Chesapeake Community Research Symposium 2024

Session 7: River Corridor Sciences and Management

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Legacies lost and found: Improving stream restoration practice and water quality policies

Stream restoration as a means of improving water quality, ecosystem processes, and biodiversity is widely practiced and accelerating in the United States, but restoring degraded waterways requires deep understanding of root causes of impairments. Here we present research that improves our understanding of restoration success and cost-effectiveness, which may aid in developing science-based policies for restoration practices. Instead of focusing on single-thread, meandering stream planforms as restoration targets, we highlight the benefits of using geological and historical trajectories of valley bottoms as a guide. In the mid-Atlantic region of the eastern United States, stream-wetland complexes were common valley bottom features during the Holocene Epoch (the past ~11,500 years) until European settlement in the 17th and 18th C. Anthropogenic degradation of waterways that followed was swift and widespread, particularly because of damming for waterpower.

Restoring stream-wetland complexes requires a comprehensive aquatic ecosystem approach that integrates process- and form-based restoration principles. Here we trace intersecting scientific research and policy developments that led to inclusion of a novel aquatic floodplain wetland restoration as a Best Management Practice (BMP), with implications for substantial water-quality improvements in the Chesapeake Bay Watershed. We implemented an extensive monitoring program at Big Spring Run in Lancaster County, PA to quantify reduction efficiencies in nutrient and sediment loads and quantify geomorphic and ecosystem enhancements. This restoration resulted in substantial, rapid reductions in sediment, nitrogen, and phosphorus loads at low unit costs in comparison to many agricultural BMPs.

Hydrogeomorphic, floral, and faunal shifts indicate substantial improvements in ecosystem services.
Landscape legacies matter greatly in diagnosing causes of degradation, bank erosion, and high sediment and nutrient loads in streams. Considering these trajectories in restoration designs and targeting stable Holocene valley bottom conditions as a guide can lead to cost effective solutions and policies to restore regional waterways.

James Pizzuto

New Data On Mid-Atlantic Piedmont River Corridor Sediment Transport Processes From the mid-Holocene to the Present: Implications for Restoration and Management

Stratigraphic data are used to reconstruct river corridor sediment transport processes and sediment budgets from before European colonization to the present, which in turn provides the foundation for calibrating a watershed scale sediment routing model that can quantify "lag" effects caused by floodplain sediment storage. While a mosaic of environments characterized river corridors prior to European settlement, floodplain sedimentation during overbank flows was the dominant process of river corridor sediment storage. Anastomosing wetland channel systems (often used as a template for current restoration) were present, but rare. Channels were floored with partially mobile gravel, with a few low-amplitude pebbly bars similar to those of modern streams. While many mill dams were built during the 19th century, mill pond deposits are unusual, and overbank deposition remained the dominant process of river corridor sediment storage, as it is today. Sediment budget modeling, calibrated to stratigraphic data and contemporary observations of floodplain deposition and erosion, suggests that the balance of sedimentation and erosion has not changed google . A model for downstream sediment movement, calibrated using these data, suggests that most particles will be deposited on a floodplain within ~ 100 km of first entering a river corridor, implying that Best Management Practices in headwater streams far from the Chesapeake Bay may not yield their full intended benefits for centuries.

Zach Clifton

Hidden legacies: investigating a buried pre-colonial stream corridor in the Atlantic Coastal Plain, Maryland, USA

Within the Mid-Atlantic Coastal Plain, widespread landscape disturbance during European colonization resulted in the erosion and subsequent storage of legacy sediments within river valleys and floodplains, altering their form and function. Landscape modification and land-use practices changed the natural dynamics of these riparian ecological networks by affecting riparian vegetation composition, sediment character, and metal concentrations. Using ground-penetrating radar, pollen records, radiocarbon dating, and sediment cores this USGS study investigated the physical form and riparian vegetation of pre-colonial stream corridors located within the Coastal Plain of Anne Arundel County, Maryland, documenting the changes from pre- to post-colonial time periods. This study provides evidence of buried, precolonial riparian corridor ecosystems dating between 750 yrs. BP – 8000 yrs. BP. These ecosystems were likely a spatiotemporally-dynamic patch ecosystem, largely dominated by dense alder scrub swamps with variable grass- and sedge-dominated meadows and organized in both multi-threaded and single-threaded channel forms. This complex network of varying stages of stream evolution and successional transitions, often disrupted by fire and beaver influences, are comparable to the patchy communities described as “kaleidoscope rivers”.
These precolonial floodplains are buried by vast amounts of postcolonial legacy sediment to the extent that pre-colonial sediments are largely not exposed in the modern valley bottom. While many of these channels are now deeply incised, Coastal Plain streams remain perched within colonial legacy sediments, and it is likely that they reside in an alternative equilibrium steady-state increasingly unlikely to return to its precolonial ecological and geomorphic form. Notably, the Coastal Plain precolonial corridors found in this study contrast to the non-wooded

stream-wetland ecosystems exposed in stream banks and described in other nearby physiographic regions. These results provide valuable information to understanding past conditions and its changes in the Mid-Atlantic Coastal Plain, channel evolution trajectories, and provide important context for management and ecosystem restoration decision-making.

Dave Guignet, Eileen Gladd, P.E.

Application of Geospatial Data in Flood Hazard Mapping

Flood maps show the relationship between a property and the areas with the highest risk of flooding. There is no such thing as a "no-risk zone," but some areas have a lower or moderate risk. The Maryland Department of the Environment (MDE) houses the State Office of the National Flood Insurance Program (NFIP) in Maryland, which serves as a Cooperating Technical Partner with FEMA and liaises flood map modernization and updates in 23 of 24 Maryland Counties. In this role, MDE coordinates data standards for the hydrologic and hydraulic modeling behind Risk maps to communicate flood risk. In addition to the high standards for credibility and review processes that all FEMA Flood Insurance Rate Maps (FIRMs) undergo to be able to be used for floodplain regulations, Maryland leads the nation by having model backed floodplains and providing geo-referenced models available for download. In this session, we will walk through the floodplain data available on mdfloodmaps.net and how it was developed using geospatial data.

Gina Lee, Andrew Miller

Application of high-resolution remote sensing to support hydraulic modeling and measurement of velocity fields

The purpose of this study is to demonstrate the utility of three different forms of remote sensing (LiDAR, Structure from Motion [SfM], and Particle Image Velocimetry [PIV]) to support measurement of channel velocity fields, 2D hydraulic modeling of in-channel flows, and sensitivity analysis of modeled flow fields to grid resolution and roughness parameterization. One goal of this analysis was to determine whether the inherent roughness of the channel bed that is captured in higher resolution DEMs results in more accurate hydraulic modeling outcomes. We have a ~2 cm-resolution SfM-derived point cloud and digital elevation model along a ~3-kilometer reach of Minebank Run, in Baltimore County, MD collected in 2020. Hydraulic modeling for sensitivity analysis of grid resolution and roughness parametrization was carried out in HECRAS-2D, using the 2020 SfM DEM merged with 2015 LiDAR data as input data for the modeling domain at various DEM resolutions (2cm, 10cm, 30cm, and 1m), at different computational grid cell sizes (50cm, 1m, and 3m), and using a various Manning's n values across the modeling domain. In addition, RiVER Particle Image Velocimetry (PIV) software was used on videos of moderate flows in the channel to extract surface velocities for discharge estimates, and were compared with official discharge at the USGS Minebank Run stream gage. Our PIV derived discharge values were within 10% of the measured discharge value at the USGS gage at the time of the recording, and thus velocities extracted from the PIV videos were used in validating our hydraulic modeling scenarios. We found that SfM derived DEMs are feasible for use in hydraulic modeling; that hydraulic models are indeed sensitive to DEM and computational grid size resolution but less sensitive to the Manning's n parameter; and that PIV provides a quick and safe way to extract stream channel velocities during moderate flows.

Rohith A N, Cibin Raj; Alfonso Mejia

Development of a medium-range ensemble streamflow forecasting system for the Potomac River Basin

Streamflow forecasting models are valuable tools for guiding water resources management decision-making, specifically to mitigate the impact of floods and droughts. The Potomac River Basin (PRB) serves as the water supply demands of Washington D.C., requires proper management of reservoir releases to ensure meeting the water supply demands under prolonged drought conditions. Hence, we develop and verify a robust modeling framework to forecast low flow conditions for the PRB. Generally, verifying the flow forecasting system emphasizes high flows to mitigate the flood, ignoring the implications during drought. We employ a low-flow centric verification system that emphasizes the accuracy of low flow and ensures reasonable high-flow forecasts. The retrospective weather forecasts from the Global Ensemble Forecast System for the period 2000 to 2019 and operational Climate Forecast System archives from 2017 to 2023 were used to verify the accuracy of precipitation and streamflow. The retrospective and operational weather forecasts were driven through a hydrological model, which is a combination of Soil and Water Assessment Tool Plus and process-based detailed groundwater simulation (SWAT+gwflow) for improved representation of groundwater flow. The model incorporated detailed reservoir operation rules and was calibrated for streamflow and verified for streamflow and groundwater well observation. The results evaluated through several performance metrics indicate good performance in the low flow forecasting model and the potential to serve as a tool to coordinate reservoir operations to meet water supply and water quality demands in the region.

Ollie Gilchrest

Hydrodynamics and Sediment Transport in the Tidally Influenced James River, VA

The tidally influenced James River is an important economic, ecologic, and cultural resource for VA residents. Tidal rivers have been historically understudied, however they are critical transition zones, the dynamics of which have implications for freshwater supply and sediment trapping. Globally, estimates suggest that >30% of fluvial sediment is trapped in the tidal zone, the location and dynamics of which are actively changing due to sea level rise and saltwater encroachment. In addition, analysis of historical water levels on the James River has shown a decrease in the tidal range since 1940. The present study combines >1-year's worth of hydrographic measurements collected using sensors deployed in 2018-2019 with more-recent ship-based observations, to evaluate the dynamics of saltwater intrusion and sediment trapping.

Analysis of these data provides a better understanding of the mechanisms behind the location of the ETM and extent of saltwater in the James River. The cross-channel measurements of velocity collected across a complete tidal cycle are used to describe the internal water structure and mixing processes observed during the transition from ebb to flood tide and vice versa. Visualizations of these data depict a lag in the tidal reversal in the main thalweg during the transition from ebb to flood tide. This demonstrates some of the system's complexity, and will have important implications for predicting sediment deposition. Calculations of the discharge in the system were combined with suspended sediment data to quantify the transport of sediment in the system. Subsequent analysis will combine the time-series observations with the ship-based measurements to extend our understanding of the tidal dynamics in both space and time.