EARLY WARNINGS AND LONG-TERM CHANGES: APPLICATION OF CONTINUOUS TURBIDITY MONITORING TO PROTECT AN ENDANGERED FISH SPECIES DURING CONSTRUCTION OF A LARGE-SCALE FLOOD-REDUCTION EFFORT

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Flooding of the Roanoke River has caused substantial damage in the City of Roanoke, Virginia, over the past century. With over $1 billion worth of property at risk from potential flood damage, the City of Roanoke partnered with the U.S. Army Corps of Engineers (USACE) to construct the Roanoke River Flood Reduction Project (RRFRP) in an effort to reduce flooding impacts within the City. Construction of the RRFRP was complicated by concern that construction-related increases in sediment transport would potentially harm the endangered Roanoke logperch (*Percina rex*).

In early 2005, approximately coincident with the beginning of RRFRP construction, the U.S. Geological Survey (USGS) Virginia Water Science Center (VAWSC) partnered with the USACE to initiate a monitoring program using continuous turbidity monitoring stations and suspended-sediment sampling to assess changes in sediment transport through the affected reach and to provide a real-time warning system for potential impacts from sediment releases on logperch habitat. Specifically, the objectives were to:

a) Detect short- term changes in suspended-sediment transport during construction of the RRFRP in near real-time; and to
b) Assess spatial and temporal trends in suspended-sediment transport in the affected section of the Roanoke River.

This suspended-sediment monitoring program was conducted in synchrony with complementary monitoring programs focused on assessing geomorphological change and logperch community structure during construction of the RRFRP. These complementary programs were conducted by the VAWSC and the USGS Virginia Cooperative Fish and Wildlife Research Unit at Virginia Polytechnic and State University, respectively.

Continuous turbidity monitors were deployed at multiple locations along the construction reach for various time periods. These deployments were located, spatially and temporally, such that active construction reaches were closely bracketed with a monitor near the upstream and downstream extents of active construction to monitor flow into and out of the active construction reach – construction reaches were limited to 4,000 linear feet, progressing upstream. Continuous turbidity monitors also were deployed at the upstream and downstream extent of the RRFRP for the duration of the RRFRP, and suspended-sediment sampling was conducted at these benchmark stations throughout the period of study (2005-2012).

During the study, and particularly during active construction phases, differences between upstream and downstream turbidity measurements were tracked daily by construction managers

to identify potential inputs of sediment from construction activities. With instruments monitoring the water flowing into and out of active construction reaches, an input potentially attributed to the RRFRP would be expected to generate an increased turbidity response at the outflow location as compared to turbidity at the inflow location. In the event of such a pattern, further data exploration utilizing other measured water-quality parameters would be conducted, and, if warranted, a site visit would be conducted to rule out instrument fouling or other malfunction as the cause of the observed pattern. Upon completion of the construction activities, cumulative distribution frequencies (CDFs) were plotted by construction phase to evaluate discrepancies in turbidity between the inflow and outflow monitors to assess whether changes in the turbidity regime occurred that were indicative of RRFRP activities altering sediment transport.

The relation between turbidity and SSC was determined, and potential changes in this relation over time and/or space were explored, using multiple linear regression. Site-specific simple linear regression (SLR) models were developed using SSC and corresponding turbidity measurements from the discrete sampling activities at the two benchmark stations. Determination of change in the turbidity-SSC relation over time was accomplished by adding a time term to the turbidity-SSC model and evaluating the significance of time in the model. Evaluation of whether the turbidity-SSC relation varied between the benchmark stations was accomplished using Analysis of Covariance (ANCOVA), in which indicator variables were added to the turbidity-SSC SLR to determine significance of location within a pooled model calibrated using data from both stations.

Results of the analysis of turbidity distributions by construction phase indicated that turbidity generally increased in the downstream direction throughout the overall study reach and that turbidity was highly variable throughout the period of the study. No evidence of RRFRP induced sediment transport was apparent in the CDFs, though this analysis was limited at times because of the lack of pre-construction monitoring for some phases.

Turbidity was an effective surrogate for suspended sediment at the two benchmark sites, as indicated by the strong statistical significance of turbidity in the models ($p < 0.0001$) and high coefficients of variation ($R^2 = 0.95$) in each of the site-specific regressions. These regression models remained static over the period of study, as evidenced by the lack of significance of a time term in the regressions, indicating that the turbidity-sediment relation was not changing over time. Additionally, these models were static spatially, as no significant difference was detected between the two stations using the ANCOVA – a single model was statistically indistinguishable from site-specific models.

The results of the temporal and spatial analysis of the turbidity-SSC regressions provide further evidence that the RRFRP did not induce sediment transport within the study reach. Increases in local contributions to suspended-sediment transport would be expected to alter sediment characteristics such as color, organic content, and size-distributions, which would result in changes in the turbidity-SSC relation. Further, these changes would only be apparent at the downstream site receiving water from the construction reach, yet no significant difference between the two stations was detected.

The results of this monitoring and analysis program indicate that no detectable changes in suspended-sediment transport occurred in association with RRFRP construction, suggesting that the construction activities did not have deleterious effects on logperch habitat. These findings are consistent with findings of the complementary geomorphological and logperch community monitoring programs.