



## **Chesapeake Community Research Symposium 2026**

Session 2: Advancing Chesapeake Bay Water-quality Science and Management: I.  
Innovative monitoring techniques and modeling tools

Session Leads: Qian Zhang, Kaylyn Gootman, Peter Tango, & Breck Sullivan

---

**Richard Zimmerman (Department of Ocean & Earth Sciences, Old Dominion University),  
Victoria Hill, David Ruble, Chandler Slater, Jason Boynewicz, Isabella Chandler**

A Low-Cost Spectroradiometer for Aquatic Sciences and Water Quality Monitoring

In situ radiometry represents a key optical tool for monitoring water quality, ecosystem productivity and biogeochemistry. While expensive instruments (>\$20,000) capable of measuring the spectral properties of the submarine light field have been in existence for some time, low cost radiometers (<\$2,000) commonly used for water quality monitoring have been limited to single channel measurements of photosynthetically active radiation (PAR). There will be greater need for ground-based and in-water measures of spectral radiance, irradiance and other optical properties of natural waters as spectrally resolved numerical models such as GrassLight and high spatial resolution multispectral and hyperspectral satellite imagery becomes more widely used. Using a miniature sealed spectrographic chip from Hamamatsu, we designed a low-cost radiometer system that costs ~\$1,000 in parts and covers the spectral range from 340 to 850 nm in 288 channels (<10 nm FWHM) at 12-bit resolution using sampling times from 1ms to 9 s. It is capable of measuring the range of spectral intensity from moonlight to full sunlight at noon without saturation. The spectrograph is controlled by an Arduino-based microcontroller and software capable of autonomous field operation for several days using rechargeable or disposable AA batteries. The system is housed within a water-tight enclosure that can be deployed with radiance or plane irradiance collecting optics to depths of 100 m as a moored or profiling instrument to facilitate in-water measurements of spectral downwelling or upwelling irradiances, radiances, attenuation coefficients and in-water reflectances. It can also be deployed above water to measure remote sensing reflectance, providing a pathway to validation of satellite derived ocean color data. Field testing across the Chesapeake Bay, Delmarva coastal lagoons, and the Mid-Atlantic Bight confirms that this system provides a viable, scalable solution for high-resolution optical oceanography and improved water quality monitoring.

---

**Victoria Hill (Old Dominion University), Richard Zimmerman, Jacob Gallagher, Damien Taylor, Maria Guardado, Anamika Kona, Mary LePere, Alexandria Rhodes**

Mapping Seasonality in Submerged Aquatic Vegetation Growth in the Chesapeake Bay Using Planet Satellite Imagery

Submerged aquatic vegetation (SAV) plays a critical role in the Chesapeake Bay ecosystem by stabilizing sediments, improving water quality, and providing essential habitat for fish and invertebrates. Monitoring SAV distribution at bay-wide scales, however, has historically been challenged by logistical constraints and limited temporal resolution of traditional aerial surveys. To address these challenges, we leveraged high-resolution Planet Labs satellite imagery from 2020 through 2024 to map SAV across the entire Chesapeake Bay from freshwater to mesohaline and polyhaline regions, with the goal of detecting seasonal patterns and long-term trends in SAV extent.

Satellite-derived maps revealed strong seasonal variability in SAV distribution that differed by salinity regime. Seasonality was most pronounced in low salinity environments where SAV area and density expanded rapidly during the spring and early summer, peaked between June and August, and declined to minimal winter coverage. In contrast, polyhaline regions exhibited weaker seasonal changes in areal extent, with density increases associated with spring growth and flowering. Beyond seasonal variability, results indicate a general increase in total SAV extent across the Bay since 2020, although localized declines were observed in several sub-regions. To investigate environmental drivers of these patterns, ongoing analyses are integrating satellite products with ancillary datasets including turbidity, nutrient concentrations, salinity, and temperature.

Overall, this study demonstrates the power of high-resolution satellite imagery for monitoring SAV at ecosystem scales with unprecedented temporal frequency. By capturing both seasonal and interannual variability in SAV dynamics, Planet imagery provides valuable insights into the health and resilience of coastal ecosystems like the Chesapeake Bay. Our findings have important implications for resource management and restoration planning and illustrate the potential of satellite-based approaches for long-term coastal monitoring in a changing climate.

---

**Maria Guardado (Old Dominion University), Victoria Hill, Richard Zimmerman**

Quantifying Seasonal Variability in Seagrass Extent and Density Using Physics-Based Remote Sensing Models

Accurate and frequent monitoring of SAV extent and condition is essential for tracking restoration progress and understanding responses to environmental variability. In this study, high-resolution Planet Labs satellite imagery (3-m resolution) was used to map seagrass distribution in Pocomoke Sound, Virginia, from 2021 through 2025. Supervised classification methods were used to quantify SAV extent across seasonal timescales. Seagrass density was estimated using a physics-based model to retrieve leaf area index (LAI), which was converted to aboveground biomass using published transfer coefficients. Mapping SAV in this region is particularly challenging due to optically complex waters characterized by high concentrations of suspended sediments and colored dissolved organic matter, which strongly attenuate light and reduce water-leaving reflectance. Additionally, seagrass beds in Pocomoke Sound exhibit

patchy spatial structure, increasing classification uncertainty and complicating detection of fine-scale changes in coverage. Despite these challenges, the time-series analysis reveals a consistent seasonal pattern in SAV extent, with 3.5 km squared average summer extent area that declines in the winter. Ongoing fieldwork conducted during the summer of 2025 will collect in situ measurements to tune the LAI and carbon retrieval algorithms, including refinement of the empirical relationship between LAI and bottom reflectance (R<sub>b</sub>). Together, these results demonstrate the potential of high-resolution imagery for capturing seasonal dynamics of SAV in optically complex coastal environments and advancing quantitative monitoring of seagrass ecosystems.

---

**Jacob Gallaher (Old Dominion University), Victoria Hill, Richard Zimmerman**

Using Satellite Imagery to Map Seasonal Variation of Seagrass Meadow Area and Blue Carbon in Chincoteague Bay

Understanding and quantifying seagrass abundance is critical for conserving coastal ecosystems where these ecosystem engineers provide shelter for fish and shellfish, improve water quality, and help stabilize shorelines. However, recent interest has focused on understanding carbon cycling and sequestration within shallow coastal waters. Satellite imagery can enable more efficient and higher frequency assessment of seagrass abundance and above ground carbon biomass compared to traditional annual aerial surveys. Using Planet Labs 8-band satellite imagery (3-meter resolution) and manually delineated training patches, we employed a support vector machine classification model to map temporal variation in seagrass distributions across Chincoteague Bay from 2021 through 2025. We then applied a physics-based model to retrieve Leaf Area Index (LAI), a measure of submerged plant density, for each seagrass pixel and converted those densities to above ground carbon biomass using linear transfer coefficients. Clear seasonal patterns in extent were observed with total seagrass area reaching 11 – 21 km<sup>2</sup> in the summer and decreasing by >50% in winter. Mean density within seagrass pixels was remarkably stable throughout the year at on average ~1.0 m<sup>2</sup> leaf m<sup>-2</sup> seafloor, as seagrass contracted in areal extent in the winter, density within the beds remained stable. Total carbon in seagrass biomass was estimated to be ~1.3 Gg carbon during the summer maximum. We also observed significant interannual variation in seagrass distribution during the growing season, from a high of 18.5 km<sup>2</sup> in 2021 to 11.1 km<sup>2</sup> in 2023, with apparent recovery to 18.9 km<sup>2</sup> in the 2024 growing season. We are currently exploring impacts of water clarity, temperature, and salinity metrics on patterns seen in time series observations. This study illustrates how access to high-frequency, high-resolution satellite imagery can transform our ability to measure and monitor the dynamics of coastal resources in the critically important coastal bays of the Mid-Atlantic region.

---

**Max Ruehrmund (NOAA Chesapeake Bay Office), Jay Lazar**

Leveraging Collaborative Infrastructure for Monitoring Dissolved Oxygen in Chesapeake Bay

Water-quality impairment in Chesapeake Bay manifests as seasonal hypoxia in the deep troughs of water bodies of all sizes and most notably in the mainstem of the Bay. Capturing the full vertical and horizontal extent, as well as the duration, of these hypoxic zones is essential for accurately assessing the system's health and response to improvements. To address this challenge, NOAA Chesapeake Bay Office (NCBO) has deployed a novel infrastructure designed to collect continuous high-temporal-frequency water column data, which stakeholders are using for advanced ecological forecasting and effective ecosystem management.

This presentation outlines our data collection methodology and the collaborative framework used to sustain it. We are piloting a resource-sharing model wherein NCBO supplies the necessary monitoring equipment, IT infrastructure, and Quality Assurance/Quality Control (QA/QC) protocols, while regional stakeholders and partners execute field operations and maintenance. We will discuss the current status of the network and our strategic plans to expand partnerships across the region. Extending this collaborative reach will increase data density, ultimately helping to improve forecast models and track the progress of vital restoration efforts.

---

**Weston M. Slaughter (University of Maryland College Park, Department of Geology)**

Sensor networks reveal salinity-dependent controls on hypoxia, diel extremes, and productivity–alkalinity coupling in a Chesapeake Bay tidal tributary

Salinity gradients structure ecological communities and biogeochemical processes in estuaries. Understanding how water-quality extremes and their drivers shift with salinity requires observations that capture high temporal variability and are sufficiently dense along the salinity gradient. We analyze two decades (2000–2023) of high-frequency (15-minute) sensor measurements and Chesapeake Bay Program discrete chemistry data collected at stations spanning the tidal Potomac River. We emphasize a two-year intensive period (2007–2008) when ~20 stations operated simultaneously across the Potomac's 0–18 ppt salinity gradient, enabling evaluation of how DO, pH, chlorophyll-a, and nutrient relationships vary across salinity zones. Continuous sensor data displayed broader value ranges and more frequent threshold exceedances than discrete sampling, showed strong longitudinal structure in DO and pH extremes, and revealed how discrete sample measurements of DO and pH compare to the total distributions of these values gathered by sensors. Summertime daily maximum pH exceeded 8.5 on ~88% of days in tidal fresh waters and ~68% in oligohaline zones, but <10% of days in mesohaline regions. Daily minimum pH fell below 7.5 on ~25% of days in tidal fresh waters and ~35% in high mesohaline zones, and on ~55% of days in oligohaline and low-mesohaline zones. Diel DO and pH variability declined with increasing salinity. Coupling between DO departure from equilibrium and pH—a metabolic and carbonate-system indicator—was significant across salinity zones and seasons, with slopes decreasing with salinity, indicating changing process controls. High-frequency data also revealed bimodal timing of daily DO minima, with a growing fraction occurring between sunset and midnight at higher

salinity—patterns not detectable with discrete daytime sampling. Nutrient–pH relationships reversed along the gradient, consistent with shifting nitrogen versus phosphorus limitation. Strong DO–pH coupling alongside alkalinity data indicates that short-term pH extremes can occur even under relatively high buffering capacity. Together, these results show that integrated sensor–discrete frameworks improve interpretation of thresholds and provide process constraints for Chesapeake Bay water-quality assessment and model development.

---

**Claire Welty (UMBC), Mary McWilliams, Andy Miller, PJ Terhune, John Lagrosa, Bob Bathurst**

Evaluation of pollutant removal effectiveness of stormwater facilities using high-frequency water quality sensors

We have outfitted inlets and outlets of three stormwater management facilities in the Baltimore region with high-frequency sensors to estimate load reduction of total nitrogen, total phosphorus, and total suspended solids. Under Maryland requirements, pollutant removal effectiveness must be demonstrated using laboratory analysis of grab samples spanning entire storms, which can be challenging to collect. We aim to demonstrate correlation of grab samples TN, TP, and TSS to relevant sensor data, such that sensor data can be used as an adequate proxy in pollutant removal calculations. In addition, we are installing SmartSWM Continuous Monitoring and Adaptive Control technology after one year, to test the hypothesis that CMAC can be used to enhance pollutant removal in addition to flood control. Facilities being instrumented include one wet pond and two extended-detention dry ponds upgraded with gabion sand filters. Sensor data include specific conductance, temperature, turbidity, nitrate, and discharge. System design and initial data will be presented. This work is supported by Chesapeake Bay Trust.

---

**Alexander Soroka (U.S. Geological Survey)**

Large sediment yield after mitigation projects, then development: The story of Foster Branch

The Foster Branch watershed in Harford County, Maryland, is small (less than 2 square miles) and until recently the land cover was split between forest and suburban residential communities. From 2014 to 2018, Harford County implemented restoration and stormwater mitigation projects to improve water quality in Foster Branch. In 2015, the USGS installed a continuous water quality monitoring station (USGS 01585075) and began water sample collection to monitor for environmental benefits of these projects. In 2022, forest clearing and subsequent development occurred in the upper portion of the Foster Branch watershed, coinciding with increases in suspended sediment concentrations and turbidity. The enhanced data collection at Foster Branch allowed for accurate sediment load calculation before, during, and after development. In 2022, the year of greatest watershed disturbance, the suspended sediment load was greater than 1200 tons per square mile of watershed. Load models incorporating high-frequency data

predicted sediment loads at least 25% higher than those based on discrete samples. This presentation will discuss the advantages of high frequency monitoring to understand the effects of changing land management.

---

**Shuyu Y. Chang (Franklin & Marshall College), Robert C. Walter, Mia Aaronson, Michael Rahnis, Dorothy Merritts**

Cooler Waters, Reconnected Valleys: Restoration Gains from Milldam Legacy Sediment Removal

More than a hundred thousand of milldams were constructed across the northeastern U.S., fundamentally altering the landscape. Sediment trapped and accumulated behind these structures buried pre-settlement Holocene wetlands, and after milldam failure has become a significant source of pollution in the Chesapeake Watershed. A new restoration paradigm is taking shape through the removal of legacy sediments, allowing original wetland-stream ecosystems to re-emerge.

Here, we continue to examine thermal and hydrological responses following floodplain-wetland valley bottom restoration in 2011 at Big Spring Run (BSR) in Pennsylvania. We hypothesize that legacy sediment removal and floodplain-wetland restoration will enhance stream-groundwater connectivity by promoting the daylighting of springs buried for centuries, and increase base-flow resilience within this human-impacted, sediment-filled terrain.

Our pre-to post-restoration observations indicate that BSR exhibits: (1) the re-emergence of previously buried springs. (2) enhanced floodplain connectivity; and (3) reduced coupling of surface water with atmospheric temperature. Despite widespread warming trends at most monitored sites in the Chesapeake Bay region, BSR stands out as an anomaly: spring–summer water temperatures declined by approximately 3 °C per decade, even as air temperatures increased by 1.5 °C per decade. The ratio of annual water to air temperature signal amplitude declined from 0.5 to 0.38, suggesting a shift toward a more groundwater-dependent thermal regime. Hydrologically, the runoff ratio decreased from 0.6 to 0.4, accompanied by reduced runoff volumes, attenuated peak flows, resilient baseflows, and enhanced buffering capacity - consistent with increased hydrologic connectivity and infiltration. Additionally, winter drone imagery revealed thermal hotspots that pinpointed the locations of newly emerged springs. Together, these results demonstrate the potential of this novel valley-bottom restoration approach to improve water and ecosystem quality, restore local streams, and mitigate flooding.

---

**Greg Noe (U.S. Geological Survey)**

Watershed controls and Chesapeake-wide predictions of streambank erosion rates

Excess fine sediment is a common stressor of stream ecosystem health and is critically important to pollutant loading to the Chesapeake Bay. Streambank erosion is a source of excess fine sediment in watersheds that directly affects stream habitat and human infrastructure and property. However, rates of streambank erosion are highly variable across stream drainage networks and different watershed land use. Updates to a statistical model will be presented in which we have nearly doubled the number of study sites where streambank erosion rates were measured using dendrogeomorphology, sediment collection, and surveying, is being updated by nearly doubling the number of sites collected. These measured rates of streambank erosion will be combined into a new machine-learning statistical model to explain spatial variation in rates using upstream watershed attributes such as land use, soils, hydrology, and topography, and to extrapolate predicted rates of streambank erosion to the entire 1:24K digital stream network of the National Hydrology Dataset – High Resolution for the Chesapeake Bay watershed. The new understanding of drivers and fine-scale predictions of streambank erosion could help watershed managers to identify priority areas for stream management and improve watershed models of pollutant sources and transport."

---

**Andrew Sekellick (U.S. Geological Survey - MD-DE-DC Water Science Center), Alexander Soroka**

Modeling Nutrient Sources, Fate, and Transport in the Chesapeake Bay Watershed Using an Updated SPARROW Framework to Support Stakeholder Decision-Making

Evaluating the fate and transport of nutrients in streams as well as the effects of agricultural conservation practices on regional water quality remains challenging due to complex factors such as diverse nutrient sources, delivery factors, and transport mechanisms. To address these and other challenges, an updated SPARROW (SPATIally Referenced Regression On Watershed attributes) model has been developed to estimate nitrogen and phosphorus loads in more than 86,000 stream reaches across the Chesapeake Bay watershed. Flow-normalized monitoring data from up to 122 stations as part of the Chesapeake non-tidal network is used in conjunction with spatially referenced landscape and climate data. This approach provides coverage in unmonitored areas, isolation of source contributions, flow-normalized estimates, quantified uncertainty, and a data-driven foundation for analysis.

Model outputs are generated at the 1:100,000 NHDPlus Version 2 scale and include estimates of local catchment (incremental) loads and accumulated (total) loads delivered to the estuary under flow-normalized conditions for the year 2021. These estimates quantify the relative contributions of major nutrient sources, the influence of landscape characteristics on nutrient delivery, and the effects of in-stream decay. In addition to the nitrogen and phosphorus models developed for the year 2021, a framework was designed for continuous updates, supporting future scenario analyses and multi-timestep applications. By providing spatially detailed, source-specific nutrient load estimates, these models can improve understanding of nutrient dynamics and inform management strategies aimed at improving water quality in the Chesapeake Bay watershed.

---

**Qian Zhang (University of Maryland Center for Environmental Science / USEPA Chesapeake Bay Program Office, Annapolis, MD, United States), Gopal Bhatt, Kaylyn Gootman**

Are we on track? Integrating monitoring and models to track load reduction progress in the Chesapeake Bay watershed

Reductions of nitrogen, phosphorus, and sediment loads are central to watershed restoration efforts worldwide, including in the Chesapeake Bay. Watershed models and riverine monitoring programs both provide critical information on progress toward these goals; however, they often yield inconsistent interpretations. To address this challenge, a watershed-wide Total Maximum Daily Load (TMDL) indicator was developed for the Chesapeake Bay to explicitly quantify progress toward nutrient reduction goals by integrating monitored and model-expected load trends (<https://doi.org/10.1016/j.ecolind.2023.111357>). Application of this indicator shows that the Bay watershed has made measurable long-term progress toward its nutrient reduction targets. The indicator framework is transferable to other watersheds where similar data exist, enabling broader evaluation of restoration trajectories and the pace of change. Therefore, we developed a R Shiny application—Monitored and Expected Total Reduction Indicator for the Chesapeake (METRIC)—that provides an interactive platform for integrated visualization and analysis of monitored and model-expected loads at the subwatershed scale (<https://wqs.chesapeakebay.net/metric/>; <https://doi.org/10.1016/j.ecolind.2023.111357>). Although both data types are available from multiple agencies, they are rarely presented in a unified, directly comparable format. METRIC is designed to bridge this gap by making complex datasets accessible and interpretable for managers, scientists, and stakeholders. The current version of METRIC includes up-to-date information for nitrogen, phosphorus, and sediment at 92, 80, and 78 stations, respectively. These data are further synthesized to characterize spatial patterns of response classes—defined by agreement or disagreement between monitored and expected trends—across the Bay watershed, providing a system-wide perspective on restoration progress and uncertainty. By explicitly linking observed system responses with management expectations, METRIC offers a transparent, evidence-based tool to identify where restoration strategies are performing as intended, where they may be underperforming, and where model assumptions warrant re-evaluation. This integrated framework supports adaptive management, improves accountability, and offers a pathway for strengthening data-informed restoration decision making.

---

**Thomas Fisher (UMCES), Judith O'Neil, Anne B. Gustafson, Paleena Amy**

Assessment of phytoplankton nutrient and light limitation in Chesapeake Bay in response to nutrient management strategies over the last 25 years

Reduction of nutrient inputs and phytoplankton biomass is a central goal of Chesapeake Bay restoration, aimed at improving water transparency and reducing organic matter delivery to hypoxic bottom waters. Understanding the spatial and temporal controls on phytoplankton growth—specifically limitation by light, nitrogen (N), and phosphorus (P)—has therefore been critical for management and regulatory decision-making. During 1990–2003, a series of experimental phytoplankton bioassays conducted at up to 16 stations throughout Chesapeake Bay and its tributaries revealed pronounced spatial and seasonal variability in resource limitation. Light limitation dominated turbid, nutrient-rich oligohaline regions under high river discharge and unstratified conditions, particularly from late fall through early spring. Under lower flow and stratified conditions, P limitation prevailed in summer in oligohaline waters and during early spring and late fall in mesohaline regions, while N limitation was most common in mesohaline and polyhaline waters during summer. These findings directly informed the development of spatially explicit Total Maximum Daily Loads (TMDLs) and watershed management strategies. To evaluate whether decades of nutrient management have altered these fundamental controls on phytoplankton growth, identical bioassays were repeated during 2023–2025 at six mainstem Chesapeake Bay stations and six tributary sites, coordinated with the Chesapeake Bay Program monitoring network. This effort aimed to validate and refine current statistical models of nutrient and light limitation and to assess progress toward long-term water quality goals. Ongoing analyses incorporating river discharge, vertical stratification, and nutrient concentrations will further quantify long-term changes. Together, these results will provide a rare multi-decadal experimental perspective on ecosystem response to management and will support continued optimization of restoration strategies for Chesapeake Bay.

---

### **Kelly Kosiarski (Pennsylvania State University)**

#### **Evaluating Riparian Buffer Zone Effectiveness at Mitigating PFAS from Surface Runoff of Biosolids Amended Fields**

The land application of biosolids in agricultural settings is a widely used practice to reduce reliance on synthetic fertilizers. Biosolids application has been shown to improve soil and crop health, and has long been viewed as a sustainable practice. However, there is concern for unintended, adverse effects due to the presence of per and polyfluoroalkyl substances (PFAS). PFAS are a diverse family of persistent organic compounds. They have been linked to significant health effects such as cancer and thyroid disease. Once PFAS enter soils from biosolids application, they can accumulate in crop and livestock tissue. Additionally, PFAS have potential to transport to nearby surface water and groundwater supplies. PFAS accumulation in agricultural products and rural water supplies can have implications for human health. Agricultural systems already have established best management practices to mitigate nutrient and sediment impact to nearby water supplies such as riparian buffer zones. Although, it is unclear how riparian buffer zones may perform for PFAS. A two year study was conducted in order to better understand the effectiveness of riparian buffer zones on mitigating PFAS transport to nearby surface water from biosolids amended fields. Three agricultural sites with established riparian buffer zones and a history of biosolids applications were recruited. Samples

were gathered from the streams, biosolids, soils (pre and post application), and crop tissue at time of harvest. Buffer characteristics known to affect riparian buffer zone effectiveness (such as vegetation type, width, and slope) were considered alongside biosolids application rate and timing. Results indicate that concentrations in the stream and soils are correlated with application rate, and riparian buffer zone effectiveness varied between sites. The findings of this study have implications for current management practices. They can be used to inform decision making about the recommendation of riparian buffer zones for PFAS mitigation in agriculture.

---

**Kathryn Dixon (University of Maryland School of Public Health, Department of Global, Environmental, and Occupational Health), Claire Barlow**

### Rapid Water Quality Evaluation of the Potomac River Sewage Overflow

Sewage exposure continues to burden U.S. waterways, despite the intentions of the Clean Water Act to eliminate illicit discharges and regulate standards for swimmable and fishable water quality. On January 19 2026, a wastewater interceptor pipe collapsed, causing millions of gallons of untreated sewage to be released into the Potomac River and the surrounding environments. Wastewater can contain harmful pathogens including *Staphylococcus aureus* and its antibiotic-resistant form, methicillin-resistant *S. aureus* (MRSA). Nearly 47,000 residents live directly along this river, but many thousands more could be impacted that interact with the Potomac and surrounding area. In order to rapidly investigate the public health threats associated with this sewage contamination, we collected samples (n=30) from the sewage overflow site and downstream sites and plan to follow this over time to better understand the public health risks. From samples we collected, we detected *E. coli* levels 2,500-10,000 times above EPA recreational water quality standards ( $\leq 410$  MPN/100mL) and detected enterococci levels 30-6000 times above standards ( $\leq 130$  MPN/100mL). We also detected *S. aureus* and MRSA at the overflow site. Continued evaluation of this waterway is important for understanding long-term impacts of sewage exposure and communicating effective messaging for the public potentially interacting with these sewage-burdened waters at the overflow site and downstream.