MN Lake Superior Watershed Stream Science Symposium

Annotated Bibliography

A Bibliography of Beaver, Trout, Wildlife, and Forest Relationships

A total of 446 references to beaver (Castor canadensis) ecology and the relationships of beaver to trout, waterfowl and other wildlife, and forests are presented. Annotations of 36 papers selected from the general references deal specifically with the relationship of beaver and their activities to wild trout in low to moderately high gradient streams in Wisconsin (10), Michigan (9), Minnesota (10), New York (5), Maine (2), Massachusetts (1), and Ontario (1).

Duluth Metropolitan Area Streams Snowmelt Runoff Study.

This study was conducted because water quality information on the Duluth streams is extremely limited during the snowmelt runoff period, and because research has demonstrated that during snowmelt in urban areas, a large percentage of annual pollutant loads can reach and adversely impact receiving waters. The goal of the study was to develop baseline water quality information on four streams in the DMA during the snowmelt runoff period. A secondary goal was to compare pollutant yielding rates between snowmelt and baseflow periods among the sampling sites, thereby identifying stream reaches at risk of impairment.

DEVELOPING ECOLOGICAL CRITERIA FOR SUSTAINABLE WATER MANAGEMENT IN MINNESOTA.

The goal of this project was to develop recommendations and indicators for ecological criteria for instream flow protection in Minnesota, with special attention to rivers and streams in Minnesota's Great Lakes basin. Products were developed through a collaborative process with public agencies in Minnesota and other experts, building on partnerships between the Conservancy and U.S. Geological Survey (USGS) across the Great Lakes. This report assesses available data, tools and approaches that can be used to establish ecologically- based instream flow protections in Minnesota. To this end, we introduce the Ecological Limits of Hydrologic Alteration (ELOHA) approach, a science and policy framework for organizing the elements of an instream flow protection program and synthesizing available information. Applications of ELOHA that have been implemented in several other states are featured in this report as case studies.

DETECTING LEVELS OF SUSTAINABLE LAND-USE IN LAKE SUPERIOR WATERSHEDS USING STREAM INVERTEBRATE.

We have been investigating the relationship between watershed land-use and stream ecosystem "health" within 48 western Lake Superior watersheds, trying to identify sustainable land-use levels. Aquatic invertebrates, often useful in evaluating stream condition, were collected from riffles in each

stream. Nonmetric multidimensional scaling (NMDS) ordination was used to evaluate invertebrate community differences and to correlate those differences with landscape, habitat, water chemistry, sediment, and hydrology variables. NMDS of the invertebrate communities indicated that invertebrates in both north and south shore streams were responding primarily to substrate, hydrology, and temperature differences among the diverse stream types. Ordinations on streams grouped by major common features were evaluated to better detect possible anthropogenic influences. Invertebrates in 21 north shore streams seemed to be most influenced by stream bottom type, temperature, and presence of fine sediments, while invertebrates in 9 rocky and 11 clay south shore streams appeared to be responding to differences among bottom substrate and temperature, stream and watershed size, and flow. Direct effects of human activity on stream communities were not apparent. However, land use may be altering sedimentation rates, hydrologic regimes, and stream temperature, and, thus, may be indirectly affecting stream invertebrates.

Manitou Stream Monitoring Project Field Methods.

This stream monitoring protocol primarily describes collection of data about basic geomorphological and physical habitat parameters of stream reaches. Suggested protocols for future monitoring of stream biota and nutrients have been included at the end.

ASSESSING RELATIVE RISKS TO AQUATIC ECOSYSTEMS : A MID-APPALACHIAN CASE STUDY.

Aquatic monitoring aims to assess the condition of aquatic habitats and biota. To make statements about condition, the range of human activities and the risks they pose to aquatic ecosystems must be identified. Assessing relative risk and placing sample sites on a human disturbance gradient is necessary for interpreting biological response and distinguishing human disturbance from natural controls in aquatic systems. We describe a process that uses readily available sources, such as topographic maps, aerial photographs, and field information, to identify and prioritize stream reach and watershed stressors for 102 streams in the mid- Appalachian region of the United St.at.es. All perceptible human alterations to riparian and upland areas along with their number, type, intensity, and extent of impact were recorded and ranked; a relative risk index was developed to assign scores to the water- sheds. The resulting risk index scores were consistent with measures of stream condition based on water chemistry and benthic macroinvertebrates. The risk index gives a cost-effective, regional picture of the relative risk of impairment to aquatic ecosystems in the mid-Appalachian region of the USA and could be modified for other regions or ecosystem types.

A Guide to Understanding the Hydrologic Condition of Wisconsin ' s Lake Superior Watersheds.

The Lake Superior Basin Partner Team developed a water- shed health strategy aimed at slowing the flow in the Lake Superior Basin. The focus of the strategy was to develop a model watershed management guidance that would be promoted across the entire basin. To aid in developing the

guidance, the group selected a pilot area from the Wisconsin portion of the basin to try out the approach, determine the best information sources, and identify important features that may be common throughout the basin, as well as assessing the hydrologic condition of the pilot area. The pilot report, Assessing the Hydrologic Condition of the Marengo River Watershed, outlines the steps taken to assess the hydrologic condition of the pilot area, provides information about the hydrologic condition of the pilot area, and companions this Guide to Understanding the Hydrologic Condition of Wisconsin's Lake Superior Watersheds.

The Superior Mixed Forest Ecoregion: A Conservation Plan (Vol. 2002)

The plan identifies 51 conservation areas, totaling 26.8 million acres (11.3 million hectares). Seventy-one percent of the land in these conservation areas is in public ownership. These areas represent the best opportunities for conserving the full diversity of terrestrial and aquatic ecosystems and globally rare or declining species. Descriptions, maps, and information regarding the ecological systems and rare species are provided for each of the conservation areas. Conservation goals were met for 72% of the ecological systems, but for only 33% of the rare species.

RECOMMENDED DESIRED OUTCOMES, GOALS AND STRATEGIES NORTHEAST LANDSCAPE REGION.

The Minnesota State Legislature enacted the Sustainable Forest Resources Act (SFRA) in 1995, which established the MN Forest Resource Council (MFRC) and formalized the state's policy to: o pursue the sustainable management, use, and protection of the state's forest resources to achieve the state's economic, environmental, and social goals; o encourage cooperation and collaboration between public and private sectors in the management of the state's forest resources; o recognize and consider forest resource issues, concerns, and impacts at the site and landscape levels; o recognize the broad array of perspectives regarding the management, use, and protection of the state's forest resources and establish processes and mechanisms that seek and incorporate these perspectives in the planning and management of the state's forest resources. The MFRC Landscape Program establishes landscape committees on a regional basis to implement these state policies at the landscape level throughout the State.

Integrated Measures of Anthropogenic Stress in the U.S. Great Lakes Basin.

Integrated, quantitative expressions of anthropogenic stress over large geographic regions can be valuable tools in environmental research and management. Despite the fundamental appeal of a regional approach, development of regional stress measures remains one of the most important current challenges in environmental science. Using publicly available, pre-existing spatial datasets, we developed a geographic information system database of 86 variables related to five classes of anthropogenic stress in the U.S. Great Lakes basin: agriculture, atmospheric deposition, human population, land cover, and point source pollution. The original variables were quantified by a variety of data types over a broad range of spatial and classification resolutions. We summarized the original data for 762 watershed-based units that comprise the U.S. portion of the basin and then used principal components analysis to develop overall stress measures within each stress category. We developed a cumulative stress index by combining the first principal component from each of the five stress

categories. Maps of the stress measures illustrate strong spatial patterns across the basin, with the greatest amount of stress occurring on the western shore of Lake Michigan, southwest Lake Erie, and southeastern Lake Ontario. We found strong relationships between the stress measures and characteristics of bird communities, fish communities, and water chemistry measurements from the coastal region. The stress measures are taken to represent the major threats to coastal ecosystems in the U.S. Great Lakes. Such regional-scale efforts are critical for understanding relationships between human disturbance and ecosystem response, and can be used to guide environmental decision-making at both regional and local scales.

A TEST OF WATERSHED CLASSIFICATION SYSTEMS FOR ECOLOGICAL RISK ASSESMENT.

To facilitate extrapolation among watersheds, ecological risk assessments should be based on a model of factors influencing watershed response particularly vulnerability. We propose a conceptual model of landscape vulnerability to serve as a basis for watershed classification systems to predict resistance and resilience of aquatic ecosystems to hydrology-related stressors. Watershed area, storage capacity, channel slope, and soil permeability determine sensitivity or lotic systems stressors associated with land-use activities that impact hydrologic regimes. Natural hydrologic disturbance regimes also influence the resilience of aquatic systems by selecting for life history strategies associated with rapid recolonization following disturbance. Variability in some of these physiographic driving factors can be partitioned by landscape classification schemes such as the U.S. Forest Service Ecological Unit Classification System, while others (watershed storage) may explain remaining variability within landscape units. We are conducting a comparative watershed study to examine simple and interactive effects of physiographic units, watershed storage (lakes + wetlands), and land clearing activities in watersheds surrounding the western arm of Lake Superior. Initial results for second-order watersheds indicate significant watershed class effects on baseflow water quality, percent motile biraphid diatom species in periphyton communities, habitat quality and fish community integrity. Future studies have been designed to examine cumulative effects downstream.

Effects of hydrogeomorphic region, catchment storage and mature forest on baseflow and snowmelt stream water quality in second-order Lake Superior Basin tributaries.

In this study we predict stream sensitivity to non-point source pollution based on the non-linear responses of hydrological regimes and associated loadings of non-point source pollutants to catchment properties. We assessed two hydrologically based thresholds of impairment, one for catchment storage (5-10%) and one for mature forest «50% versus >60% of catchment in mature forest cover) across two different hydrogeomorphic regions within the Northern Lakes and Forest (NLF) ecoregion: the North Shore [predominantly within the North Shore Highlands Ecological Unitl and the South Shore (predominantly within the Lake Superior Clay Plain Ecological Unit). Water quality samples were collected and analyzed during peak snowmelt and baseflow conditions from 24 second-order streams grouped as follows: three in each region x catchment storage x mature forest class. 2. Water quality was affected by a combination of regional influences, catchment storage and mature forest. Regional differences were significant for suspended solids, phosphorus, nitrogen/phosphorus ratios, dissolved organic carbon (DOC) and alkalinity. Catchment storage was significantly correlated with dissolved silica

during the early to mid-growing season, and with DOC, specific conductance and alkalinity during all seasons. Total nitrogen and dissolved nitrogen were consistently less in low mature forest than in high mature forest catchments. Catchment storage interacted with the influence of mature forest for only two metrics: color and the soluble inorganic nitrogen: phosphorus ratio. 3. Significant interaction terms (region by mature forest or region by storage) suggest differences in regional sensitivity for conductance, alkalinity, total organic carbon, and color, as well as possible shifts in thresholds of impact across region or mature forest class. 4. Use of the NLF Ecoregion alone as a basis for setting regional water quality criteria would lead to the misinterpretation of reference condition and assessment of condition. There were pronounced differences in background water quality between the North and South Shore streams, particularly for parameters related to differences in soil parent material and glacial history. A stratified random sampling design for baseflow and snowmelt stream water quality based on both hydrogeomorphic region and catchment attributes improves assessments of both reference condition and differences in regional sensitivity.

Effects of Historical Land-Cover Changes on Flooding and Sedimentation, North Fish Creek, Wisconsin.

North Fish Creek, a Wisconsin tributary to Lake Superior, is an important recreational fishery that is potentially limited by the loss of aquatic habitat caused by accelerated flooding and sedimentation. A study of the historical flooding and sedimentation characteristics of North Fish Creek was done to determine how North Fish Creek responded to human-caused changes in land cover since European settlement of the region in the 1870's. Geomorphic field evidence combined with hydrologic and sediment-transport modeling indicate that historical clear-cut logging, followed by agricultural activity, significantly altered the hydrologic and geomorphic conditions of North Fish Creek. The geomorphic responses to land-cover changes were especially sensitive to the location of reaches along the main stem and on the timing of large floods. On the basis of geomorphic evidence in flood-plain deposits and abandoned channels, the size of floods and sediment loads increased in North Fish Creek after conversion of forested land to cropland and pasture. Changes in channel characteristics were particularly noticeable after record floods in 1941 and 1946. The upper main stem channel bed eroded downward at least 3 meters and the channel capacity at least doubled after European settlement. In the lower main stem, the post- settlement sedimentation rate on the flood plain and in the channel is 4 to 6 times pre-settlement rates. The water table also appears to be rising near the mouth of North Fish Creek, perhaps consistent with (1) elevated local streambed elevations caused by sedimentation and (2) a slow relative rise in the local level of Lake Superior due to crustal rebound from glaciation. Along a transitional reach of the main stem between the upper and lower main stem, there is evidence of accelerated flood-plain sedimentation initially following European settlement. Since at least the 1940's, however, the channel bed in the transitional reach has eroded about 1 meter and the channel capacity has at least doubled. Results from hydrologic and sediment-transport modeling indicate that modern flood peaks and sediment loads in North Fish Creek may be double that expected under pre-settlement forest cover. During maximum agricultural activity in the mid-1920's to mid-1930's, flood peaks probably were about 3 times larger and sediment loads were about 5 times larger than expected under pre-settlement forest cover. These results indicate that future changes from pasture or cropland to forest will help reduce flood peaks, thereby reducing erosion and sedimentation. The addition of detention

basins (to decrease flood peaks) on tributaries to North Fish Creek, or bank and instream restoration (to decrease erosion) in the upper main stem, also may help reduce the contribution of sediment from the upper main stem to the transitional section and lower main stem of the creek.

A Comparison of Multi-Disciplinary Methods for Measuring Physical Conditions of Streams.

A wide range of scientists, including fluvial geomorphologists, ecologists, fisheries managers, and river engineers, study human impacts on the physical characteristics of streams, Data gathered for stream physical conditions are useful for water- and fish-resource management, water-quality monitoring, and stream restoration. The physical condition of streams reflects a variety of natural and anthropogenic effects and multiple spatial and temporal scales. Thus, systematic approaches among scientific discipline differ in terms of spatial and temporal scales of measurement and are heavily dependent on the academic background and field experience of the investigators. Data-collection efforts range from rapid, qualitative descriptions and categorizations to more time-consuming quantitative measurements. Most geomorphic assessments, stream classifications, and habitat characterizations measure similar key hydrologic and geomorphic features, even though individual methodologies may differ substantially. These key features include channel morphology and plan form, valley and channel gradient or slope, sediment characteristics and movement, and bank characteristics. This paper examines several commonly used habitat characterizations, stream classifications, and geomorphic assessments in terms of how they effectively measure the physical condition of streams that are most likely to change in response to land-cover perturbations. Advantages and disadvantages of each type of assessment are discussed in the context of potential study goals and outcomes, and time, labor, and· expertise constraints. The major goal of this paper is to promote communication among ecologists, geomorphologists, fisheries· managers, and engineers, thereby reducing duplication of effort and increasing the utility of methods used to describe the physical characteristics of streams. By improving the understanding of the geomorphic processes within a watershed and their effect on physical features in a stream channel, various scientific disciplines will make better interpretations of the development of riverlne habitat. Adjustments in sampling routines for each discipline may then create a complementary and more uniform data set from which decision makers can develop management strategies.

Geomorphic Characteristics and Classification of Duluth-Area Streams, Minnesota.

In 2003 and 2004, a geomorphic assessment of streams in 20 watersheds in the Duluth, Minn., area was conducted to identify and summarize geomorphic characteristics, processes, disturbance mechanisms, and potential responses to disturbance. Methods used to assess the streams included watershed characterization, descriptions of segment slopes and valley types, historical aerial photograph interpretation, and rapid field assessments and intensive field surveys of stream reaches. Geomorphic conditions were summarized into a segment-scale classification with 15 categories mainly based on drainage-network position and slope, and, secondarily, based on geologic setting, valley type, and dominant geomorphic processes. Main causes of geomorphic disturbance included historical logging and agriculture, and ongoing urban development, human-caused channel alterations, road and storm sewer drainage, ditching, hiking trails, and gravel pits or quarries. Geomorphic responses to these disturbances are dependent on a combination of drainage-network position, slope, and geologic setting. Geologic

setting is related to drainage-network position because the geologic deposits parallel the Lake Superior shoreline. Headwater streams in large watersheds flow over glacial deposits above altitudes of about 1,200 feet (ft). Headwater tributaries and upper main stems have ditch-like channels with gentle slopes and no valleys. Urban development and road drainage cause increased runoff and flood peaks in these segments resulting in channel widening. Below about 1,200 ft., main- stem segments generally are affected by bedrock type and structure and have steep slopes and confined or entrenched valleys. Increases in flood peaks do not cause incision or widening in the bedrock-controlled valleys; instead, the flow and scour areas are expanded. Feeder tributaries to these main stems have steep, confined valleys and may be sources for sediment from urban areas, road runoff, or storm sewer outfalls. Main-stem segments near the glacial deposits/surficial bedrock contact (1,000–1,200 ft.) have the most potential for response to disturbance because they tend to have narrow valleys with sandy glacial lakeshore deposits and moderate slopes. Increases in flood peaks (from upstream increases in runoff) increase the potential for landslides and mass wasting from valley sides as well as channel widening.

Geomorphic Assessment and Monitoring for Stream Rehabilitation, Bayfield Peninsula, Wisconsin.

In 2002, a watershed-scale geomorphic assessment of five tributaries 10 Lake Superior in Wisconsin was initiated to identify past and present geomorphic factors that affect native brook trout habitat. The tributaries included in the study are the Cranberry River, Bark River, Raspberry River, Sioux River, and Whittlesley Creek. Past studies indicated that sedimentation problems were caused by bank and bluff erosion in upper main stem reaches of the tributaries. As part of the geomorphic assessment the success of stream bank stabilization structures constructed in the 1960s and 19705 were evaluated in the context of flood history. Results from the geomorphic assessment are being used to identify management implications for rehabilitation alternatives for the five tributaries. Monitoring of geomorphic conditions and hydrologic events before and after installation is necessary to adequately evaluate the success of rehabilitation techniques.

Climate Change and Renewable Energy : Management Foundations Final Copy Edit DRAFT.

Climate Change and Renewable Energy Management Foundations provides a platform for DNR staff to discuss and build management strategies that address climate change and renewable energy challenges. With accelerating climate change, DNR will need to evaluate its most basic management work. We will need to incorporate future climatic conditions into our decisions. Are we managing public lands in ways that improve their resilience to a changing climate? Are we planting the right tree species in the right places? Are we protecting the right lands in the right places and connecting habitat in climate-smart ways? DNR will base these and other management decisions on the best available science and adapt its actions as new information is developed. The report serves, as a bridge between the broad climate change and renewable energy strategies identified in DNR's Strategic Conservation Agenda and more specific actions DNR must take to mitigate climate change and adapt to its effects. The report:

• provides common definitions for explaining climate and renewable energy concepts,

• summarizes the science on climate and energy trends, impacts, and responses,

• outlines DNR's current work responding to climate and renewable energy challenges, and

• describes a framework for integrating and improving climate change and renewable energy strategies as we learn more.

This report is a foundational first step. It is DNR's first coordinated assessment of the risks and opportunities associated with a changing climate and a growing demand for new energy sources. Future reports, fact sheets, and training workshops will provide more operational guidance applicable to specific habitats, resources, and energy challenges.

Riparian area management: Riparian and wetland classification review and application

Classification is defined as a systematic arrangement of items into groups or categories according to established criteria. The purpose of classification for land management applications often has to do with providing a reasonably easy way to talk about management areas, establish priorities for decision-making, determine cost- effective strategies for dealing with resource restoration, or simply provide a basis to summarize inventory data into meaningful groups. Kondolf (1995) states that "classification allows scientists to stratify an otherwise confusing universe into sets of similar objects, conduct careful study on representative objects, and apply results to other members of that class." Classification should permit comparison and reproducibility, provide an estimate of potential success or failure, and improve communication.

ATLAS OF THE SPAWNING AND NURSERY AREAS Volume II - Lake Superior (Vol. II).

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues that Impact fish and wildlife resources and their supporting ecosystems. The mission of the program is as follows: o To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wild- life resources, particularly in respect to environmental impact assessment. To gather, analyze, and present information that will aid decision makers in the identification and resolution of problems associated with major changes in land and water use. To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development. Information developed by the Biological Services Program is intended for use in the planning and decision making process to prevent or minimize the impact of development on fish and wildlife. Research activities and technical assistance services are based on an analysis of the issues, a determination of the decision makers involved and their information needs, and an evaluation of the state of the art to identify information gaps and to determine priorities. This is a strategy that will ensure that the products produced and disseminated are timely and useful.

Effects of Forest Practices on Peak Flows and Consequent Channel Response : A State-of- Science Report for Western Oregon and Washington

This is a state-of-the-science synthesis of the effects of forest harvest activities on peak flows and channel morphology in the Pacific Northwest, with a specific focus on western Oregon and Washington.

We develop a database of relevant studies reporting peak flow data across rain-, transient-, and snow-dominated hydrologic zones, and provide a quantitative comparison of changes in peak flow across both a range of flows and forest practices. Increases in peak flows generally diminish with decreasing intensity of percentage of watershed harvested and lengthening recurrence intervals of flow. Watersheds located in the rain-dominated zone appear to be less sensitive to peak flow changes than those in the transient snow zone; insufficient data limit interpretations for the snow zone. Where present, peak flow effects on channel morphology should be confined to stream reaches where channel gradients are less than approximately 0.02 and streambeds are composed of gravel and finer material. We provide guidance as to how managers might evaluate the potential risk of peak flow increases based on factors such as presence of roads, watershed drain- age efficiency, and specific management treatments employed. The magnitude of effects of forest harvest on peak flows in the Pacific Northwest, as represented by the data reported here, are relatively minor in comparison to other anthropogenic changes to streams and watersheds.

Environmental Geology of the North Shore.

The geologic foundations of any part of the Earths surface, and the geologic processes which currently and could potentially affect that area, are of great significance for wise use of the land. Wise use encompasses not only avoiding harmful uses but also taking advantage of opportunities offered by the particular geologic materials, forms or processes of the area. Many planners have recognized this…

This study of the environmental geology of the North Shore was carried out as an element of the State of Minnesota's Coastal Zone Management (CZM) Program.

A Function-Based Framework for Stream Assessment & Restoration Projects.

This document provides a new framework for approaching stream assessment and restoration from a function-based perspective; as such, it will benefit from review, comments, and example experiences and applications.

Forest treatment effects on water yield.

Results are reported for thirty-nine studies of the effect of altering forest cover on water yield. Taken collectively, these studies reveal that forest reduction increases water yield, and that reforestation de-creases water yield. Results of individual treatments vary widely and for the most part are unpredictable. First-year response to complete forest reduction varies from 34 mm to more than 450 mm of increased streamflow. A practical upper limit of yield increase appears to be about 4.5 mm per year for each per- cent reduction in forest cover, but most treatments produce less than half this amount. There is strong evidence that in well-watered regions, at least, streamflow response is proportional to reduction in forest cover. As the forest regrows following treatment, increases in streamflow decline; the rate of decline varies between catchments, but appears to be related to the rate of forest recovery. Seasonal distribution of streamflow response to treatment is variable; response in streamflow may be almost immediate or considerably delayed, depending on climate, soils, topography, and other factors.

The Myths of Restoration Ecology.

“Based on our experiences as researchers and practitioners in conservation and restoration ecology, we propose five central myths (Table 1) under which many ecological restoration and management projects seem to be conceived and implemented. Myths have value because they help us to organize and understand complex systems and phenomena. Identifying myths can help make the tacit explicit by revealing assumptions that are otherwise hidden (Holling 1982). However, they remain simplified and potentially misguided models for understanding and application (Holling 1982,The first Myth, the Carbon Copy, addresses the goal-setting process, and as such, it forms the basis of how restorations are evaluated. The Carbon Copy is closely tied to the remaining four myths, which involve the process of restoration and management: the Field of Dreams; Fast Forwarding; the Cookbook; and Command and Control: the Sisyphus Complex. We believe that describing these myths will be useful in understanding how some management or restoration strategies are conceived, designed, and implemented. For example, adherence to different myths may direct actions in divergent directions, as could be the case when choosing between a focus on ecosystem structure (Carbon Copy) or on key processes (Field of Dreams). Examining these myths may also help us better understand why some restoration projects do not meet our expectations. In the pages below, we briefly describe each myth and its assumptions, and give examples where the myth exists.”

Knife River Implementation Plan for Turbidity

This implementation plan was written by the South St. Louis Soil and Water Conservation District (SWCD), with the assistance of the Knife River Stewardship Committee and guidance from the Minnesota Pollution Control Agency, based on the report Total Maximum Daily Load Study of Turbidity on the Knife River Watershed. The primary authors of the plan were Nathan Schroeder and Kate Kubiak (South St. Louis SWCD) with assistance from Greg Johnson (MPCA).

Design for Stream Restoration.

Stream restoration, or more properly rehabilitation, is the return of a degraded stream ecosystem to a close approximation of its remaining natural potential. Many types of practices $\mathcal{L}$dam removal, levee breaching, modified flow control, vegetative methods for streambank erosion control, etc.$\hat{C}$ are useful, but this paper focuses on channel reconstruction. A tension exists between restoring natural fluvial processes and ensuring stability of the completed project. Sedimentation analyses are a key aspect of design since many projects fail due to erosion or sedimentation. Existing design approaches range from relatively simple ones based on stream classification and regional hydraulic geometry relations to more complex two- and three-dimensional numerical models. Herein an intermediate approach featuring application of hydraulic engineering tools for assessment of watershed geomorphology, channel-forming discharge analysis, and hydraulic analysis in the form of one-dimensional flow and sediment transport computations is described.

River Restoration and Meanders

Among the most visually striking river restoration projects are those that involve the creation of a new channel, often in a new alignment and generally with a form and dimensions that are different from those of the pre-project channel. These channel reconstruction projects often have the objective of creating a stable, single-thread, meandering channel, even on rivers that were not historically meandering, on rivers whose sediment load and flow regime would not be consistent with such stable channels, or on already sinuous channels whose bends are not symmetrical. Such meandering channels are often specified by the Rosgen classification system, a popular restoration design approach. Although most projects of this type have not been subject to objective evaluation, completed post-project appraisals show that many of these projects failed within months or years of construction. Despite its, at best, mixed results, this classification and form-based approach continues to be popular because it is easy to apply, because it is accessible to those without formal training in fluvial geomorphology, and probably because it satisfies a deep-seated, although unrecognized, cultural preference for single-thread meandering channels. This preference is consistent with 18th-century English landscape theories, which held the serpentine form to be ideal and led to widespread construction of meandering channels on the country estates of the era. The preference for stability in restored channels seems to be widely accepted by practitioners and funders despite the fact that it is antithetical to research showing that dynamically migrating channels have the greatest ecological richness.

Marengo Marengo River Watershed Case : Assessing the Hydrologic Condition of the Marengo River Watershed, Wisconsin.

The Partner Team wanted specifically to learn which hydrologic factors had the most influence on the timing, quality and quantity of water in the Marengo River watershed. They further wanted to use this analysis to help identify and prioritize projects in the watershed.

Lake Superior Lakewide Management Plan LaMP 2008.

The Lake Superior Binational Program is an integrated program addressing critical pollutants, human health, sustainability, habitat, aquatic and terrestrial communities, and communications. The approach described in these ecosystem goals supports and is integrated with the other chapters of the LaMP. The Vision for Lake Superior expresses the desire for, among other things, a watershed where diverse life forms exist in harmony, that is free of toxic substances that threaten fish, wildlife and human health, and where wild shorelines and islands are maintained. The Aquatic, Habitat and Wildlife Committees of the Lake Superior Work Group, have put forward a mission to “support intact, diverse, healthy and sustainable ecosystems and the native plant and animal communities that depend upon them.” The Committees have described the natural processes that must be present and functioning well in order for a healthy ecosystem to exist, as well as a set of principles that guided, and continue to guide, their work in developing these Ecosystem Goals. These components can be found in the consolidated ecosystem chapter of the Lake Superior LaMP. The Strategic Outcomes that the committees have set in order to achieve the Vision for Lake Superior and to preserve, protect and enhance healthy, sustainable ecosystems.

A fish-based index of biotic integrity to assess intermittent headwater streams in Wisconsin, USA.

I developed a fish-based index of biotic integrity (IBI) to assess environmental quality in intermittent headwater streams in Wisconsin, USA. Backpack electrofishing and habitat surveys were conducted four times on 102 small (watershed area 1.7-41.5 km(2)), cool or warm water (maximum daily mean water temperature > or = 22 C), headwater streams in spring and late summer/fall 2000 and 2001. Despite seasonal and annual changes in stream flow and habitat volume, there were few significant temporal trends in fish attributes. Analysis of 36 least-impacted streams indicated that fish were too scarce to calculate an IBI at stations with watershed areas less than 4 km(2) or at stations with watershed areas from 4-10 km(2) if stream gradient exceeded 10 m/km (1% slope). For streams with sufficient fish, potential fish attributes (metrics) were not related to watershed size or gradient. Seven metrics distinguished among streams with low, agricultural, and urban human impacts: numbers of native, minnow (Cyprinidae), headwater-specialist, and intolerant (to environmental degradation) species; catches of all fish excluding species tolerant of environmental degradation and of brook stickleback (Culaea inconstans) per 100 m stream length; and percentage of total individuals with deformities, eroded fins, lesions, or tumors. These metrics were used in the final IBI, which ranged from 0 (worst) to 100 (best). The IBI accurately assessed the environmental quality of 16 randomly chosen streams not used in index development. Temporal variation in IBI scores in the absence of changes in environmental quality was not related to season, year, or type of human impact and was similar in magnitude to variation reported for other IBI's.

Geomorphology Riparian reforestation and channel change : A case study of two small tributaries to Sleepers River, northeastern Vermont

Measurements of two small streams in northeastern Vermont, collected in 1966 and 2004–2005, document considerable change in channel width following a period of passive reforestation. Channel widths of several tributaries to Sleepers River in Danville, VT, USA, were previously measured in 1966 when the area had a diverse patchwork of forested and nonforested riparian vegetation. Nearly 40 years later, we remeasured bed widths and surveyed large woody debris (LWD) in two of these tributaries, along 500mof upper Pope Brook and along nearly the entire length (3 km) of an unnamed tributary (W12). Following the longitudinal survey, we collected detailed channel and riparian information for nine reaches along the same two streams. Four reaches had reforested since 1966; two reaches remained nonforested. The other three reaches have been forested since at least the 1940s. Results show that reforested reaches were significantly wider than as measured in 1966, and they are more incised than all other forested and nonforested reaches. Visual observations, cross-sectional surveys, and LWD characteristics indicate that reforested reaches continue to change in response to riparian reforestation. The three reaches with the oldest forest were widest for a given drainage area, and the nonforested reaches were substantially narrower. Our observations culminated in a conceptual model that describes a multiphase process of incision, widening, and recovery following riparian reforestation of nonforested areas. Results from this case study may help inform stream restoration efforts by providing insight into potentially unanticipated changes in channel size associated with the replanting of forested riparian buffers adjacent to small streams.

WHERE RIVERS ARE BORN : The Scientific Imperative for Defending Small Streams and Wetlands.

Our nation's network of rivers, lakes, and streams originates from a myriad of small streams and wetlands, many so small they do not appear on any map. Yet these headwater streams and wetlands exert critical influences on the character and quality of downstream waters. The natural processes that occur in such headwater systems benefit humans by mitigating flooding, maintaining water quality and quantity, recycling nutrients, and providing habitat for plants and animals. This paper summarizes the scientific basis for understanding that the health and productivity of rivers and lakes depends upon intact small streams and wetlands. Since the initial publication of this document in 2003, scientific support for the importance of small streams and wetlands has only increased. Both new research findings and special issues of peer reviewed scientific journals have further established the connections between headwater streams and wetlands and downstream ecosystems. Selected references are provided at the end of the document.

North Shore Data Atlas.

The North Shore Data Atlas is a collection of information in the form of maps, graphs, charts and tables: about the North Shore of Lake Superior in Minnesota. The information gives both an overview of the characteristics of the entire North Shore and more specific information about the land close to Lake Superior. It is not detailed enough to identify specific characteristics of a location, such as one's backyard. The information should be used to relate general areas to each other to capture the overall characteristics of the North Shore. The information in this atlas describes the natural resources and cultural patterns of the North Shore. Included in the natural re- sources section are features such as land forms, soils, water systems and forest cover. Included in the cultural patterns are ownership patterns, transportation and land use. Data are displayed at two levels of detail-the Lake Superior Watershed and a detailed study area concentrating on land close to Lake Superior. The Lake Superior Watershed defined for this atlas covers the area of Minnesota which is drained by streams that flow directly into Lake Superior. The watershed map provides a broader perspective of the North Shore's resources. Because most of the development is concentrated along the shore of Lake Superior, a detailed study area was defined within the watershed. The detailed study area maps provide more specific information about the North Shore. Map 2 on page 4 shows the relationship of these two areas.

Executive Summary Report : Erosion and Sedimentation in the Nemadji River Basin.

In 1993, the Citizen's Advisory Committee of the RAP requested the Natural Resources Conservation Service (NRCS -- formerly the Soil Conservation Service) to identify methods for reducing sedimentation in the Nemadji River. Under the authority of Public Law-566 Watershed Protection and Flood Prevention Act, the NRCS began work on the Nemadji River Basin Project in January 1994. The Carlton County Board of Commissioners, Douglas County Supervisors, Douglas County Land Conservation Committee, Carlton County Soil and Water Conservation District, and the Metropolitan Interstate Committee served as sponsors to provide local support and input. The mission of the Nemadji River Basin Project is to recommend remedial actions and treatments to implement restoration to beneficial uses to the Nemadji River Basin.

Riparian vegetation : degradation, alien plant invasions, and restoration prospects.

Rivers are conduits for materials and energy; this, the frequent and intense disturbances that these systems experience, and their narrow, linear nature, create problems for conservation of biodiversity and ecosystem functioning in the face of increasing human influence. In most parts of the world, riparian zones are highly modified. Changes caused by alien plants — or environmental changes that facilitate shifts in dominance creating novel ecosystems — are often important agents of perturbation in these systems. Many restoration projects are underway. Objective frameworks based on an understanding of biogeographical processes at different spatial scales (reach, segment, catchment), the specific relationships between invasive plants and resilience and ecosystem functioning, and realistic endpoints are needed to guide sustainable restoration initiatives. This paper examines the biogeography and the determinants of composition and structure of riparian vegetation in temperate and subtropical regions and conceptualizes the components of resilience in these systems. We consider changes to structure and functioning caused by, or associated with, alien plant invasions, in particular those that lead to breached abiotic- or biotic thresholds. These pose challenges when formulating restoration programs. Pervasive and escalating human-mediated changes to multiple factors and at a range of scales in riparian environments demand innovative and pragmatic approaches to restoration. The application of a new framework accommodating such complexity is demonstrated with reference to a hypothetical riparian ecosystem under three scenarios: (1) system unaffected by invasive plants; (2) system initially uninvaded, but with flood-generated incursion of alien plants and escalating invasion-driven alteration; and (3) system affected by both invasions and engineering interventions. The scheme has been used to derive a decision-making framework for restoring riparian zones in South Africa and could guide similar initiatives in other parts of the world.

Why Climate Change Makes Riparian Restoration More Important than Ever : Recommendations for Practice and Research.

Over the next century, climate change will dramatically alter natural resource management. Specifically, historical reference conditions may no longer serve as benchmarks for restoration, which may foster a “why bother?” attitude toward ecological restoration. We review the potential role for riparian restoration to prepare ecological systems for the threats posed by climate change. Riparian ecosystems are naturally resilient, provide linear habitat connectivity, link aquatic and terrestrial ecosystems, and create thermal refugia for wildlife: all characteristics that can contribute to ecological adaptation to climate change. Because riparian systems and the projected impacts of climate change are highly variable geographically, there is a pressing need to develop a place-based understanding of climate change threats to riparian ecosystems. Restoration practitioners should consider how they can modify practices to enhance the resilience of riparian ecosystems to climate change. Such modifications may include accelerating the restoration of private lands, participating in water management decisions, and putting the emerging field of restoration genetics into practice.

Compendium of Tools for Watershed Assessment and TMDL Development. Environmental Protection.

This document represents an update to and expansion of a previous EPA publication, Compendium of Watershed-scale Models for TMDL Development, EPA 841-R-92-002 (USEPA, Office of Water, 1992). The revised manual, renamed Compendium of Tools for Watershed Assessment and TMDL Development broadens the review of models and techniques from solely watershed loading models to include receiving water models and ecological assessment techniques and models.

Suspended-sediment transport rates at the 1.5-year recurrence interval for ecoregions of the United States: transport conditions at the bankfull and effective discharge

Historical flow and suspended-sediment transport data from more than 2900 sites across the United States have been analyzed in the context of estimating flow and suspended-sediment transport conditions at the 1.5-year recurrence interval flow (Q1.5). This is particularly relevant with the renewed focus on stream restoration activities and the urgency in developing water-quality criteria for sediment. Data were sorted into the 84 Level III ecoregions to identify spatial trends in suspended-sediment concentrations and yields to meaningfully describe suspended-sediment transport rates across the United States. Arguments are developed that in lieu of form-based estimates of say the bankfull level, a flow of a given recurrence interval (Q1.5) is more appropriate to integrate suspended-sediment transport ratings for the purpose of defining long-term transport conditions at a site (the ''effective discharge''). The use of the Q1.5 as a measure of the effective discharge for suspended-sediment transport is justified on the basis of literature reports and analytic results from hundreds of sites in 17 ecoregions that span a diverse range of hydrologic and topographic conditions (i.e., Coast Range, Arizona/New Mexico Plateau, Mississippi Valley Loess Plains, Middle Atlantic Coastal Plain). There is sufficient data to also develop regional curves for the Q1.5 in all but eight of the ecoregions. At the Q1.5 the highest median suspended-sediment concentrations occur in semiarid environments (Southwest Tablelands, Arizona/ New Mexico Plateau and the Mojave Basin and Range); the highest yields occur in humid regions with erodible soils and steep slopes or channel gradients (Mississippi Valley Loess Plains [MVLP] and the Coast Range). Suspended-sediment yields for stable streams are used to determine ''background'' or ''reference'' sediment transport conditions in eight ecoregions where there is sufficient field data. The median value for stable sites within a given ecoregion are generally an order of magnitude lower than for nonstable sites.

A Categorization of Approaches to Natural Channel Design,

Presented herein is a categorization of commonly applied approaches to natural channel design. Approaches have been categorized as analog, empirical, or analytical. Methods and limitations of each approach and considerations for selection of an appropriate approach are discussed. Analog design replicates historic or adjacent channel characteristics and assumes equilibrium sediment and hydrologic conditions. Empirical design uses equations that relate various channel characteristics derived from regionalized or “universal” data sets, and also assumes equilibrium sediment and hydrologic conditions. Analytical design makes use of the continuity equation, roughness equations, hydraulic models, and a variety of sediment transport functions to derive equilibrium channel conditions, and thus is applicable

to situations where historic or current channel conditions are not in equilibrium, or where applicable analogs or empirical equations are unavailable.

Total Maximum Daily Load Study of Turbidity on the Knife River Watershed.

The Knife River watershed is a heavily forested watershed along the North Shore of Lake Superior, 15 miles north of Duluth, MN. The purpose of this TMDL study is to identify the amount of turbidity-causing pollutants that can be in the water and still meet the water quality standard for turbidity. The TMDL is also intended to identify the sources and amounts of pollutants causing turbidity in the river, the relative impacts of human-related activities (primarily development, agriculture, and forestry) within the Knife River watershed and to identify appropriate sediment reduction strategies that will achieve the load goals. The ultimate goal of the TMDL is to return the water quality of the stream to the levels identified by the State of Minnesota as water quality standards that protect the beneficial uses of the Knife River Watershed.

Predicting bed load and suspended sediment export in low-order Lake Superior streams.

To evaluate the effects of human disturbance and wetland loss on small upper midwestern streams, we collected bed load samples from 48 second and third order Lake Superior tributaries during snowmelt in 1998 and 1999. Suspended sediment samples from these watersheds were collected during base flow, rain events, and snowmelt. To explain differences in sediment export a geomorphic stream classification system was used to integrate stream geomorphological characteristics such as width:depth ratio, entrenchment, and channel slope. Strong correlations existed between bankfull discharge and both wetted cross sectional area and watershed area when streams were classified by geomorphic type. Geomorphic stream types and stream power accounted for 71 percent of the variation in bed load mass exported. Suspended sediment export increased with greater proportions of fine sediments in the stream beds, with increased discharge, recent logging, agriculture, stream and road densities, and with decreased woody debris. Overall, bed load appears to be power-limited, while suspended sediment is more supply-limited.

Analysis of the Current Science Behind Riparian Issues Report to the Minnesota Forest Resources Council

Two of the most important benefits from forested watersheds are favorable runoff and water quality. Management of riparian forests has the potential to influence these benefits. The Riparian Science Technical Committee (RSTC) reviewed the literature on riparian functions and how alternative forest management practices can affect twelve abiotic parameters of hydrology, water quality, and microclimate. Based on that review, the RSTC concluded that sediment and temperature are keystone parameters that should influence riparian management decisions. Direct sediment in- put to channels is addressed largely by the existing filter strip requirements, although roads and concentrated disturbance activities need continued attention. The use of slope as a modifier of filter strip width is consistent with the literature. Increased sediment from channel scour will result from elevated bankfull flows, but this issue is addressed only through landscape-level land use policies. Increases in stream temperatures can be managed by maintaining shade. Most shade functions can be pro- vided with a 50 to 75 foot riparian management zone (RMZ) if shade is dense. Issues of risk to these functions and the rate of function

recovery after disturbance influence decisions about appropriate dimensions of filter strips and streamside management zones. Two key risk factors that the Minnesota Forest Resources Council (MFRC) needs to consider are windthrow and beaver activity. RSTC team members dealing with hydrology and geochemical functions could not come to consensus on how to ad- dress these risk factors. Data are scant, but RMZs appear to be most vulnerable to windthrow in the outside 25 foot edge. Beaver dams can reduce sediment transport through a stream reach, resulting in sediment deposition and channel widening. This can be addressed by excluding early succession forests on streams where the impact is critical (e.g., cold water trout streams). Most foraging by beaver occurs within the first 10 m (33 ft.) of water, but guidelines from Ontario recommend that vegetation management extend 50 m (165 ft.) from the water to discourage beaver activity. Minnesota DNR Fisheries and Wildlife Division recommends a 91 m (300 ft.) exclusion of timber sales on cold water trout streams. Beaver dams can also adversely modify stream channel geometry so that warming occurs. One conclusion is that windthrow risk for the outside 7 m (25 ft.) edge of RMZs should be considered to protect riparian functions. For coldwater streams integrated pest management strategies are needed for beaver. An alternative position recommends a 61 m (200 ft.) timber sale exclusion on coldwater trout streams and their tributaries where aspen suckering would be the resulting tree regeneration, and 37-91 m (120-300 ft.) RMZs to balance windthrow mortality with growth. All RSTC members agreed that there is clearly a lack of investment in watershed research to resolve management/water quality issues in this region. The Pokegama Watershed Study represents one of the few efforts to test alternative management practices.

A Framework for HYDROLOGIC CONDITION of Watersheds.

To evaluate the effects of human disturbance and wetland loss on small upper Midwestern streams, we collected bed load samples from 48 second and third order Lake Superior tributaries during snowmelt in 1998 and 1999. Suspended sediment samples from these watersheds were collected during base flow, rain events, and snowmelt. To explain differences in sediment export a geomorphic stream classification system was used to integrate stream geomorphological characteristics such as width:depth ratio, entrenchment, and channel slope. Strong correlations existed between bankfull discharge and both wetted cross sectional area and watershed area when streams were classified by geomorphic type. Geomorphic stream types and stream power accounted for 71 percent of the variation in bed load mass exported. Suspended sediment export increased with greater proportions of fine sediments in the stream beds, with increased discharge, recent logging, agriculture, stream and road densities, and with decreased woody debris. Overall, bed load appears to be power-limited, while suspended sediment is more supply-limited.

Land Use and Stream Condition.

Changes in bankfull flows will affect stream shape (width and depth) when the 60% threshold is exceeded on flat watersheds (having hill slopes less than 3%) of 10 square miles or more. In steep watersheds, like moraine hills, with land slopes of 3% to 50"10, a watershed of 1 square mile or more is needed before channel erosion occurs. Streams eventually reshape themselves into channels with normal width/depth ratios, but in the Clay Belt Region, it takes 50 to 100 years or more.

LAND FRAGMENTATION AND IMPACTS TO STREAMS AND FISH IN THE CENTRAL AND UPPER MIDWEST

Fragmentation of the land means changes in the vegetative cover. This alone has caused significant and wide spread physical and water quality changes to the streams and rivers in the central and upper Midwest. Removal of the forest canopy that changes land use to "open" conditions: agricultural, urban, or rights of way, is sufficient to initiate and prolong in-channel stream erosion and sedimentation for more than a century. The comparison between cropland and forestland, shows the loss of forest cover will cause nearly annual, bankfull, peak flows to double or triple. The processes causing higher bankfull flows are synchronized snowmelt in open land and young-aged forestland and rapid delivery of rainwater from compacted soils. In contemporary forestlands, very high rates of harvesting can also increase bankfull flows. Where forestland is not fragmented, undersized road culverts, eroding road surfaces, and road washouts are a significant source of sediment to streams. Both high velocities in culverts, high dams, and high bankfull stream velocities have fragmented the fish, invertebrate, and mussel communities of the Midwest. This paper considers how and where these impacts occur, and suggests riparian restoration measures to bring Midwest streams to their productive best.

Aspen clearcutting increases snowmelt and storm flow peaks in north central Minnesota.

Clearcuttlng aspen from the upland portion of an upland peatland watershed in north· central Minnesota caused snowmelt peak discharge to increase 11 to 143 percent. Rainfall peak discharge size increased as much as 250 percent during the first two years after clearcutting, then decreased toward precutting levels in subsequent years. Storm flow volumes from rain during the first two 'years in- creased as much as 170 percent but: declined to preharvest volumes in the third year. Snowmelt volumes did not significantly change. Snowmelt peak discharge occurred about four to five days earlier after clearcutting but the timing of storm flow from rainfall was not changed. Snowmelt peaks remained above precut size for nine years after clearcutting on an area undergoing natural regeneration to aspen sap- lings. Partial cutting up to approximately one-half of the watershed reduced" peak snowmelt discharge because melt water desynchron1zed in cleared and forested parts. Clearing more than 2/3 of the watershed caused snowmelt flood peak size to double during years with snowpack’s in excess of seven inches of water that remained until a day when maximum air temperatures exceeded 60oF.

Watershed Vulnerability Analysis

This technical release outlines the basic process for performing a rapid Watershed Vulnerability Analysis and serves as an update to the Handbook. The analysis compares subwatershed quality across the watershed and yields four primary outcomes of interest to the watershed manager. These are: (A) A defensible rationale for classifying subwatersheds. Typically, these classifications are used to develop specific management criteria' for each subwatershed class within the framework of an overall watershed overlay district. (B) An effective framework to organize and integrate mapping and monitoring data that are currently being collected in the subwatershed assessments to make final

classifications. (C) A rapid forecast of which specific subwatersheds are most vulnerable to future watershed growth and warrant immediate subwatershed planning efforts. (D) A priority ranking identifying subwatersheds that merit prompt restoration actions. The basic watershed vulnerability analysis presented follows an eight-step process. Considerable judgment and discretion needs t&' be exercised in most steps; we have attempted to outline the key choices to be made in these areas. Section 3 of this document goes over each step in detail.

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