Mar 18th, 3:15 PM

Session 2D

Kentucky Water Resources Research Institute, University of Kentucky

A STABILITY INDEX FOR NORTHERN KENTUCKY STREAMS

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A stream stability index was developed using hydrogemorphic field data at 35 unique sites in Northern Kentucky. Stream stability was quantified using annually repeated surveys at 28 of the 35 sites, with eight of the sites having two rounds of surveys and 20 of the sites having three rounds of surveys. Expert scores, which were only assigned to sites with at least two rounds of surveys, encompassed measured rates of instability across five individual dimensions, including 1) Left Bank, 2) Right Bank, 3) Cross Section, 4) Profile, and 5) Bed Material. These individual scores were synthesized into an overall expert score on a 0 to 10 scale.

The next step statistically tested the power of simple, field-derived metrics in predicting the expert scores to develop a 'Stability Index' that could be computed in the field in about 15 minutes. Channel shape, bank heights and angles, embeddedness, riffle frequency, and the depth of the deepest pool were all significant at $p < 0.10$ in predicting the overall expert score. Approximately 74% of the variance in the overall expert score could be explained by channel shape, embeddedness, and the depth of the deepest pool, which were all significant at $p \leq 0.05$.

The stability index attempts to balance the statistical strength of metrics with 1) a physically-based framework, 2) ease of application in the field, and 3) a preference toward quantitative over qualitative metrics. The stability index explains ~80% of the variability in the overall expert score, and is computed as:

Stability Index

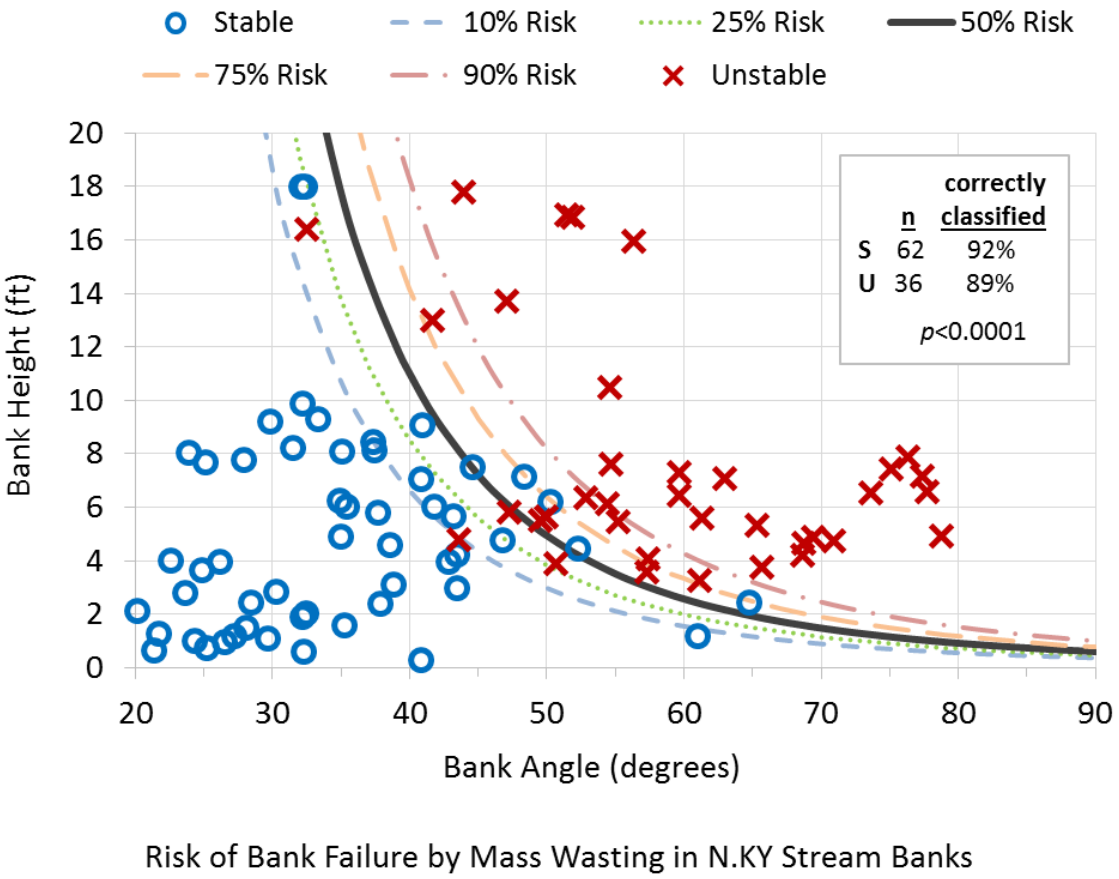
= -8.5 + 0.15 * LB + 0.15 * RB + 0.3 * Shape + 0.15 * Bedrock
+ 0.25 * Embeddedness + 0.25 * Pool Depth + 0.25 * Riffle Freq.

Where:

LB = Left Bank Score, RB = Right Bank Score, Shape = Shape Score, Bedrock = Bedrock Score, Embeddedness = Embeddedness Score, Pool Depth = Pool Depth Score, and Riffle Freq. = Riffle Frequency Score

All of the variables are significant at $p < 0.10$, with the exception of the Right Bank (RB, $p = 0.54$) and Bedrock Score ($p = 0.28$). Preliminary validation compared stability index scores against values of macroinvertebrate biotic index (MBI scores), habitat scores, and watershed imperviousness, showing positive correlations with MBI ($p = 0.50$) and habitat ($p = 0.008$), and negative correlations with watershed imperviousness ($p = 0.12$). These correlations were more significant when withholding sites with vertical grade control (i.e. p-values of 0.17, 0.002, and 0.03 for MBI, habitat, and imperviousness, respectively), indicating that streams with exposed bedrock or similar grade control (e.g. exposed utility lines, culverts, etc.) may show less evidence of instability, but that aquatic life and habitat may still be impacted by erosive flows or other factors.

The stability index is currently undergoing a field testing/validation period. To date, the two-page field form has been applied at 61 sites, and documents similar relationships with MBI and habitat. The correlation with habitat scores was particularly strong ($p < 0.0001$), confirming that stream stability is positively correlated with habitat integrity.



Risk of Bank Failure by Mass Wasting in N.KY Stream Banks

Logistic Regression thresholds (p< 0.0001) developed for stable vs. unstable banks with failure dominated by mass wasting, withholding bedrock banks and unstable banks dominated by fluvial failure.

Figure 1 – Regional Bank Stability Diagram Used to Determine Bank Scores

THE GUNPOWDER AND WOOLPER CREEK WATERSHED INITIATIVES
LOCAL CASES OF A NATIONAL PROBLEM

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Nonpoint source runoff (i.e. storm water) has been identified as one of the leading causes of impairment to stream water quality throughout the state. The addition of improperly mitigated impervious surfaces (roads, parking lots, rooftops, etc.) disrupts a watershed's hydrology, altering the natural flow regime which impacts stream quality. It is important that the consequences of these changes be more clearly understood.

Boone County in northern Kentucky is one of the most rapidly developing counties in the state, and its watersheds are currently experiencing the impacts associated with that development (i.e. stream bank erosion/instability, excess sedimentation, degraded biological communities, loss of ecological function etc.). Specifically, the Gunpowder Creek and the Woolper Creek Watersheds have been under increasing pressure as development continues to expand. These watersheds cover approximately one-third of the county's land area and are home to two-thirds of the county's population. Driven by concerned and interested groups and agencies, led by the Boone County Conservation District, the Gunpowder and Woolper Creek Watershed Initiatives have formed to develop strategies to improve and/or protect these vital resources. The Boone County Conservation District has been awarded two §319(h) grants from the U.S. Environmental Protection Agency through the Kentucky Division of Water. These grants will enable the Conservation District and partners to develop Kentucky Division of Water (KDOW) approved watershed plans designed to address nonpoint source pollution and related issues in the watersheds.

As part of watershed plan development, a review of historic data collected by various agencies and organizations was conducted, and six sites in Gunpowder Creek and 18 sites in Woolper Creek were selected for further monitoring. This additional monitoring included parameters such as bacteria, nutrients, sediment, flow, and biological assessments. Additionally, hydromodification surveys and pebble counts were conducted at 4 sites in Gunpowder Creek and 18 sites in Woolper Creek. Data was collected at the Gunpowder sites in 2011 and 2012 and analysis is underway. Monitoring is on-going in Woolper Creek and will be completed in autumn 2013. Analysis of this data will help provide a better understanding of the issues facing each watershed, as well as aid in identifying appropriate management strategies to mitigate nonpoint source pollution in specific watersheds.

Community outreach and education efforts are a vital component of these projects. The goals are to inform stakeholders and the general public about the water quality issues facing these watersheds and solicit their input and participation in the planning process. Two public meetings outlining the Gunpowder project were held in 2011 and 2012 with a third is scheduled for spring 2013. The initial public meeting for the Woolper Creek Initiative will be scheduled for autumn 2013. As data analysis reports are completed, interested agencies, stakeholders, landowners and the general public will be invited to participate in the development of the watershed plans. Participants will assist with evaluation and selection of appropriate Best Management Practices (BMPs) for implementation. Such public participation and commitment is critical to ensuring that the improvement and protection of water quality in Gunpowder and Woolper Creek is feasible, cost effective and continues beyond the grant funding period.

Preliminary analyses have provided insights into identifying appropriate BMP strategies for specific impairments. KDOW has developed a report card that translates the data into a format that can be readily shared with the public. For example, our least developed sub-watershed, Riddles Run, received some of the best assessment scores, with the exception of *E. coli* (KDOW Report Card Grade of F), indicating that BMPs may focus on common rural sources such as septic systems maintenance and/or buffer strips/fencing for livestock. In contrast, *E. coli* were less concerning in our most developed, but sewered, sub-watersheds in the headwaters of the main branch and south fork of Gunpowder Creek; however, macroinvertebrate scores were the worst (KDOW Grade of F). These are also two of our most unstable reaches, indicating that BMPs in these watersheds may need to target ways to reduce the erosive force of stormwater runoff. Our project team, in collaboration with US EPA, is currently investigating the efficacy of retrofitting conventional detention basins as an economical alternative to reduce the erosive power of most storms in a typical year, and provide extended hold times for water quality benefits. In conclusion, all of these efforts have gained synergy as a result of active stakeholders, engaged community partners, a progressive stormwater utility, and a data-driven approach focused on monitoring the root cause of the problems.

WATERSHED-SCALE MODEL OF CARBON AND NITROGEN CYCLES IN STREAMS

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The ability of benthic sediments to assimilate carbon and nitrogen to the streambed and remove dissolved inorganic nitrogen from the water column has implications for fluvial carbon and nitrogen budgets. Low-gradient, agriculturally and urban disturbed watershed systems in the Inner-Bluegrass Region of Central Kentucky are characterized by pronounced sediment retention, bedrock control and high background nutrients which support a thin micro-ecosystem at the sediment surface. The complexity of these systems is compounded by the coupling of hydrologic, sediment, carbon and nitrogen processes which result in unreliable *in situ* and laboratory measurements. To this end, a need exists for a coupled modeling framework that helps to constrain the stream nitrogen and carbon budgets at the watershed scale. We propose a modeling framework that couples hydrologic, sediment, carbon, nitrogen and nitrogen stable isotope processes, using ambient measurements of sediment and streamwater constituents to parameterize and calibrate the model. The modeling framework consists of a series of mass-balance, black box models in a nested watershed network in which water, sediment, and nutrients are routed to the watershed outlet. Model outputs include fluxes from the watershed *via* fluid advection and net removal of constituents either from degassing to the atmosphere or assimilation by the benthos.

The model is being applied to the South Elkhorn watershed (62 km^2) located primarily within western Fayette County. The watershed is dominated by agricultural and urban land uses which promote non-limiting nutrient conditions for autochthonous growth and bacterial consumption. Low stream and hillslope gradients and high sinuosity of the stream channel promote zones of pronounced sediment storage.

Preliminary results of the model suggest that benthic sediment processes result in pronounced seasonal and annual variability of sediment, carbon and nitrogen. Results of the sediment model suggest a dynamic, long-term equilibrium in which low-moderate flows scour the sediment bed and high flows deposit excessive sediment loads during the receding limb of the storm event. This resulting dynamic significantly impacts the fluvial carbon and nitrogen cycles since the elemental compositions of upland soil organic matter vary significantly from that of newly derived autochthonous material. The influence of benthic assimilation and decomposition is the driving factor for seasonal variability of the transported organic carbon concentrations. The annual carbon flux from the system was estimated as 0.3 $t/km^2/yr$ with benthic autochthonous carbon contributing 22% of the annual carbon flux on average. The stream nitrogen budget showed high seasonal variability in terms of the $\delta^{15}N$ signature of the sediment nitrogen. The seasonality is attributed to nitrification and denitrification processes (which have been shown to vary with carbon content of sediment organic matter) and the assimilation rate of the dissolved inorganic nitrogen (DIN). Preliminary budget results for the system suggests that 13% of inflowing nitrogen is uptaken by sediments, with 5% being permanently removed from the system *via* denitrification. The remaining fraction is either eroded and transported as particulate nitrogen or regenerated to the water column.

Further work will strive to better constrain model parameters and model uncertainty by performing a tighter coupling of carbon and nitrogen processes. A dense dataset including measurements of isotope and elemental signatures of sediment and streamwater constituents will be collected in tributaries and the main stem of the study watershed. Calibration, validation and uncertainty analysis will be performed using the most up to date methods.

SENSOR NETWORK FOR SUSPENDED SEDIMENT MONITORING

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The focus of this research is (i) the creation and verification of inexpensive instrumentation for sediment transport measurements within intelligent sensor networks, and (ii) the design and implementation of environmental monitoring network to measure sediment discharge. Recent technological developments in the miniaturization of electronics and wireless communication have begun a revolution in Environmental Sensor Networks. Wireless sensor networks are expected to decrease the cost and time associated with manual collection of water samples, increasing the temporal and spatial data resolution to that of the process scale for watershed monitoring efforts. The present research is motivated by the need to develop low cost, wireless sensors for sediment discharge measurements within highly sensed stream monitoring networks. The meet this need we introduce, *Salamander* the Serial Amphibious Linear Arrays of Micro And Nano Devices for Environmental Research. The *Salamander* is a tool that provides a versatile, instrumentation platform for deploying hydraulics and water quality sensors within stream monitoring networks.

Salamanders outfitted for sediment discharge measurement make use of inexpensive pressure sensors, velocity bend sensors (VBS), and light attenuation sediment sensors (LASS). Water velocity causes the VBS sensor, which acts as a strain gage, to bend and change the electrical resistance of the sensor. A semi-theoretical relationship between VBS output and velocity was developed by coupling an energy balance model to predict elastic beam bending with circuitry analysis. The newly developed light attenuation sediment sensors (LASS) are called such due to their operating mechanism. LASS is a vertical array of cadmium sulfide light dependent resistors which measures light intensity to calculate light attenuation by suspended sediment with the Beer-Lambert equation. Light attenuation dependence on suspended sediment properties in upland watersheds was modeled using geometric optical theory. These newly developed sensors were then calibrated in the laboratory under a range of field representative conditions. The laboratory results show the models to predict sensor output can be used to make reasonably accurate estimates of velocity and sediment concentration.

Salamander was equipped with calibrated sensors and deployed to the field site located in the South Elkhorn watershed near the bluegrass airport. The field site selected for testing the sensor network was the confluence of 1^{st}, 2^{nd}, and 3^{rd} order streams. This site was selected to enable testing of intelligent network features, data quality controls, and gain a better understanding of the effect of spatial scales on sediment transport within the watershed. The field deployed *Salamander* unit reads sensed metrics and wirelessly transmits this information to a centralized data storage location. The results of this work show that the inexpensive *Salamander* network can be quickly deployed in the field to monitor hydrologic events of interest to the researcher. Within the *Salamander* network, on-going research is underway to model velocity and sediment distribution and thereafter compute sediment flux for a stream location. Wireless intelligent features are currently being designed and implemented to check for erroneous data based on calculations of parameter gradients. This research initiative is expected to produce a sediment discharge monitoring network that will provide data at temporal and spatial scales adequate to evaluate sediment transport processes.