Regional status and trends monitoring of small streams for the Stormwater Action Monitoring (SAM) program

A proposal prepared by the U.S. Geological Survey for Washington State Department of Ecology

February 3, 2020

BACKGROUND/INTRODUCTION

The Stormwater Action Monitoring (SAM) program is a cooperative regional monitoring effort collectively funded by the Phase I and II Municipal Stormwater Permittees in the Puget Sound region of Washington State. Under the SAM program, there is a regional effort to document and track the status and trends of small streams in the Puget Lowlands with respect to water chemistry, sediment chemistry, stream habitat and biota (algae and macroinvertebrates). The main goal of this status and trends program is to document whether stormwater management activities are protecting small streams in the region.

The study design for the SAM streams program uses a master sample list that generates a spatially balanced and random sample site list that can be used in probabilistic studies within the Puget Lowland ecoregion. The probabilistic approach allows the extrapolation of data collected at sampled sites to those at unsampled sites to generate a general understanding of regional stream condition. Results from this program are then used to track overall status and trends of small streams in the region and provide local projects with a context they can compare.

The first round of the SAM small streams sampling took place in 2015 and analysis of that data was released in 2018 (DeGasperi and others, 2018). The original study design for the SAM small streams program was to sample up to 100 streams in a year and repeat this one time sample every five years. However, DeGasperi and others (2018) proposed several changes the stream program for to round 2 which began in water year 2020 (October 1, 2019 to September 30, 2020). These changes included how sites were selected in future rounds, how many sites are sampled, how frequent sampling takes place, the total number of sites to be sampled, and what parameters are sampled. The biggest changes included (1) changing the sampling frequency from 100 sites once every five years to 35 sites a year over the next 5 years, (2) dropping monthly water quality sampling and constraining it to a one-time summer sample, and (3) including the measurement of continuous temperature and stream stage at each site.

The U.S. Geological Survey (USGS) was asked by the Washington State Department of Ecology (Ecology), the SAM administrative agency, to provide technical assistance for this long-term status and trends program and this proposal outlines a 5-year plan to assist in administering this regional program.

PROBLEM

Stormwater runoff is a national problem and stormwater from developed areas can contribute to flashy flows and deliver a wide range of pollutants to our local waterways. Prior stormwater monitoring permit requirements focused on characterizing the quality of stormwater, primarily through outfall monitoring. However, there is a need to understand how stormwater runoff is impacting the quality of receiving waters and if the management activities to lessen these impacts are adequate for protecting small streams. The SAM small stream program aims to

address this need by examining the status and trends of small streams in the Puget lowlands with respect to water and sediment quality, stream habitat (in-channel and riparian), and stream biota (algae and macroinvertebrates).

OBJECTIVES and SCOPE

The objective of this project it to assist local cooperators in conducting a 5-year status and trends monitoring program of small streams in the Puget lowlands. This work will include site evaluation and selection, deployment and maintenance of continuous water level sensors, and a one-time summer sample for water and sediment quality, stream habitat (in-channel and riparian), and stream biota (algae and macroinvertebrates). In addition, the USGS will be the lead on annually reporting of the findings for each water year to the Stormwater Work Group and regional stakeholders.

RELEVANCE and BENEFITS

This proposal addresses many of the key elements of the strategic plans of the Department of the Interior (DOI) (https://www.doi.gov/sites/doi.gov/files/uploads/fy2018-2022-strategic-plan.pdf), the USGS (U.S. Geological Survey, 2007) and its Water Mission Area, and elements of the Washington Water Science Center science plan.

For the DOI strategic plan, this project addresses the goal of applying science to land, water, and species management under the 'Conserving our Land and Water' Mission Area. Through the collaboration of USGS and Ecology, the status and trends assessment will provide monitoring and assessments of streams around the Puget lowlands in order to understand the changes to water quality and stream health in response to stormwater and land-use management.

This project addresses science directions of the USGS to understand ecosystems and predict ecosystem change through monitoring small streams in the region to better understand how protect and manage the impacts to these systems. In addition, this work falls under the science direction of a 'Water census for the United States' by ensuring water quality will meet human and ecological needs in the face of growth and development. Specifically, this work will assess the status of freshwater resources and how they are changing (U.S. Geological Survey, 2007).

Under the Water mission area of the USGS, a water science strategy was developed (Evenson, and others 2013) to identify water science goals and objectives for the Nation. In particular, to provide information on the quality of water, to assess water resources to meet human and ecosystem needs, and to provides tools to manage and maintain the quality of our water resources.

Lastly, this project addresses the current science plan at the Washington Water Science Center by addressing the science themes of (1) Water Resources Monitoring (2) Managing, Protecting, and Restoring Aquatic Ecosystems, and (3) Integrated Watershed Resources Management and Landscape-scale Assessments (Barton and others, 2018). This project will develop a long-term and resilient data collection network of small streams in the region. This data collection will help managers understand the current status of stream condition and how it is changing and help better understand relations between land-use and ecosystem health.

APPROACH

The USGS will oversee the small streams status and trends monitoring program for the next 5 years. The approach will involve completing the following tasks annually:

- Conduct site selection and level logger deployment at 35 sites consisting of 33 randomly chosen sites across a range of urbanization and 2 reference sites. Level loggers will be deployed by October 1 and be retrieved by Sept 30 the following year.
- Conduct periodic data downloads and maintenance for all level loggers throughout the year.
- Conduct a one-time watershed health measure (WHM) and water and sediment chemistry sampling in summer (July through September) at the 35 sites.
- Process and quality control continuous records (water level and temperature) each water year and calculate temperature and flow metrics; this data will be posted annually to ScienceBase
- Provide an annual progress report to stakeholders to track the status of small streams in the region.

Site selection and level logger deployment

Ecology has generated a master sample list of candidate streams and will provide the USGS with the list of current year sampling sites by July of each calendar year. Once the list is provided, the USGS will select 35-40 suitable small streams sites in the order they appear in the master list to be sampled in summer of the following year. Site selection will begin using desktop reconnaissance to examine the site for access, gather landowner information, and determine suitability for the SAM program. For each site that looks acceptable, a field visit will take place to verify the site will conform to the site requirements for the SAM program. This verification will include (1) access to the site is possible either through right of way or private landowner permission, (2) the site is safe to sample, (3) there is a long enough reach to conduct the summer watershed health measure (WHM) sampling, which includes sampling for invertebrates, algae and habitat along a 150 meter (or greater) reach, and (4) there is flow at the site.

The goal is to conduct the site selection process during summer (August to September) to confirm there will be flow during the time when the WHM will take place the following sample year. For example, in summer of 2020, sites will be selected for WHM sampling in summer of 2021. During the 2015 SAM small streams sampling, several sites had to be dropped because there was no flow present during the summer sampling. A recommendation for round 2 of SAM small streams sampling was to conduct site selection at the same time the summer sample will take place so the number of sites that might be dropped is reduced. Detailed records of the site selection process, including reasons for sites being dropped will be kept and archived. Site

selection will be completed by September 30th of each calendar year. A total of 33 random sites will be chosen across a range of percent imperviousness cover within the basin. In addition, two reference sites will be sampled for a total of 35 streams sites each year.

Once the set of 35 final SAM sites are selected and confirmed, the USGS will deploy pressure transducers to measure stream stage and temperature at each location. A recommendation for round 2 of the SAM small streams program was to include continuous stage, an indicator of flow condition, at each site (DeGasperi and others, 2018). Flow is an important factor to stream health and it was not included in the 2015 SAM small stream program. The stage data will be used to calculate several flow metrics known to correlate to biological condition and vary with watershed urbanization (DeGasperi and others 2009, Booth and Konrad, 2017). Ideally, a full year of stage data will be needed to calculate these metrics, so the goal is to have the level loggers installed at each site by October 1 each year. In addition to the water level data, the loggers also record temperature; therefore, a continuous record of stream temperature will also be available for each location.

Pressure transducer data for each stream will be used to calculate a continuous record of average stream depth in the reach which can be used to estimate various flow metrics such as the flashiness index (Booth and Konrad, 2017). To calculate depth at each site, the pressure transducer must be corrected to the local barometric pressure to determine the pressure of the water column only. Therefore, two (2) pressure transducers are needed per site, one for the water pressure, and one for the local barometric (air) pressure. For 35 stream sites, at least 70 pressure transducers will be needed. This equipment will be continuously used in subsequent monitoring years. Unused pressure transducers will be stored at the USGS office in Tacoma and available to other SAM projects if they are not being used.

Prior to deployment, each level logger will be checked for depth and temperature in the laboratory. Level loggers will be placed in a calibrated tank to check the pressure at a minimum of 2 different water levels. For temperature, a 5-point check will take place in a constant temperature water bath. The 5-point temperature check will follow standard USGS protocols and occur prior to and at the end of deployment to document instrument drift (Wagner and others, 2006).

Deployment of the level loggers in the field will follow USGS guidelines and recommendations for measuring stage (Sauer and Turnipseed, 2010) and procedures used during a recent (2015) USGS study in Puget Sound (Sheibley and others, 2017). The USGS Puget Sound study focused on the same types of streams for the SAM study so those procedures are directly applicable for the SAM study. Each site will provide unique conditions for the installation of the instream level loggers and installation will vary on a site by site basis. Briefly, each level logger will be secured to an anchor to the stream bed consisting of a fence post, rebar, or angle iron. Each level logger will be installed off the bottom of the streambed to ensure they are not buried during their deployment and stage will be related to stream depths measured during the WHM sampling in

summer. A reference point will be established during deployment in order to account for instrument drift or physical changes in the logger location during the water year.

Deliverable 1: Final SAM sampling list of selected and dropped sites with brief site description and reasons for sites being dropped. Calibration and installation of water level loggers will also be completed by Sept 30th of each year. Target Date: September 30th each year.

Operation and maintenance of level loggers

Throughout the water year, USGS staff will visit each site to maintain each level logger deployment. Site visits will include the confirmation of logger location to the reference point established during initial deployment. Data will be downloaded from the level loggers, loggers will be cleaned as needed and reinstalled in the stream. Finally, a reference point measure will be recorded to correct the record for any inadvertent shifts during data download. Data will be archived on an internal server and data checked for quality and completion.

Deliverable 2: Confirmation email of data completeness and data quality issues for each site after each data download. Target date: Approximately quarterly each water year (Jan 31st, March 31st, June 30th, September 30th).

Summer watershed health measure

Each site will be visited in the summer (July 15 through October 15) for a one-time watershed health measure (WHM). The WHM at each SAM site is modeled after an existing program at Ecology called the Watershed Health program. In 2015, a quality assurance project plan (QAPP) was published that provided detailed protocols and procedures to follow when conducting the WHM for the first round of SAM stream sampling (Lubliner, 2014). Although an updated QAPP in currently in development at Ecology for the 2020 SAM streams sampling, sampling procedures will be similar to those in 2015. In addition to Lubliner (2014), the Ecology watershed health team maintains an ongoing and updated list of standard operating procedures (SOPs) for each aspect of the WHM (https://fortress.wa.gov/ecy/publications/UIPages/PublicationList.aspx?IndexTypeName=Topic&NameValue=Standard+Operating+Procedure+(SOP)+%e2%80%94+Watershed+Health+Monitoring&DocumentTypeName=Publication).

The WHM consists of a detailed field measure of in-channel and riparian metrics across 11 transects over a 150-meter reach at the study site. In channel characteristics are estimated for large woody debris, stream slope and sinuosity, assessing bank erosion vulnerability, substrate

size and embeddedness, quantifying habitat units, estimating fish cover features, and channel dimensions (width, depth and thalweg distance). In addition, several riparian measures are determined and include riparian cover using a densiometer, assessing human influence, and assessing riparian vegetation structure. Data collection for this part of the WHM is facilitated using a standardized electronic field form developed by Ecology that is used with a field tablet to ensure data collection is complete and follows the same protocols at each study site. Data from the tablet is then uploaded to the Ecology Environmental Information Management (EIM) database where it undergoes a quality review and physical metrics are calculated (Janisch, 2013).

In addition to the physical measures of channel and riparian characteristics, samples for sediment chemistry, water quality, periphyton (algae), and macroinvertebrates are collected and processed at the site. The procedures for the collection of these parameters will follow the 2015 SAM streams QAPP (Lubliner, 2014) and Ecology QAPP for algae and invertebrate sampling (Adams, 2010). Invertebrates will be classified to calculate the benthic index of biological integrity (BIBI) for each site, a multimetric index based on the invertebrate species (Karr, 1991). Periphyton species will be identified and quantified to determine a trophic diatom index (Van Dan and others, 1994). Water quality samples will be collected following standard procedures used by Ecology (Lubliner, 2014; Hartman, 2019) and consistent with USGS protocols. Water quality parameters include total and dissolved nutrients, chloride, total suspended sediment, turbidity, dissolved organic carbon, hardness, dissolved oxygen, pH, temperature, specific conductance, total and dissolved metals, and fecal coliform bacteria. Sediment chemistry will be determined on a composite sample collected from depositional areas of the reach based on USGS methods and described in Lubliner (2014). Sediments will be analyzed for grain size, percent solids, total organic carbon, metals, PAHs, PBDEs, and phthalates.

The summer watershed health measure and collection of samples for sediment, water, algae and invertebrates will be completed at all 35 sites annually between July 15 and October 15.

Deliverable 3: Confirmation email of data completeness and data quality issues for each site; submission of EIM compatible spreadsheet containing pH, temperature, dissolved oxygen, and specific conductivity; submission of the data collection event (DCE) file for each site compiled by the WHM electronic field forms. Target Date: all sites sampled and all files submitted by October 31st each year.

Annual reporting and status assessment

Annually, USGS will provide a status update to the Stormwater Work group (SWG), stakeholder group that oversees the SAM program. The random study design will allow classification of stream condition (biological, physical, and chemical) each sample year by generating a cumulative distribution function (CDF) of important stream metrics of the sample population. These CDFs will be used to describe the overall condition of regional streams and the change in

CDFs over time can provide insight on how the regional stream condition is changing. Annual summaries will be provided on the SAM status and trends website.

Deliverable 4: Each annual summary will be provided to Ecology and the SWG by April 30th following the end of the sample year. For example, the first summary will be complete March 30th, 2021 for the data collected in water year 2020 (October 1, 2019 to September 30, 2020). In addition to written summaries for release on the SAM website, an annual presentation to the SWG will take place by their June meeting.

QUALITY ASSURANCE/QUALITY CONTROL/LAB EVALUATION

All activities proposed under this proposal will follow approved QAPPs and SOPs to ensure that all data collection is representative, complete, and consistently collected across all sites. For reference, the SAM small streams QAPP from the 2015 sampling (Lubliner, 2014) will be followed and updated to reflect changes in the program for sample year 2020. The updated QAPP is not yet complete but will go through a USGS-Ecology review process and no field work will begin until this approved QAPP is published. Field procedures will be consistent with the USGS procedures in the National Field Manual (https://water.usgs.gov/owq/FieldManual/index.html) and the Washington Water Science Center quality assurance plan (Conn and others, 2017).

Quality control samples for water and sediment chemistry will be collected and analyzed each sample year. There will be a minimum of 3 field replicates and 1 field blank analyzed for all water quality parameters each sample year. For sediment chemistry, a single site will be chosen each year where triplicate sediment samples will be analyzed to examine variability in the field collection and homogenization methods.

Ecology will be working with a contract lab (either King County Environmental Lab, or Manchester Environmental Lab) for all water and sediment chemistry analyses. Both laboratories are Washington State accredited labs and meet the requirements for lab analysis for this project. Samples for algae and macroinvertebrates will be analyzed by Ecology's contract lab. All interlaboratory comparisons, standard reference materials, and general laboratory quality control are being managed by Ecology with USGS input.

DATA MANAGEMENT

All data for this project will be uploaded to and stored in the Ecology EIM database, as required under this permittee funded program. Continuous stage and temperature records and metrics calculated from these records will be archived in ScienceBase (or similar) as a companion Data Release to the project report on an annual basis.

All field forms and field notes will be scanned and uploaded to an internal USGS server which is backed up daily. All electronic records will be available to Ecology upon request. All WHM data collected using field tablets are uploaded as single data collection event (DCE) file per site to Ecology's EIM database.

TIMELINE and PRODUCTS

The timeline for this project will begin once the Joint Funding Agreement is signed extend up to a maximum of 5 years. However, due to the volatility of funding and uncertainty in budgeting a long-term project, the project timeline and budget below will represent the first 2 years of sampling. The first 2 years of this project run from October 1, 2019 through March 31, 2022.

During the summer sampling period in year 2 (summer 2021), Ecology and USGS will reassess the budget and scope prior to completing the final 3 years of the 5-year project.

Within each sample year, the deployment of new level loggers will be completed by October 1 of that water year and all field work (WHM, water and sediment, and biological sampling) will be completed by September 30 of the sample year.

Under this project, the USGS will assist Ecology in publishing an annual update on small stream status that will be published on the Ecology's SAM website (https://ecology.wa.gov/Regulations-Permits/Reporting-requirements/Stormwater-monitoring/Stormwater-Action-Monitoring). This will resemble the style and format of a USGS fact sheet. A more detailed and formal status and trends report will be completed after 4 years of sampling and will be funded under a different joint funding agreement.

As stated previously, continuous stage and temperature records and metrics calculated from these records will be archived in ScienceBase (or similar) as a companion Data Release on an annual basis (approximate publication data March following the sample year; for example, data from WY2020 will be published by March 2021).

The approximate timeline is outlined below. Note: the federal fiscal year (FY) corresponds to the water year (FY2020 goes from October 1, 2019 to September 30, 2020).

Task or Element	FY 2020				FY 2021				FY 2022			
	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-June	July-Sept
Site selection/logger deployment			X	X			X	X				
Logger O&M	X	X	X	X	X	X	X	X				
Summer sampling				X				X				
Publish temperature and stage data					X	X			X	X		

BUDGET and FUNDING SUMMARY

As stated previously, this project will be funded for the first 2 years of sampling (with an end date of March 31, 2022) but can extend up to a maximum of 5 years. For the first two full years of sampling, the budget and funding summary is provided below.

Budget Item	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Salary	$ 157,741	$ 167,449	$ 61,700	$ -	$ -
Travel	$ 1,000	$ 3,150	$ -	$ -	$ -
Equipment and supplies	$ 5,000	$ 2,625	$ 1,000	$ -	$ -
Level Loggers	$ 20,000	$ -	$ -	$ -	$ -
Total Direct Costs	$ 183,741	$ 173,224	$ 62,700	$ -	$ -
Total Indirect Costs	$ 143,087	$ 148,834	$ 53,200	$ -	$ -
Total	$ 326,828	$ 322,059	$ 115,900	$ -	$ -

Note: For year 1 (October 1, 2019 through September 30, 2020) there is an additional line item for an equipment purchase to obtain 70 level loggers. These are needed in order to deploy the next round of level loggers prior to October 1, 2020.

Indirect costs include all overhead charged to the project. Indirect costs include a percentage of salary for center management, IT, safety and administrative staff; facilities charges for building rent and maintenance; support for IT equipment and computer networks; USGS editorial and publication expenses; and services from the USGS headquarters office in D.C. The indirect fund rates are determined annually by the Department of Interior as a percentage of total project costs.

Funding by source:

Agency	FY2020	FY2021	FY2022	Total for Agency
Dept. of Ecology	$326,828	$322,059	$115,900	$764,787
USGS	$0	$0	$0	$0
Total	$326,828	$322,059	$115,900	$764,787

In addition, the complete 5-year budget is also included here for reference and planning purposes. It is assumed that during summer 2021, Ecology and USGS will revisit this budget and make any adjustments that are needed.

Budget Item	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Salary	$ 157,741	$ 167,449	$ 172,439	$ 177,442	$ 177,699
Travel	$ 1,000	$ 3,150	$ 2,200	$ 2,300	$ 3,000
Equipment and supplies	$ 5,000	$ 2,625	$ 2,750	$ 2,875	$ 3,000
Level Loggers	$ 20,000	$ -	$ -	$ -	$ -
Total Direct Costs	$ 183,741	$ 173,224	$ 177,389	$ 182,617	$ 183,699
Total Indirect Costs	$ 143,087	$ 148,834	$ 152,412	$ 156,905	$ 157,835
Total	$ 326,828	$ 322,059	$ 329,801	$ 339,522	$ 341,534

REFERENCES

Adams, K., 2010, Quality Assurance Monitoring Plan: Ambient Biological Monitoring in Rivers and Streams: Benthic Macroinvertebrates and Periphyton; Ecology publication 10-03-109, 183p. https://fortress.wa.gov/ecy/publications/summarypages/1003109.html

Barton, C., Dinicola, R., Munn, M.D., and Konrad, C.P., 2018, USGS Washington Water Science Center Strategic Science Plan 2018-2023. 66p.

Booth, D. B. and C. P. Konrad (2017). Hydrologic metrics for status-and-trends monitoring in urban and urbanizing watersheds. Hydrological Processes 31(25): 4507-4519.

Conn, K.E., Huffman, R.L., and Barton, Cynthia, 2017, Quality-assurance plan for water-quality activities in the U.S. Geological Survey Washington Water Science Center: U.S. Geological Survey Open-File Report 2017–1044, 66 p., https://doi.org/10.3133/ofr20171044.

Cusimano, R., G. Merritt, R. Plotnikoff, C. Wiseman, C. Smith, 2006, Status and Trends Monitoring for Watershed Health and Salmon Recovery: Quality Assurance Monitoring Plan: Ecology publication 06-03-203, 62p.
https://fortress.wa.gov/ecy/publications/summarypages/0603203.html

DeGasperi, C. L., H. B. Berge, K. R. Whiting, J. J. Burkey, J. L. Cassin and R. R. Fuerstenberg (2009). Linking hydrologic alteration to biological impairment in urbanizing streams of the Puget Lowland, Washington, USA. Journal of the American Water Resources Association 45(2): 512-533.

DeGasperi, C.L., R.W. Sheibley, B. Lubliner, C.A. Larson, K. Song, and L.S. Fore, 2018, Stormwater Action Monitoring Status and Trends Study of Puget Lowland Ecoregion Streams: Evaluation of the First Year (2015) of Monitoring Data, King County Water and Land Resources Division, Seattle, Washington, 228 p.

Evenson, E.J., Orndorff, R.C., Blome, C.D., Böhlke, J.K., Hershberger, P.K., Langenheim, V.E., McCabe, G.J., Morlock, S.E., Reeves, H.W., Verdin, J.P., Weyers, H.S., and Wood, T.M., 2013, U.S. Geological Survey water science strategy—Observing, understanding, predicting, and delivering water science to the Nation: U.S. Geological Survey Circular 1383–G, 49 p.

Hartman, C., 2019, Standard Operating Procedure EAP095, Version 1.2: Collecting Water Samples for Watershed Health Monitoring; Ecology publication 19-03-216, 20p.
https://fortress.wa.gov/ecy/publications/SummaryPages/1903216.html

Janisch, J., 2013, Dictionary of Metrics for Physical Habitat: Definitions and Calculations Used for Watershed Health Monitoring and Related Studies: Ecology publication 13-03-033, 147p.
https://fortress.wa.gov/ecy/publications/SummaryPages/1303033.html

Karr, J.R., 1991. Biological Integrity: A long-neglected aspect of water resource management. Ecological Applications, 1:66-84.

Lanksbury, J., B. Lubliner, M. Langness, and J. West, 2017, Stormwater Action Monitoring 2015/16 mussel inventory survey, Final report August 9, 2017, Washington State Department of Fish and Wildlife, Olympia, WA, 124 p.

Lubliner, B., 2014, Quality Assurance Project Plan for Status and Trends Monitoring of Small Streams in the Puget Lowlands Ecoregion for Monitoring Conducted using Pooled RSMP Funds contributed by Western Washington Municipal Stormwater Permittees; Ecology publication 14-10-054, 65p. https://fortress.wa.gov/ecy/publications/SummaryPages/1410054.html

Sauer, V.B., and Turnipseed, D.P., 2010, Stage measurement at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A7, 45 p. https://pubs.usgs.gov/tm/tm3-a7/

Sheibley, R.W., Morace, J.L., Journey, C.A., Van Metre, P.C., Bell, A.H., Nakagaki, Naomi, Button, D.T., and Qi, S.L., 2017, Design and methods of the Pacific Northwest Stream Quality Assessment (PNSQA), 2015: U.S. Geological Survey Open-File Report 2017-1103, 46 p., https://doi.org/10.3133/ofr20171103.

U.S. Geological Survey, 2007, Facing tomorrow's challenges—U.S. Geological Survey science in the decade 2007–2017: U.S. Geological Survey Circular 1309, x + 70 p.

Van Dam, H., A. Mertens, and J Sinkeldam, 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Netherlands Journal of Aquatic Ecology 28(1) 117-133.

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments; accessed April 10, 2006, at http://pubs.water.usgs.gov/tm1d3

MAP OF STUDY AREA