 115-25*, by Peter Folger.

[133] For example, Congress recently passed water resources legislation with provisions to increase streamgage coverage in the Upper Missouri River Basin. America's Water Infrastructure Act of 2018 (P.L. 115-270) called for expedited completion of activities authorized in under Section 4003(a) of the Water Resources Reform and Development Act of 2014, which directed the USACE to operate streamflow gages and related interpretive studies in the Upper Missouri River Basin under the Cooperative Water Program and the National Streamflow Information Program of the USGS.

[134] Personal correspondence between CRS and the Interstate Council on Water Policy, November 16, 2018.

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