Maryland Water Resources Research Center
Annual Technical Report
FY 2016

Introduction

During Funding Year 2016, the Maryland Water Resources Research Center's support focused on research into stream-forest interactions, with one project in Western Maryland (Antietam Creek) and another in the Coastal Plain (Zekiah Swamp Run and other streams). For scheduling reasons, this year's Maryland Water Symposium was postponed to Fall 2017. Work was begun on an educational watershed app. The Center continues seeking to serve the diversity of Maryland geography, educational institutions, water quality and quantity concerns, and students.

Research Program Introduction

Maryland's 104(B) projects in this funding year focused on freshwater rivers and their riparian zones:

- 2016MD336B: Assessing riparian hydrologic pathways as controls on forested buffer function in the Antietam Creek watershed, western Maryland
- 2016MD337B: Comparison of Channel Velocity, Momentum, and Flood Wave Celerity in Forested vs Channelized Coastal Plain Streams

A supplemental project, in partnership with the U.S. Army Corps of Engineers Institute for Water Resources, was also active during this period:

- 2016MD347S: Impact of the “308 Reports” on Water Resources Planning and Development in the United States and Implications of these Results for the Future

Environmental Concentrations and Exposure Effects of Environmental Gestagens on a Sentinel Teleost Fish

Basic Information

Title:	Environmental Concentrations and Exposure Effects of Environmental Gestagens on a Sentinel Teleost Fish
Project Number:	2014MD321G
USGS Grant Number:	G14AS00014
Start Date:	9/1/2014
End Date:	8/31/2017
Funding Source:	104G
Congressional District:	MD-005
Research Category:	Water Quality
Focus Categories:	Water Quality, Toxic Substances, Wastewater
Descriptors:	None
Principal Investigators:	Edward F Orlando, Michael T Meyer, Patrick Phillips

Publications

There are no publications.

Status Report: 2014MD321G
Environmental Concentrations and Exposure Effects of Environmental Gestagens on a Sentinel Teleost Fish

Dr. Edward Orland, PI, left his faculty position at the University of Maryland in July 2016. He is currently seeking a new faculty position. As arranged with USGS, the Maryland Water Resources Research Center is holding this project, and will transfer it to Dr. Orlando when he has found his new position.

A no-cost extension will be requested to extend the project beyond its current end date of 8/31/2017.

K. Brubaker, June 2017

Assessing riparian hydrologic pathways as controls on forested buffer function in the Antietam Creek watershed, western Maryland

Basic Information

Title:	Assessing riparian hydrologic pathways as controls on forested buffer function in the Antietam Creek watershed, western Maryland
Project Number:	2016MD336B
Start Date:	4/1/2016
End Date:	3/31/2017
Funding Source:	104B
Congressional District:	MD-001
Research Category:	Water Quality
Focus Categories:	Surface Water, Non Point Pollution, Nutrients
Descriptors:	None
Principal Investigators:	Keith N. Eshleman

Publications

There are no publications.

Assessing riparian hydrologic pathways as controls on forested buffer function in the Antietam Creek watershed, western Maryland

Federal award #:*G16AP00061;* UMCP subaward #: *Z9212101*

Stephanie Siemek & Keith N. Eshleman
University of Maryland Center for Environmental Science (UMCES)
Appalachian Laboratory

Progress Report

May 30, 2017

Study Objectives:

- Determine how well planted and natural riparian forest buffer systems (RFBS) function in the Ridge and Valley (R&V) province of western Maryland and identify optimal locations for future RFBS plantings that could maximize nutrient retention.
- Quantify how groundwater-surface water interactions within a representative watershed located in the R&V province of western Maryland affect the efficacy of nutrient retention by riparian buffers.

Research Methods:

- Synoptic survey design and sampling. Systematic synoptic surveys were designed to capture and understand spatial variations in water chemistry along the mainstems of four subwatersheds in western Maryland: Murleys Branch (area = 31.1 km^2; 34 sites) in the Town Creek watershed near Flintstone, MD (**Fig. 1**) and three subwatersheds of Antietam Creek near Hagerstown, MD (Little Antietam Creek North: area = 63 km^2, 9 sites; Beaver Creek: area = 86 km^2, 17 sites; and Little Antietam Creek South: area = 82 km^2, 16 sites) (**Fig. 2**). Three complete synoptic surveys were conducted in the four subwatersheds under seasonal baseflow conditions in spring 2016, fall 2016, and spring 2017. One-L "grab" samples were collected at each site and analyzed for specific conductance, pH, acid neutralizing capacity (ANC), total dissolved nitrogen (TDN), total phosphorus (TP), orthophosphate- P (PO_4-P), ammonia (NH_3-N), nitrite (NO_2-N), nitrate (NO_3-N), chloride (Cl), bromide (Br), sulfate (SO_4), dissolved organic carbon (DOC), and silica (Si) using established analytical methods. Streamflow measurements were made at each of the 76 stations using the standard velocity-area method. Preliminary results suggest that the source of nitrate in the Antietam Creek watershed is likely associated with groundwater discharge from the watersheds' limestone aquifers (**Fig. 3**).

- Intensive, reach-based monitoring. Based on results from the synoptic surveys, we were able to identify several candidate reaches for an intensive, reach-based study of surface water-groundwater interactions in the Antietam Creek watershed. The goal was to identify a reach dominated by planted riparian forest buffer, a control reach lacking forest buffering, and a third reach with a naturally-vegetated riparian buffer (**Fig. 4**). After reconnoitering these reaches and obtaining permission from landowners, we began installing instrumentation. As of this report, one reach (the planted riparian site) has been fully instrumented after installing: 1) staff gauges/water level loggers at the upstream

Figure 1 Map of Murleys Branch watershed in Allegany County, Maryland. Points in upper right map indicate study sites along the mainstem and yellow polygons represent riparian buffers. Stream water runs from south to north.

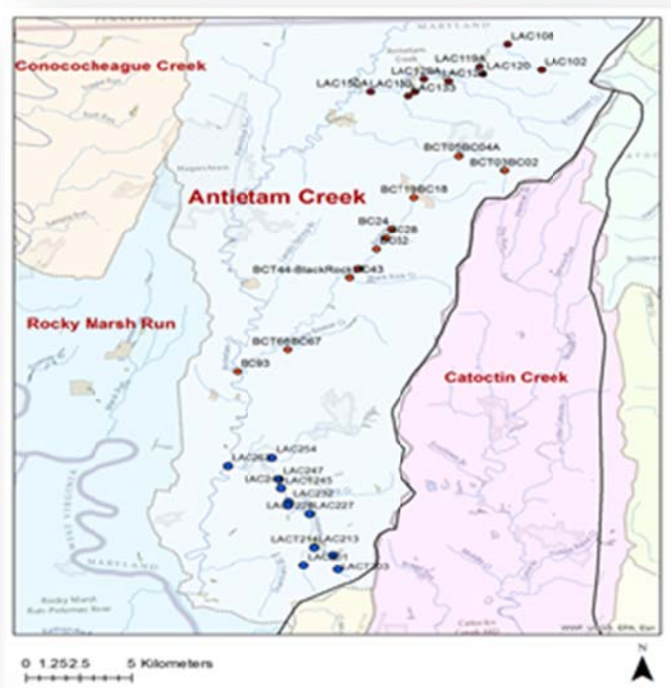

Figure 2 Map of Antietam Creek watershed sites in Washington County, Maryland. Red points in upper region indicate study sites in the Little Antietam Creek North watershed, orange dots indicate study sites in Beaver Creek watershed, and blue dots indicate study sites in Little Antietam Creek South.

and downstream ends of the reach; and 2) a piezometer transect near the middle of the reach containing three shallow (< 1.5 m deep) piezometers each equipped with a water level logger. One piezometer was sited at the edge of the adjacent cropland, one midway across the riparian forest buffer, and one at the edge of the stream (**Fig. 5**). Water level loggers were deployed in each piezometer and at upstream and downstream locations within the planted riparian buffer site. Presently, we are gaging the reach continuously (**Fig. 6**), developing a rating curve, collecting surface and groundwater samples on a biweekly basis, and analyzing the samples for the same set of constituents as in the synoptic work. Quantitative, comparative analysis of hydrologic and biogeochemical exchanges within these reaches will be conducted and discussed in the final project report.

- <u>Geospatial analyses.</u> For all synoptic and intensive monitoring stations, land use was determined using ArcMap 10.2.2 and Light Detection and Ranging (LiDAR) imagery acquired from Department of Geographical Sciences (DGS) at the University of Maryland (UMD); land use coverage was calculated and expressed as a percentage of the total land area (e.g. % forest canopy, % agriculture, etc.). Planted riparian buffers were identified and verified using documentation from Maryland Department of Natural Resources (MDNR). Watersheds (and local contributing areas) were delineated using ArcHydro or TauDEM routines.

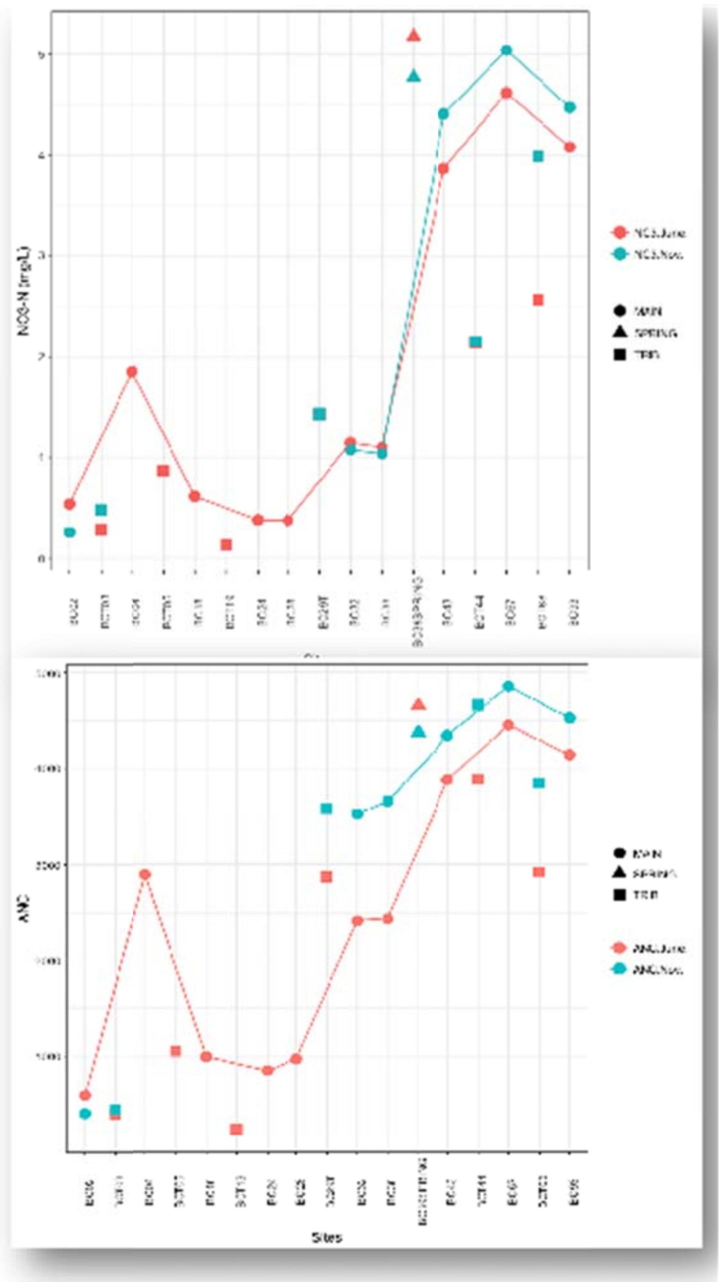

Figure 3 Results from synoptic survey performed in Beaver Creek watershed during June (red) and November (blue) in 2016 showing a possible relationship between NO3-N (mg/L) (top graph) and acid neutralizing capacity (bottom graph). Shapes indicate whether sample was taken from mainstem (circle), spring (triangle), or tributary (square).

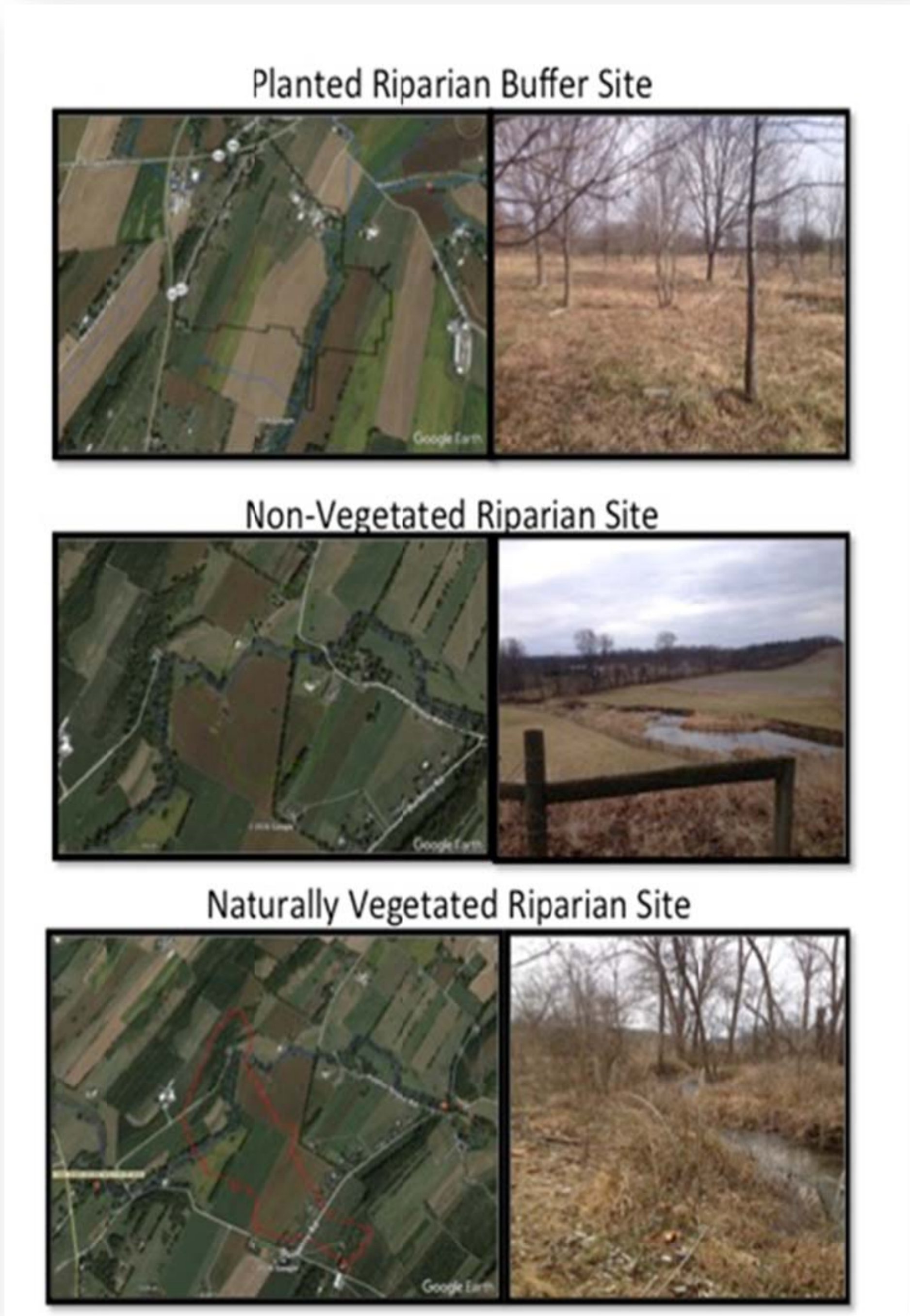

Figure 4 Google Earth images of intensive sites (left) along with pictures taken in the field (right) showing actual landscapes.

Figure 5 Installation of shallow piezometers by hand auguring at the planted riparian forest buffer site.

Figure 6 Stream gaging in the Antietam Creek watershed.

Comparison of velocity, momentum, and flood wave celerity in natural versus channelized Coastal Plain streams

Basic Information

Title:	Comparison of velocity, momentum, and flood wave celerity in natural versus channelized Coastal Plain streams
Project Number:	2016MD337B
Start Date:	5/1/2016
End Date:	4/30/2017
Funding Source:	104B
Congressional District:	
Research Category:	Climate and Hydrologic Processes
Focus Categories:	Floods, Geomorphological Processes, Surface Water
Descriptors:	None
Principal Investigators:	Karen Prestegaard

Publications

There are no publications.

Project Report 2016MD337B
Comparison of Channel Velocity, Momentum, and Flood Wave Celerity in Forested vs Channelized Coastal Plain Streams

Dr. Karen Prestegaard and Carolyn Plank, UMD Geology Dept.

Introduction

River velocity increases with flood magnitude, but the rate of increase of velocity is influenced by channel morphology and flow resistance. In the Maryland Coastal Plain, un-channeled rivers often have wide floodplains and multi-thread channels. The floodplain and channel morphology may significantly affect both channel velocities and flood wave transmission. In particular, flow velocities, and thus momentum (mass * velocity) can be significantly altered by stream channelization and floodplain alteration. In this study we compared flood wave transmission and channel hydraulics in the channelized NE Branch Anacostia with the intact channel-floodplain system of Zekiah Swamp Run.

Study sites selection and rating curve development

Six temporary gauging stations were installed in Zekiah Swamp Run and 5 were installed in the NE Branch Anacostia, supplementing 3 USGS gauges. Water level was monitored with Hobo data loggers set at 5 minute recording intervals. Sites in both tributary and main stem locations provided data for watersheds ranging in size from 1.2 to 120 km^2 in both river systems. Discharge measurements were made at each location for events ranging from low base flow to bankfull stages (fig. 1, left). Rating curves (relationships between gauge height and discharge) were constructed for each of the temporary gauging stations.

Fig. 1: Left: stream discharge measurements, Right: surveying water surface elevations at bankfull stage, both in Zekiah Swamp Run.

Field measurements of channel width, area, and velocity were used to calculate average depth and discharge for each gauge location. Longitudinal bed and water surface gradient was determined from field surveys (fig. 1, right). Water surface gradient at different discharges was used along with depth measurements to calculate the Manning coefficient, n, for selected gauge locations:

$$n = \frac{d^{2/3} S^{1/2}}{V}$$

Where d = depth, S = water surface (energy) gradient, and V = velocity.

These measurements of channel hydraulic variables were used to develop at-a-station hydraulic geometry equations for each gauging station location (Leopold and Maddock, 1953). At-a-station hydraulic geometry depicts the adjustment of the hydraulic variables (width, depth, velocity, gradient, and roughness) to changing discharge at one cross section location. Cross sections can be quite different from place to place, so the hydraulic geometry will also vary. The basis of at-a-station hydraulic geometry is the continuity equation:

$$Q = w * d * v$$

where Q is discharge, w is width, and d is depth. Leopold and Maddock (1953) expressed each discharge component, width, depth, and velocity as power functions of discharge:

$$w = aQ^{b}$$

$$d = cQ^{f}$$

$$V = kQ^{m},$$

Where b, f, and m are exponents. Continuity requires that $Q = a\,Q^{b} * cQ^{f} * kQ^{m}$, therefore $b + f + m = 1$ and $a*c*k = 1$. At-a-station hydraulic geometry can vary along stream reaches, such as the observed differences between riffle and pool sections. (Richards, 1983; Knighton, 1975). Dingman (2007) demonstrated that the hydraulic geometry exponent differences are largely due to cross section shape and flow resistance. Recent work by Gleason (2015) suggests that the coefficients also provide important information on channel adjustments.

We evaluated the hydraulic geometry equations for the various sites along the NE Branch Anacostia and Zekiah Swamp Run. These data indicate significant differences between upstream tributaries and downstream channels in both locations, but the largest differences were between the main stem Anacostia and Zekiah River systems. We are currently evaluating different approaches to characterizing the at-a-station hydraulic geometry of multi-thread channels that we measured in the Zekiah River system (Prestegaard et al., 2016).

Rating curves established for each temporary gauge were used to develop time series of discharge for the period June 1, 2016 to January 15, 2017. These time series data included a number of major storm events. The timing of storm hydrographs peaks at tributary and main stem locations were used to evaluate flood wave celerity, c. The lag time between the initial flood peak at the upstream gauging station and the downstream gauges was determined from the stage data recorders. Wave celerity between gauges was calculated as: distance/lag time. An example of river stage for a series of flood events from the early summer of 2016 is shown in fig. 2. These data indicate that the flood wave was largely translational for events that stayed within the channel banks.

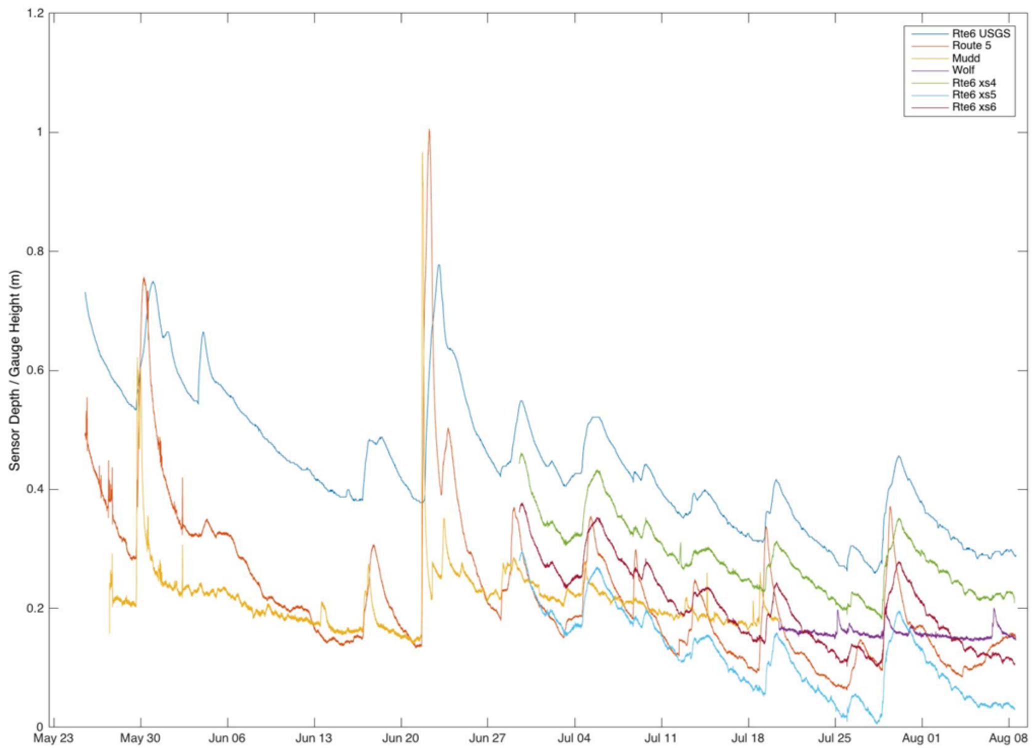

Fig. 2: River stage for the temporary gauge sites within Zekiah Swamp Run. These data indicate the primarily translational movement of flood waves downstream for events below bankfull stage.

Methods for determining river velocity from flood wave celerity have been derived for rivers with simple morphology that provide uniform flow conditions. For these simple channels, flood wave celerity, c, can be related to the average channel velocity, V:

$$c = 5V/3$$

Bedient and Huber 2002. Therefore, it was thought that flood celerity data could be used to estimate channel velocity for these difficult to gauge Coastal Plain streams. Previous studies of wetland –channel systems have used these methods effectively (e.g. Quinton et al., 2003).

Comparison of channel velocity data and celerity calculated from travel time data indicates, however, that actual celerity data are much slower than predicted from the measured velocity data (Prestegaard et al., 2016). This suggests that either: a) the sites we selected for gauging were not representative of the system, or b) that the complex channel morphology in the multiple channel system prevents the use of simple relationships between flood wave celerity and average channel velocity. We are currently evaluating both of these possibilities. We are continuing to work on the data that we have collected from both the Anacostia and Zekiah River systems.

Urban and suburban land-uses continue to expand in the Coastal Mid-Atlantic region. These land-use changes can affect the frequency and magnitude of flood events in both large and small drainage basins. The choices that are made on where land is developed, how to mitigate flood hazards, and whether to naturalize or restore streams requires information on channel morphology, hydraulic geometry, and flood wave transmission in these systems.

References

Dingman, S. L. *(*2007*),* Analytical derivation of at-a-station hydraulic-geometry relations*,* J. Hydrol*., 334(1–2), 17–27*

Bedient P.B., and Huber W.C. 2002. *Hydrology and Floodplain Analysis*, 3rd ed. Prentice-Hall: Upper Saddle River, NJ.

Gleason, C. J. *(*2015*),* Hydraulic geometry of natural rivers: A review and future directions*,* Prog. Phys. Geogr.*,* 39*(*3*)*

Knighton, A. D. *(*1975*),* Variations in at-a-station hydraulic geometry*,* Am. J. Sci.*,* 275*(*2*),* 186–218

Leopold, L.B. and Maddock, T., 1953, The hydraulic geometry of stream channels and some physiographic implications US Geol. Surv. Prof. Pap., 252 (1953), pp. 1–57

Miller, A. (1990): Flood hydrology and geomorphic effectiveness in the central Appalachians, Earth Surface Processes and Landforms, Vol. 15, 119-134.

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Impact of the "308 Reports" on Water Resources Planning and Development in the United States and Implications of the Results for the Future

Basic Information

Title:	Impact of the "308 Reports" on Water Resources Planning and Development in the United States and Implications of the Results for the Future
Project Number:	2016MD347S
USGS Grant Number:	G16AP00019
Sponsoring Agency:	Army Corps of Engineers
Start Date:	2/7/2015
End Date:	9/6/2017
Funding Source:	104S
Congressional District:	None
Research Category:	None
Focus Categories:	
Descriptors:	None
Principal Investigators:	

Publications

There are no publications.

Jeffrey Brideau, Ph.D.

June 1, 2017

Project Progress Summary

Maryland Water Resources Research Center

Below, is a brief summary of the progress made on the project *Impact of the "308 Reports" on Water Resources Planning and Development in the United States and Implications of these Results for the Future*, funded by the National Institutes of Water Resources (NIWR) through a grant administered by the United States Geological Survey (Grant/Cooperative Agreement Number G16AP00019).

In January 1927, the U.S. Congress, speaking through the Rivers and Harbors Act (PL 70-560), instructed the U.S. Army Corps of Engineers (USACE) to prepare a nationwide series of river surveys to determine the feasibility of developing hydroelectric power in combination with navigation, irrigation, and flood control measures. Collectively known as the "308 Program" – named after House Document 308, 69th Congress, 1st Session, which defined the surveys' scope and intent – this program marked the first national, basin-wide, multipurpose water resources planning program in the United States.

The stated objective of this research project is:

> "to explore the linkages between the production of large-scale water resources planning studies by a federal agency, and the material development of water resources at the federal, state, and local levels. Through the analysis of the set of reports, participant motivations, as well as contemporary economic and political events, key lessons will be sought with applications for the development of 21st century water resources planning in the United States."

To achieve these objectives, the co-PI – Dr. Jeffrey Brideau – developed an archival research agenda, identified and reviewed the secondary literature, and proposed a set of project outputs. Early in the project, Dr. Brideau identified a set of archival repositories and specific record groups for the collection of data related to specific case studies. Accordingly, he travelled to archives in Augusta, Athens, and Atlanta, Georgia to examine and capture records related to the Savannah District's 308 report; as well as records from the Office of the Chief of Engineers (RG 77) at the National Archives and Records Administration facility in College Park, Maryland. In sum, Dr. Brideau collected over 10,000 research documents, which were copied, indexed, scanned with optical character recognition, and annotated. Additionally, the 308 surveys have been located, organized, and made publically available on the website of USACE's Institute for Water Resources' website [http://www.iwr.usace.army.mil/Library/IWR-Library/308-Reports-Series/].

Over the past year, Dr. Brideau reviewed this abundance of the archival and secondary material. Last autumn, at the outset of the project's second phase, he presented his preliminary findings to a large group of IWR and University of Maryland scholars in a presentation entitled: *Designing Rivers, Redesigning Institutions: The U.S. Army Corps of Engineers' 308 Reports*. Incorporating the feedback from that presentation and subsequent discussions, Dr. Brideau developed a historical narrative that includes a set of historical and strategic policy lessons to be incorporated into a set of reports, papers, and a presentation. In May of 2017, he submitted a report that delineated the history of the 308 program, including the Savannah River case study, and proposed seven historical lessons as well as eight lessons for decision-makers to consider in the construction of a national-scale water resources strategy. This report was well received within IWR and its reception prompted a reevaluation of the proposed project outputs.

First, during the summer of 2017, the co-PI will produce a modified report for publication by IWR that is composed of a set of historical vignettes that advance lessons for constructing a national water resources strategy. This report will be complemented by a presentation addressed to USACE leadership and other water resources decision makers. Second, the co-PI has engaged the editor-in-chief of the *Journal of Water Policy* about the submission of a peer-reviewed article that delineates the findings of the aforementioned report. They are corresponding about a timeframe for submission, review, and revision; and the co-PI plans to have this paper submitted by Autumn 2017. Third, the Co-PI has proposed a later submission of a second peer-reviewed article to the journal *Environmental History* focused on the research's historiographical interventions – in particular, the institutional transformation of USACE from a dam adverse agency to dam enthusiasts within a national big-dam consensus. Finally, in terms of proposed publications, the PI and co-PI have discussed placing a short article in a significant engineering magazine (e.g. *Civil Engineering* or *The Military Engineer*) to reach a wider audience and publicize ongoing research. Drafts of these publications, in various stages of completion and revision, can be made available upon request.

In terms of data management and dissemination, the co-PI is working with the USACE Office of History to digitally retain and offer wider access to the substantial volume of research materials collected. Dr. Brideau has also worked with the USACE Office of History and U.S. Army's Center for Military History to establish an oral history project at IWR. These oral histories are designed to capture individual stories related to water resources planning and development as well as institutional dynamics at IWR. To date, Dr. Brideau has conducted, recorded, and assembled seven oral history interviews with senior and retired staff at IWR as well as past recipients of the Maass-White fellowship. Several more interviews are planned and scheduled over the upcoming months – with the goal of 15 interviews completed by the end of 2017. Once there is a critical mass of interviews, they will be transcribed, edited, and published by IWR. The oral history component of this will complement a written history of IWR awaiting publication, capture institutional memory at the Institute, and offer a variety of perspectives on

IWR's evolution, the current state of water resources planning and development, and ideas for its future.

Additional information on the project's status, ongoing research endeavors, citations, submitted reports or anticipated publications and other outputs can be provided by contacting the co-PI at: jbrideau@umd.edu.

Information Transfer Program Introduction

MWRRC's 2016 Information Transfer projects included the annual Water Resources Symposium and a seed grant to begin development of a "watershed address" app. Both will continue into funding year 2017, as described in the brief reports.

Maryland Water 2016 Symposium

Basic Information

Title:	Maryland Water 2016 Symposium
Project Number:	2016MD338B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	7
Research Category:	Not Applicable
Focus Categories:	None, None, None
Descriptors:	None
Principal Investigators:	Kaye Lorraine Brubaker

Publications

There are no publications.

2016MD338B Maryland Water 2016 Symposium

A Maryland Water Symposium was not held in 2016. One will be hosted in Fall 2017; no additional funding was requested for this purpose in the funding year 2017 application.

Maryland Watershed App Development (Seed Grant)

Basic Information

Title:	Maryland Watershed App Development (Seed Grant)
Project Number:	2016MD339B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	MD-005
Research Category:	Not Applicable
Focus Categories:	Surface Water, None, None
Descriptors:	None
Principal Investigators:	Kaye Lorraine Brubaker

Publications

There are no publications.

2016MD339B Maryland Watershed App Development (Seed Grant)

A pilot version was begun on the University of Maryland Campus, which lies in the watersheds of several headwater tributaries of the Anacostia River. We faced interesting challenges of water flow delineation in an urbanized location; because of pavement, guttering, and storm drains, surface topography is insufficient to determine flow direction. The resolution of these challenges will prove useful and interesting as we expand to the entire Anacostia watershed.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	0	0	0
Masters	0	0	0	0	0
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	1	1
Total	2	0	0	1	3

Notable Awards and Achievements

Two MWRRC investigators were awarded promotion with tenure this year:

- Dr. Stephanie Lansing, Associate Professor, Environmental Science & Technology, University of Maryland, College Park (2015MD324B)
- Dr. Joel Moore, Associate Professor, Geosciences, Towson University (2013MD306B, 2014MD313B)

The Center is pleased that NIWR support has contributed to success at the early career level.

Publications from Prior Years

1. 2015MD329B ("Retrospective Analysis of Nutrient and Sediment Loadings and Trends in the Chesapeake Bay Watershed (Graduate Fellowship)") - Articles in Refereed Scientific Journals - Zhang, Qian; William Ball, 2017. Improving riverine constituent concentration and flux estimation by accounting for antecedent discharge conditions. JOURNAL OF HYDROLOGY 547, 387-402 DOI: 10.1016/j.jhydrol.2016.12.052
2. 2015MD329B ("Retrospective Analysis of Nutrient and Sediment Loadings and Trends in the Chesapeake Bay Watershed (Graduate Fellowship)") - Articles in Refereed Scientific Journals - Zhang, Qian; Ciaran J Harman, William P Ball, 2016. An improved method for interpretation of riverine concentration-discharge relationships indicates long-term shifts in reservoir sediment trapping. GEOPHYSICAL RESEARCH LETTERS 43(19) 10215-10224 DOI:10.1002/2016GL069945.
3. 2015MD329B ("Retrospective Analysis of Nutrient and Sediment Loadings and Trends in the Chesapeake Bay Watershed (Graduate Fellowship)") - Articles in Refereed Scientific Journals - Zhang, Qian; William P Ball, Douglas L Moyer, 2016. Decadal-scale export of nitrogen, phosphorus, and sediment from the Susquehanna River basin, USA: Analysis and synthesis of temporal and spatial patterns. SCIENCE OF THE TOTAL ENVIRONMENT 563 1016-1029 DOI: 10.1016/j.scitotenv.2016.03.104
4. 2012MD262B ("Quantifying remobilization rates of legacy sediment from Maryland Piedmont floodplains") - Articles in Refereed Scientific Journals - Donovan, Mitchell; Andrew Miller, Matthew Baker, 2016. Reassessing the role of milldams in Piedmont floodplain development and remobilization. GEOMORPHOLOGY 268 133-145 DOI 10.1016/j.geomorph.2016.06.007
5. 2014MD314B ("Wetland restoration: Experimental effects of soil carbon:nitrogen ratio on growth of invasive and native Phragmites australis (common reed)") - Articles in Refereed Scientific Journals - Willson, Kevin G; Angela Perantoni, Zachary C Berry, Matthew I Eicholtz, Yvette B Tamukong, Stephanie A Yarwood, Andrew H Baldwin, 2017. Influences of reduced iron and magnesium on growth and photosynthetic performance of Phragmites australis subsp americanus (North American common reed), AQUATIC BOTANY 137, 30-38, DOI: 10.1016/j.aquabot.2016.11.005