ILLINOIS RIVER BASIN RESTORATION
COMPREHENSIVE PLAN
WITH INTEGRATED ENVIRONMENTAL ASSESSMENT

APPENDIX D

GEOMORPHOLOGY, SEDIMENT DELIVERY, SEDIMENT REMOVAL AND BENEFICIAL USE

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INTRODUCTION

This appendix summarizes several investigations undertaken as part of the Comprehensive Plan efforts related to geomorphology, sediment delivery, sediment removal, and beneficial use. The reports and efforts summarized below in sections 1 through 6 were prepared by contract. The reports are available at the Corps of Engineers, Rock Island District office in Rock Island, Illinois. Section 7 provides an overview of sediment removal and beneficial use options that have either been tested or could be tested in the basin.

1. SUMMARY OF ILLINOIS RIVER BASIN LANDFORMS AND PHYSIOGRAPHIC REGIONS

The goals of this study were to provide summaries of the geomorphology and surficial geology of the Illinois River Basin and to characterize the variability of such properties that are important for ecosystem restoration assessments. The three products developed were intended to facilitate discussions among the public, managers, and scientists.

A. ***Geological History of the Illinois River Watershed.*** This paper describes the development of landforms and surficial deposits during the Pleistocene Epoch. It focuses on glacial sedimentary processes and the complexity of glacial environments, but also discusses contemporary sediment-related problems. The paper was presented at the 2001 Governor's Conference on the Management of the Illinois River System (Phillips and Shilts 2001).

B. Revision of *Physiographic Divisions of Illinois* (Leighton et al. 1948). The product of this investigation was an updated map of the physiographic divisions of Illinois. Physiographic divisions are regions with distinctive landforms distinguished by slope and relief. The many influences on landforms/development include pre-existing variations in topography; the texture and thickness of surficial materials; relative age of the surface; and glacial, fluvial, or lacustrine molding of the surface. Recognition of the regions may be useful in identifying the expected range of geomorphological parameters for a given site. Leighton et al.'s (1948) map updated and refined Fenneman's (1928) national boundaries for Illinois and was published at a scale of 1:3,000,000. This revision is intended to create a GIS layer more useful at larger scales and to incorporate four decades of new mapping and digital elevation models to provide more accurate regional views. Models of geomorphology and landform evolution have changed considerably over the last 4 decades, so it is wise to reconsider the definition and use of the divisions. Table D-1 summarizes the updates, by division, from the 1948 map to the recent map.

Leighton et al.'s (1948) map was first digitized by Abert (1996). This digital coverage was updated to 1:500,000—the scale of most Illinois State Geological Survey (ISGS) statewide maps—by overlaying it upon a new painted relief map of Illinois (Luman et al., in press). The criteria that defined Leighton et al.'s divisions were reevaluated and manually redrawn to fit topographic features on Luman et al. (in press). These boundaries were refined where appropriate using surficial geological features (Stiff 2000) and elevation contours determined from Abert (1996). The original physiographic divisions largely hold up to new analysis, although all boundaries were moved significantly and made more complex. In addition, two new regions (the Ancient Illinois Floodplain and the Griggsville Plain) were subdivided from existing regions by virtue of several distinctive features.

C. Lexicon Map. The product of this effort was an updated map of the landforms of Illinois. Bier's (1980) interpretive landform map was successfully georeferenced to an ISGS coverage of county boundaries (http://www.isgs.uiu.c.edu/ndsihome/browse/statewide/counties.e00) and draped on Abert's (1996) shaded relief map. Although georeferencing of the Bier map was not perfect, distortions based on the county boundaries are typically less than 500 m and, more importantly, interpreted landforms generally overlie corresponding features on Abert (1996).

Table D-1. Revision of the Physiographic Classifications of Illinois

Classification by Leighton, Ekblaw, and Horberg	Classification Criteria by Leighton, Ekblaw, and Horberg	Classification Criteria by Phillips
I. GREAT LAKES SECTION	•	
I-A. Chicago Lake Plain	• Defined by highest lake level, the Glenwood Phase at ~ 640 ft • Includes headlands	• Elevation determined from DEM (Abert 1996) • Includes headlands and some Equality Formation (Stiff 2000)
I-B. Wheaton Morainal Country	• Includes northern portion of Marengo Moraine, arbitrary(?) eastward jog in Kane county to join Valparaiso Moraine, followed Rockdale-Manhattan Moraine east to Indiana (Tazewell and Carey substages) • Includes some Illinois Episode drift in McHenry and Kane counties • Highest elevation, complex topography; knob and kettle topography, small filled lake basins, eskers, and kames relatively common though not abundant	• Includes Wadsworth Formation and excludes Lemont Formation (Stiff 2000). This significantly modifies northern reach. Surface is kettled west to farthest moraine, but much less so than to east. • Portions of Rockdale Moraine dissected by sluiceways excluded; surrounded by Kankakee flood-related deposits and have smoother surface than moraine to east
II. TILL PLAINS SECTION		
II-A. Kankakee Plain	• Level to gently undulatory including low morainic islands, glacial terraces, fluviglacial bars and dunes, some lake deposits (though lakes short-lived) • Modified morainic basin • Enclosed by Iroquois, Manhattan, Minooka moraines (on E), and Marseilles and Chatsworth moraines (W & S) • Thick drift to exposed bedrock (in valleys)	• Lake Wauponsee Stage, highest level of the Kankakee Flood, at ~650 ft. Elevation from Abert (1996) • Includes fluvially modified (flat-topped to smoothed) bits of Minooka, Rockdale, Wilton Center, and Manhattan moraines • Excludes hummocky plain along Marseilles and Chatsworth moraines

Classification by Leighton, Ekblaw, and Horberg	Classification Criteria by Leighton, Ekblaw, and Horberg	Classification Criteria by Phillips
II-B. Bloomington Ridged Plain	• Wisconsin moraines of Tazewell age • Low, broad morainic ridges separated by flat to gently undulating ground moraine • Moraine slopes are gentle • Outer boundary follows Shelbyville, Bloomington moraines	• Some Henry Formation along Marseilles and Chatworth morains included because (a) relatively steep slope, (b) coarser-textured than most of Illinois Till Plain, (c) genetically linked to moraine • Near Peoria, Bloomington Moraine has straighter, less dendritic (less developed?) drainages than beyond moraine
II-C. Rock River Hill Country	• Subdued rolling hills • Bedrock controls most landforms • Thin Illinois and Wisconsin Episode drift	• Primarily defined by being *not* Green River Lowland or Wisconsin Driftless Area • Sharp ridges, relatively well-developed drainages • Topography slightly subdued relative to Wisconsin Driftless Area
II-D. Green River Lowland	• Bounded by Shelbyville Moraine, Green River Lobe, on north and south, and Bloomington Moraine on east • Merges with Cary valley-train of Rock River in west • Includes remnants of Shelbyville Moraine • Remnant of old bedrock valley forms bluff on south	• Fluvial and lacustrine landforms of the Henry and Equality Formations • Portions of sluiceways through western uplands included because they are physiographically continuous
II-E. Galesburg Plain	• Western segment of Illinoian drift sheet • Level to undulatory; few morainic ridges • Bounded by Meredosia Valley and Wisconsin drift border (NE); Illinoian drift boundary (SW) • Continues across Mississippi River into Iowa	• Southeastern boundary drawn along base of western bluff of the Illinois Valley • Distinguished from Bloomington Ridged Plain in NE by more complex drainages; boundary otherwise drawn at base of moraine ridge • Separated out Griggsville Plain in S, where uplands are less extensive, valleys are more deeply eroded, and drainages more complex

Classification by Leighton, Ekblaw, and Horberg	Classification Criteria by Leighton, Ekblaw, and Horberg	Classification Criteria by Phillips
II-F. Springfield Plain	• Western half of Illinoian till plain • Level to undulatory till plain • Shallow drainages • Southern boundary where drift thins and bedrock control becomes more predominant	• Includes smooth features with several clearly glacial landforms, i.e., moraines • Flatter uplands than the subdued ridges in Mount Vernon Hill Country • Southern drainages controlled by Kaskaskia R., Little Wabash R., or Embarras R.; MVHC drainages reach ridge crests and drain southward • In Monroe County (west), division excludes Mississippi R. drainages and boundary follows structural ridge
II-G. Mount Vernon Hill Country	• "Mature" topography of low relief • Restricted upland prairies • Broad alluviated valleys along larger streams • No glacial landforms except for portion of Jacksonville Moraine • Southern and western boundaries along outer limits of glaciation or outer margin of Carbondale Group, Pennsylvanian System	• Rounded upland ridges contrast with flatter, broader uplands of Springfield Plain • Drainages reach ridge crests and drain southward • Southern and western boundaries along outer limits of glaciation or outer margin of Carbondale Group, Pennsylvanian System
II-H. Griggsville Plain (NEW)		• More dissected than Galesburg Plain • Highly restricted uplands, though peaks more subdued than Lincoln Hills • Boundary drawn up center of McKee Creek valley, then westward following distinct linear features along ridge • Drainages less "feathery" than Galesburg Plain • Drainages more dendritic and more "feathery" than Lincoln Hills Section • May represent pre-Illinois drainages little modified by thin drift and minimal glacial erosion of Illinois Episode

Classification by Leighton, Ekblaw, and Horberg	Classification Criteria by Leighton, Ekblaw, and Horberg	Classification Criteria by Phillips
II-I Ancient Illinois Floodplain (NEW)		• Contains erosional and depositional features from Wisconsin Episode jökulhlaups (outburst floods) • Boundaries primarily follow escarpments, although southern boundary is arbitrary intersection with Lincoln Hills province • Areas with genetically-related features in southeast Mason, Loan, and Menard counties excluded because of topographic affinities with Springfield Plain
III. DISSECTED TILL PLAINS SECTION	• "Kansan" drift in area of high relief • Eastern boundary along Illinoian drift margin • Southern boundary where "Kansan" drift becomes too patchy to be significant, but arbitrary • Modified from Fenneman who drew eastern boundary at the Mississippi River	• Northern boundary distinguishes more crenulated (Griggsville Plain) from less crenulated topography
IV. WISCONSIN DRIFTLESS SECTION	• "Submaturely" dissected, low plateau bordering outwash-filled upper Mississippi Valley • Eastern boundary follows edge of Illinoian drift	• Eastern boundary follows edge of Illinoian drift
V. OZARK PLATEAUS PROVINCE		
V-A. Lincoln Hills Section	• Partially drift-covered dissected plateau above junction of Mississippi and Illinois rivers • "Maturely" dissected central ridge • Eastern boundary follows Illinoian drift border • Northern boundary arbitrary • Southern boundary along Cap au Grès flexure	• Southern part of eastern boundary drawn along limit of Illinoian drift • Includes long, oddly curved, wide-bottomed valleys with markedly steep walls and sharp ridges • Drainages less dendritic and less "feathery" than Griggsville Plain • Northern boundary arbitrary, but tangent to Pennsylvanian-Ordovician contact • Southern boundary on contact between Orodovician rocks and the Devonian Rocks of the Salem Plateau

Classification by Leighton, Ekblaw, and Horberg	Classification Criteria by Leighton, Ekblaw, and Horberg	Classification Criteria by Phillips
V-B. Salem Plateau Section	• Two segments of part of Ozark Dome • "Maturely" dissected, partially truncated cuestas dominated by single central ridge • Northern segment covered by Illinoian drift • Northern segment: arbitrary boundary with Salem Hills where coarser Pennsylvanian rocks give way to finer; east margin along overlapping edge of Pennsylvanian strata; northern boundary on Cap au Grès flexure • Southern segment: includes pre-Carboniferous rocks	• Northern segment: moved boundary eastward to include karstic regions; northern portion at Devonian-Ordovician contact • Southern segment: includes pre-Carboniferous rocks
VI. INTERIOR LOW PLATEAUS PROVINCE		
VI-A. Shawnee Hills Section	• Complex dissected upland underlain by Carboniferous rocks • Northern boundary along inner flank of lower Pennsylvanian (Caseyville LS) cuesta within Illinoian glacial drift boundary • Southern boundary along northern edge of overlapping coastal plain sediments	• Northern boundary slightly redrawn to separate more subdued topography in MVHC; actual Caseyville contact still significantly northward • Southern boundary along northern edge of overlapping coastal plain sediments
VII. COASTAL PLAIN PROVINCE	• Underlain by Cretaceous and Tertiary sediments overlapping on Paleozoic rocks to the north • Alluvial plains of Cache and Mississippi valleys • Hills between Cache Valley and Ohio River sculpted in Cretaceous rocks	• Northern boundary follows contact between coastal plain sediments and older rocks

2. STREAM DYNAMICS ASSESSMENT IN THE ILLINOIS RIVER BASIN

Andrew C. Phillips [1], Bruce L. Rhoads [2], Thomas J. McTighe, [1] and Courtney A. Klaus[1]

Dynamical behavior in planform of representative stream reaches from across the Illinois River Basin was assessed by analysis of aerial photographs in time series from 1938 to present. The analysis sought to identify mechanisms and rates of planform change, assess the variability of these behaviors across the watershed, and determine the suitability of the method for watershed-scale assessments. The analysis gives an essential historical context to modern stream conditions and provides insight into the concept of stream channel "stability" in particular. The analysis also helps to focus future field investigations by identifying important processes and targets for study.

Study reaches 1.6 km (1 mile) long were selected along 10 streams. Aerial photographs (photograph D-1) at approximately 10-year intervals were obtained for each site. Channel centerlines (threads) of each reach were digitally traced from scanned, georeferenced images in a GIS environment. Threads were buffered to the georeferencing error of their source photographs and then digitally compared with a customized tool to identify overlapping and non-overlapping polygons (figure D-1). Non-overlapping polygons were considered to represent significant change and were assigned into dynamic classes distinguishing "natural" and human-influenced change. The polygon area is the parameter for quantifying change. These changes were evaluated in context of stream power calculations from gauge data, geology and soils data, and observed changes in land use and land cover.

Stream planforms changed by lateral migration or downstream translation of meanders, by chute formation and avulsion, and by channelization. Most planform change was caused by channelization. Several channelized reaches were observed to redevelop meandering behavior or change shape as a consequence of the modification. The response of streams to channelization is particularly important because it provides important information on evaluating the feasibility of restoration projects focusing on dechannelization of streams.

At most reaches, the dominant evolutionary mode excluding channelization was by meander migration, with avulsion playing a significantly smaller role. Extent and rate of change varied considerably, but change occurred along every reach studied. McKee Creek in the southwestern portion of the Illinois River Basin exhibited singularly high rates of change with extensive meander migration and pervasive avulsion.

Average monthly stream power was calculated from USGS flow data and remote measurements of stream geometry. Streams exhibited either relatively low stream power with low variability, or relatively high power with high variability. Stream power increased with time by factor of approximately two on most reaches in watersheds that experienced extensive development; stream power on dominantly agricultural reaches showed no particular trend. A simple correlation between planform change and stream power was not identified. Although several reaches exhibited the progressive increases in change with stream power and time as expected for "unstable" stream channels, most did not. Correlation between stream power and planform change is not expected for either avulsion or channelization, but is expected for meander migration. The lack of correlation demonstrates that geomorphology of entire watersheds must be assessed to give spatial and temporal context to stream dynamical behavior.

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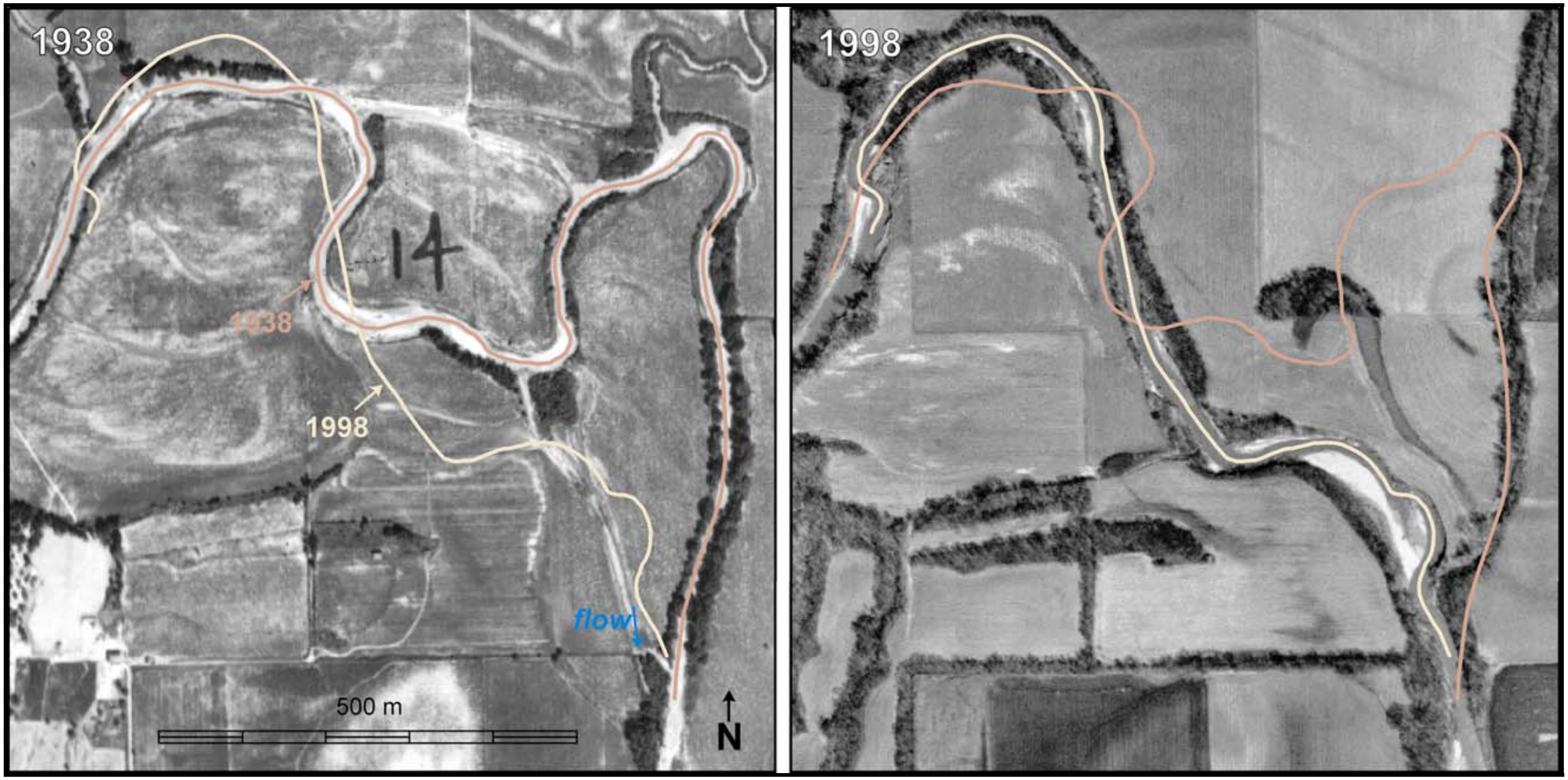

Photograph D-1. Aerial photographs of the same 1-mile stream reach showing channel locations changes from 1938 to 1998.

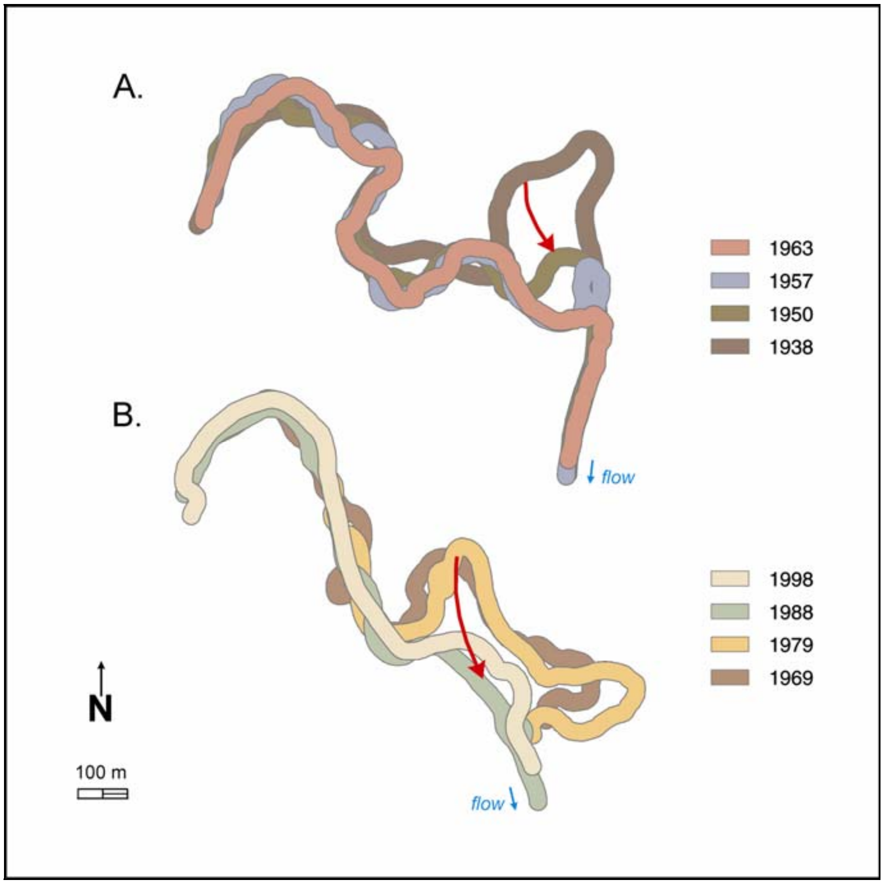

Figure D-1. Comparison of Channel Centerline Changes. Figure A: 1938 to 1963; Figure B: 1969 to 1998

3. SEDIMENT BUDGET

Sediment yield from tributary streams of the Illinois River was calculated based on suspended sediment load data collected by the USGS (Demissie et al. 2004). Sediment rating curves that relate daily sediment load and daily water discharge were developed for each of the sediment monitoring stations based on existing data. Because rating curves often underestimate sediment yield, a refined rating curve procedure was developed to minimize the underestimation. The sediment rating curves were then used to calculate annual sediment yields from all the tributary streams with available sediment load data. The annual sediment yields were then plotted against the annual water discharge to develop regional equations for annual sediment yields. The data points coalesced into four different annual sediment yield equations, which were then used to calculate annual sediment yields by tributary streams into the Illinois River Valley. A 20-year period (1981 through 2000) was used for the analysis. Tributary streams of the Spoon and LaMoine Rivers were determined to have the highest sediment yield rates. The main stems of the Spoon, LaMoine, and Vermilion Rivers had the second highest sediment yield rates, followed by the Sangamon, Iroquois, and Des Plaines Rivers.

The sediment yield calculations were used to construct a quantitative sediment budget for the Illinois River Valley. By using the four regional equations, the sediment inflow into the Illinois River Valley from tributary streams was calculated. The sediment outflow from the Illinois River Valley was determined from data collected by the USGS at the Valley City monitoring station. On the average, 12.1 million tons of sediment is delivered to the Illinois River Valley annually, and the average annual outflow of sediment from the Illinois River at Valley City is 5.4 million tons. This results in an average of 6.7 million tons of sediment delivered from tributary streams being deposited in the Illinois River Valley annually. The total amount of sediment deposited in the Illinois River Valley is probably higher than the 6.7 million tons because of the contribution of bank and bluff erosion, which is not included in these calculations.

4. DIGITIZE HISTORIC MAPS AND SEDIMENT RATE ANALYSIS

Sedimentation rates between 1903 and 2001 for four backwater rates on the Illinois River—Babb's Slough, Sawyer Slough, Meadow Lake, and Wightman Lake—ranged from 0.18 inch per year to 0.40 inch per year, and the percentage reduction in storage capacity varied from 87 percent (0.9 percent per year) to 98 percent (1.0 percent per year). In general, deeper areas have filled more quickly than shallow areas, resulting in a higher and more uniform bottom surface in 2001 as compared to 1903. The annual rates of capacity loss and sedimentation calculated between 1903 and 2001 compare closely to rates calculated in other publications between 1903 and the mid 1970s, indicating that sedimentation rates and rates of annual percent capacity loss have remained nearly constant since 1975. These recent rates are higher than expected given that the bottom surface has been progressively rising, which should result in decreased rates of sedimentation. However, water elevation duration curves from 1903 through 1975 and from 1975 through 2001 show that more recent water flow rates and corresponding water surface elevations have been higher, promoting continued high rates of sedimentation.

5. SEDIMENT CORINGS AND ANALYSIS

Determining the appropriate sediment removal technology, how that sediment is handled, and where it is placed depends on the type and quality of the sediment. As such, the Illinois State Water Survey conducted a study to characterize the sediments found in the Peoria Pool of the Illinois River. Thirty-seven deep sediment cores were collected during the course of the study. Each of the cores was split, and a lithology was developed for each. Radiographs for 25 of the cores were performed. The cores were sub-sampled in 10 cm intervals to the top of the original floodplain soil, if present. When original floodplain soils were present, larger intervals of about 25 cm were taken to the base of the core. Sub-samples were air dried and are being stored until such time as additional chemical and physical analysis can be performed.

6. SUMMARY OF INNOVATIVE TECHNOLOGIES AND TESTS FROM 2003

Three tests of innovative dredging technologies and beneficial uses were conducted in 2003. The following paragraphs briefly describe the efforts and results.

A. Sediment Handling Demonstration. Sediment excavated from an Illinois River backwater with a clamshell bucket was stockpiled on a field. The following day the sediment was loaded into concrete handling trucks. A concrete pump and placing boom had little difficulty handling the material. A telescoping conveyor also handled the material with little difficulty. The sediment stayed on the belts and negotiated the transfer point. The belt cleaners performed well. Minor problems, such as bridging in hoppers and splatter at some fittings designed for concrete, can be addressed with some operational or other changes. The pumps, booms, belts, and scrapers satisfactorily handled this material.

The sediment typical of Illinois River backwaters consists primarily of silt and clay with little sand. This material will cause little wear on belts, pumps, and pipes. As with other dredging equipment, potential objects in the sediment, such as tree branches, lumber, cables, metal parts and bricks of certain sizes, will have to be screened or avoided in order to prevent plugging or damaging the equipment. Trash racks with mechanical rakes or a grinder pump may prove useful in situations where debris is encountered.

This demonstration shows that conveyors and positive displacement pumps can move and place fine-grained sediment. The decision to use of this equipment on the Illinois River system will depend on numerous factors, including the distance material must be moved, availability of dredged material placement sites, configuration of dredge cuts, water depth, and cost. Both systems could move sediment at or near *in situ* moisture content to sites without costly containment dikes, onto islands, or into barges. The pump could also fill geotextile tubes.

B. Transport of Dredged Material Demonstration. A barge load of sediment excavated by clamshell dredge from Lower Peoria Lake was shipped to Chicago, Illinois. The barge was moved 163 miles and waited 10 days to unload. The sediment was loaded onto trucks with a large excavator and placed at a conservation area and at the Paxton I landfill reclamation site. The material handled well and maintained its consistency in the barge and after placing. It readily dumped from the trucks and formed piles about 2.5 feet high. The demonstration showed that this material can be transported and handled with conventional equipment and placed on fields without the necessity of using engineered containment structures.

A 3-cubic-yard conventional excavator bucket and semi dump trucks readily handled sediment at the destination site. The material in the trucks was cohesive, but gently rocked back and forth when the vehicles stopped and started. Although no spillage was observed from moving trucks, the potential for spillage should be considered when trucks are loaded and routed. Sediment poured from the trucks and formed thick dome-shaped piles rather than flowing across the ground and forming shallow pools.

The transport and placement of large quantities of dredged material on brownfields along waterways is technically feasible. Thick material can be unloaded from barges with an excavator or clamshell bucket into trucks, a positive displacement (concrete) pump hopper, or to a conveyor system for movement to a placement site. The material can be placed at a desired thickness and allowed to weather and gain soil structure. Alternatively, material could be placed in thin layers that would quickly dry. The dry soil could then be piled to the desired thickness by conventional earthmoving equipment.

There are other options for unloading and moving sediment to a placement site. Large off-road mining trucks could be used at sites adjacent to waterways where use of public roads is not required. It is also possible to add modest amounts of water to a barge to allow a slurry pump to move the material at a consistency similar to thick fuel oil. This would require some sort of low containment dike, as the mixture would flow. Alternatively the slurry could be sprayed in thin layers over the area and gradually built up.

C. Beneficial Use Demonstration. A proposed dredging project to improve wildlife habitat and recreation in the Peoria Lakes reach of the Illinois River will generate a large quantity of dredged sediment. The objective of this study was to investigate a possible beneficial use of the sediment as topsoil. Sediment was mixed with various amounts of biosolids, municipal compost, and horse manure. Barley and snapbeans were grown in the mixtures in the greenhouse. The plants grew well in all treatments, except snapbeans were stunted by salts in unleached biosolid mixtures. The highest overall yield for barley was obtained in the treatment composed of 50 percent sediment and 50 percent biosolid. For snapbeans, the highest yield was the treatment composed of 70 percent sediment and 30 percent biosolid. Heavy metals in plants tissue are within ranges considered normal, except for molybdenum (Mo) in snapbeans, which is at a level of concern if the plants were used exclusively as animal fodder. Addition of biosolids to sediments decreased Mo plant availability. Based on these results, this sediment has no inherent chemical or physical properties that would preclude use as topsoil substitute.

In terms of standard agronomic parameters such as plant growth, results confirm previous work that established that sediments from the Peoria Lakes reach of the Illinois River make excellent topsoil material. Both legume and grass plants grew well in all sediment mixtures and improved the plant growth potential of unleached biosolids. Addition of biosolids to sediment mitigates some of the problem with growing plants directly in sediments or biosolids. Pure sediments may have poor physical characteristics, at least initially under some field conditions. Pure biosolids have excessive salts that inhibit plant growth, particularly legumes, as evidenced by death of some snapbean plants on 100 percent biosolids. The sediments may experience improved tilth and higher plant nutrient content under field conditions when mixed with biosolids. The biosolids release less of their load of potentially toxic heavy metals, and the injurious salt content is diluted by sediment addition. Molybdenum uptake from sediments is decreased by biosolid addition.

An optimum sediment-to-biosolid ratio would range from 80:20 to 70:30 on a volume basis. This mixing ratio was also shown to reduce uptake of metals by crops, perhaps due to dilution as well as to modifications of soil properties, such as pH.

7. SEDIMENT REMOVAL AND BENEFICIAL USE

The Illinois River Basin Authority (WRDA 2000) calls for a component to address Section 519, the development and implementation of a program for sediment removal technology, sediment characterization, sediment transport, and beneficial uses of sediment. Much of the restoration effort will involve dredging outside of the navigation channel for environmental enhancement and will, therefore, differ in some respects from the more traditional navigation dredging.

The U.S. Army Corps of Engineers Dredging Operations and Environmental Research (DOER) Program conducts research that is designed to balance operational and environmental initiatives and to meet complex economic, engineering, and environmental challenges of dredging and disposal in support of the navigation mission. Research results provide dredging project managers with technology for cost-effective operation, evaluation of risks associated with management alternatives, and environmental compliance. The Corps of Engineers also operates the Regional Sediment Management (RMS) program. The RMS program is focused on managing sediment regionally in a manner that saves money, allows use of natural processes to solve engineering problems, and improves the environment. The Illinois DNR has developed dredging and beneficial use techniques suitable for Illinois River Restoration, including projects with the Corps under the Section 519 authority.

It is anticipated that Illinois DNR will continue as a partner in future efforts under this Illinois River Basin Restoration component, and that the efforts will be coordinated with the DOER and RMS program.

The scope of the work to date has been limited by fiscal constraints, particularly in relation to chemical characterization, demonstrations, and equipment testing and development. Funding and other support was provided by the State of Illinois and some local interests. Much of this work is described in Marlin 1999, 2001, 2002, 2003a, 2003b, and Darmody and Marlin 2002. Most of these documents are available at http://www.wmrc.uiuc.edu/special_projects/il_river/publications.cfm.

The following sections describe the background of this component; various technologies and beneficial use options that are available and have been tested in the basin; further technologies, testing, and applications that should be explored; and ends with recommendations regarding further work.

A. Background. Illinois River restoration efforts will require the removal and placement of several million cubic yards of sediment. There is great variation in the size and physical setting of the many backwaters (including side channels and the Peoria Lakes) within the floodplain. Additionally, the amount of material to be dredged to meet restoration objectives at specific sites will vary dramatically. These factors make it necessary to consider innovative dredging techniques, innovative methods of handling and transport, and beneficial use options and techniques in addition to conventional methods.

Manipulations in the river system have caused most backwaters to become shallow with nearly flat bottom profiles, while islands and much of the floodplain experience increased flooding and higher groundwater levels. These changes have dramatically reduced aquatic habitat values and made it difficult for floodplain trees and other plants to maintain their historic species mix. Ecological restoration in the backwaters and the floodplain includes the need for dredging shallow backwaters to various depths and elevating certain islands and floodplain areas. The current plan for backwater dredging envisions 5 percent of a typical site being at least 9 feet, 10 percent between 6 and 9 feet, 25 percent between 3 and 6 feet, with the remaining 60 percent left undredged, with existing depths ranging from 0 to 3 feet.

Conventional hydraulic dredging is an efficient and cost-effective method of removing sediment where suitable sites exist for constructing diked areas to dewater and store sediment. Sediment mixed with water can be pumped a short distance or several miles depending upon the number of pumps used and availability of placement sites. Mechanical dredging is commonly used for small jobs and projects where the dredged material can be placed within the reach of a crane or excavator arm, or where construction of a dewatering containment facility is not desired. Additional steps such as loading and unloading barges or trucks, mechanical dewatering, and transport from drying beds and mixing with other soil components all add costs to sediment management efforts.

Most Illinois River sediment washes from streambeds and banks, bluffs and farmland. Heavier sand and gravel particles that enter the floodplain tend to form deltas at stream mouths or move down the main channel. Backwater sediment is largely composed of fine-grained silt and clay particles that are carried farther and settle in slow moving backwaters. Thus, much of the sediment in the backwaters and side channels is similar in physical characteristics to native topsoil. It should, therefore, be possible to use these sediments as soil barring contamination.

Until recently, the placement of dredged material in the United States has generally been viewed as a disposal problem. Sediment from ocean ports and channels is usually sandy, salty, and often seriously contaminated. Material dredged from inland navigation channels also tends to have a high sand content. Such material is often placed in confined disposal areas. Efforts to find beneficial use for dredged material often focus on the construction of islands or wetland habitat in coastal areas. In some areas, sediment has been used as soil or a soil amendment. Large-scale restoration requires finding publicly acceptable ways of placing huge quantities of sediment in stockpiles as well as determining how to use it beneficially for economic or habitat purposes.

Many Illinois River backwaters are large or located far from areas suitable for placing dredged material. Lower Peoria Lake, for example, is surrounded by urbanized land. Other backwaters are large or in broad floodplains where only limited amounts of sediment can be placed without causing hydrologic or ecological problems. In areas where relatively small amounts of material need to be removed for fish access and over wintering, dike construction or equipment mobilization can make the cost per cubic yard removed prohibitive.

Beneficial use of sediment involves moving it from the water body, transporting it, and placing it where it will be used. Additionally it may be necessary to dewater, dry, or pulverize the sediment or blend it with other materials prior to final placement. Each step adds cost and economies of scale are often significant.

B. Summary of Available Technologies for Sediment Removal. Corps projects in Midwestern large rivers (e.g., Illinois, Mississippi) have typically utilized mechanical clamshell and hydraulic cutterhead dredges. However, an ever-increasing range of technologies is available to remove sediment. This section summarizes conventional and more recent technologies that could be utilized in future projects.

Traditional hydraulic dredging and mechanical dredging with clamshells or draglines have several limitations. These include resuspension of sediments at the point of excavation and free water entrainment in sediments, which require extensive, and potentially expensive, dewatering and return water treatment (Duke et al. 2000).

i. Mechanical Dredging. Mechanical dredges employ a bucket to excavate and lift material from the bottom. The advantages of mechanical dredging are that a minimum of additional water is added to the sediment during dredging and the dredging unit is not used to transport material, permitting uninterrupted operation. For a mechanical dredge to be efficient, the cut thickness must be sufficient to fill the bucket. In non-cohesive, fine-grained sediment, sediment will wash out of the bucket.

The clamshell dredge, using a wire rope connection, is the most common of the mechanical dredges. The mechanical dredge is able to work in confined areas and can remove many different sized materials. The clamshell is not suitable for free flowing material (like unconsolidated sediment) and may be unable to dig into extremely firm materials. Typical bucket sizes used in the Illinois River Basin would range from 1 to 4 cubic meters, though clamshells as large as 16 cubic meters are in use.

ii. Hydraulic Dredging. Hydraulic dredges remove sediment hydraulically, in the form of a slurry. Types of hydraulic dredges are straight suction and cutterhead, pipeline dredges, dustpan dredges, hopper dredges, and auger dredges.

C. Summary of Tests. A large number of placement and use options in various combinations could be used to accommodate millions of cubic yards of dredged sediment over the next 50 years. Some can be readily implemented with conventional dredging equipment, while others require innovative applications of new or existing equipment. An ideal development would be a device that could remove and transport sediment as readily as hydraulic dredges and place it with the consistency and water content of mechanical buckets. Given that areas outside the main channel are often a foot or less deep and the desired depth of much of the restoration is 3 to 6 feet, the ability to operate in shallow water is also desirable. Another factor is the fine-grained nature of most of the sediment that requires removal.

Innovative approaches to design and implementation are as necessary as innovative technology in a restoration project of this magnitude. The river system has degraded over more than a century, and several feet of sediment has accumulated in most areas.

D. Innovative Sediment Removal Technology - Hydraulic Dredging. Hydraulic dredges could be used in a number of innovative ways. It is possible to pump material for miles if suitable areas are not available near the dredging location. A pipeline over 20 miles long was used when the White Rock Reservoir was dredged in Dallas. The material went into an old mining pit. When quantities are great enough, such distances are not out of the question along the Illinois River. Corridors could follow existing highways, railways, streams, storm sewers, and the river itself. Such a system could deliver dredged material to a number of mined areas in Illinois. It may also be possible to use out-of-service gas or oil pipelines to transport slurried dredged material. For example, a 12-inch pipeline currently extends from near Chillicothe to Galesburg, which is near strip-mined land owned by the Department of Natural Resources.

Several companies, including Black and Veatch, Brennan Marine, and Phoenix Process Equipment Co. have used mechanical dewatering systems in conjunction with hydraulic dredges. The systems separate most of the water from the sediment and then run it through a belt press. It can then be placed directly into trucks or stockpiles. Brennan has also operated its system without the belt press by placing the treated material in geotextile tubes to further dewater and consolidate the dredged material. These systems could be used to dewater sediment piped from miles away for island construction, loading into barges or trucks, placing on fields or other purposes.

Polymers are used in the mechanical processes to speed thickening in the tanks. Similar polymers are in use to help settle hydraulically dredged solids in dewatering ponds. Among other things, the polymers allow the discharge to meet regulatory standards with less holding time. The polymer mixture is matched to the properties of sediment at particular sites.

E. Sediment Handling and Transport Technology

i. Conveyors. Conveyor belts have the potential to effectively extend the reach of excavator and crane mounted clamshell buckets. Backwater sediment excavated with these buckets is cohesive and contains very little free water. The sediment can be placed on islands, on shore, or in trucks that are within reach of the excavator. In order to use large buckets in backwaters, it is necessary to dig deep enough to bring in a floating crane. If material is to be moved beyond the arm’s reach, it must generally be loaded onto a barge that may require additional depth. A floating conveyor could operate in shallow water and transport material considerable distances to islands, the shore or barges in the channel. Dredged material excavated by a machine on a shallow float could be placed in a hopper feeding a belt.

In order for conveyors to operate successfully in the restoration effort, they must be able to convey freshly excavated sediment over distances and up modest inclines, transfer it from belt to belt, and the belts clean themselves during operation. Belt cleaning is essential to prevent dredged material from sticking to the belt and then falling into the shallow water and miring the floats. Some trial demonstrations were conducted to evaluate this transport and handling option.

The first demonstration occurred in March of 2002 at a gravel pit and is described in Marlin (2003b). Sediment was removed from a typical location in Upper Peoria Lake with a small clamshell bucket and placed on a deck barge. The bucket was heaped so that free water drained prior to placement on the deck. During the 8-mile trip to the gravel pit, the sediment held its shape and did not liquefy despite vibrations and rough water.

A series of three 36-inch conveyors was used for a series of tests. Sediment was placed on the first belt by the clamshell bucket, run about 50 feet before it dropped 7 feet through the first transfer point, was conveyed 100 feet up a 6 percent slope, and then transferred to a 50-foot stacking conveyor with a 25 percent slope. Because the conveyors normally handled sand, there were no belt scrapers and the transfer points had no fittings to control splatter. Various options were tried, including dropping sediment on a moving belt, starting the belt both dry and wet from a stop, and adding extra water to the sediment. In another test, an endloader took sediment to another belt where it was run 600 feet and stopped on an incline. Sediment placed into the hopper of the stacker readily climbed the belt.

The sediment stayed on the belts without difficulty. It did not liquefy and maintained a reasonably solid consistency over the belt idlers and across the transfers. Minor slumping occurred on the long belt, but the sediment cross section remained constant on the belts. The sediment did not exhibit excessive stickiness or build up on the belts or chutes after eight runs. As expected, some of the wet sediment was carried back past the transfer points on the belts and fell to the ground. This confirmed the need for belt scrapers. Likewise, a conveyor system for handling sediment will need to prevent spatter at transfer points and other locations.

In a second test, a Putzmeister truck-mounted concrete conveyor handled sediment in a September 2002 demonstration. Details of this demonstration are contained in Marlin (2003a) in the appendix. The system includes a 40-foot feeder conveyor fed by a hopper that carries material to the top of the truck where it is transferred to a 105-foot telescoping conveyor. Sediment excavated with a clam shell bucket and stockpiled in a field the day before was used for the demonstration. The equipment is designed for concrete and was not modified for this demonstration. Under ideal conditions, the system can handle 300 cubic yards per hour.

Sediment was removed from the stockpile with a skidder and placed in the hopper. The thick sediment had a tendency to bridge over the hopper bottom and was occasionally pushed through with shovels. The moving belt pulled the sediment from the bottom of the hopper. Raising the hopper a few inches greatly improved the situation. The sediment readily stayed on the belt and was compressed as it passed thorough the transfer point that had a four-inch clearance. It easily rode the extended conveyor and fell vertically off the end of the belt. Scrapers cleaned the belt and prevented drag back along the underside of the belt.

In another test, sediment was fed to the conveyor by a concrete pump. This material, that lost some of its cohesiveness during pumping, had no difficulty passing through the hopper to the belt. It, too, conveyed easily and cleared the transfer point. At one point, the extended conveyor was inclined to 30 degrees and the sediment traveled the belt without difficulty. The conveyor can be precisely controlled and made 20- by 60-foot plots of wet sediment 6 and 12 inches deep. It also made a circular pile 2 feet high at the center with a radius of 9.3 feet. The edge of the pile was about a foot high.

These demonstrations show that backwater sediment can be conveyed with conventional equipment. A system dedicated to sediment should have some modifications from the concrete system. Such features as the hopper and transfer points could have more clearance and splatter could be better controlled.

Floating conveyors over 2,000 feet long are used in the sand and gravel industry and presumably could be designed for use on the Illinois River backwaters. Given the shallow nature of the backwaters, the floating conveyor would be most useful if it drew a foot or less of water.

Pipe conveyors are another option. These systems use additional rollers to fold the conveyor belt over itself so that material is contained inside. It unfolds at each end for loading and discharging. These conveyors can curve without using a transfer point.

ii. Positive Displacement Pumps. Positive displacement pumps are commonly used for handling concrete and various slurries. They have been used for to handle sediment in several situations. Their main advantage is the ability to deliver sediment without adding large volumes of water. Large pumps can handle over 500 cubic yards per hour and pumping distances in excess of 2,500 yards are attainable. The quantity pumped generally decreases with distance. Marine sediment was pumped over 200 yards at a harbor dredging project at Ishinomaki in Japan. Sediment from the Schlichem Dam in West Germany was pumped through 5,000 feet of pipe. The reservoir was drained and the wet sediment loaded into a hopper with endloaders. This displacement pump operated at an effective rate of 78 cubic yards per hour (Putzmeister, Inc. literature). Two demonstrations of these pumps were conducted with Illinois River sediment.

The first used the DryDredge ™ that incorporates a concrete pump and sealed clamshell bucket capable of handling about 70 yards per hour (Marlin 2002). This dredge was developed in conjunction with the Corps of Engineers Waterways Experiment Station. The demonstration was conducted in Upper Peoria Lake near the EMP islands in the spring of 2001. The dredge was delivered to the area on a lowboy trailer, placed in the river with a crane and pushed to the site with jon boats. Once on site, the dredge maneuvered using walking spuds and its excavator arm. Water levels at the site fluctuated and occasionally were slightly less than 2 feet.

During the demonstration, excavated soft lake sediment was pumped through 120 feet of pipe. The operator was instructed to minimize the amount of free water entering the hopper in order to stay as close as possible to *in situ* moisture content. The dredge placed material at several locations on the overburden island and in shallow water. Sixteen sediment samples were taken from the discharge pipe over a 2-hour period. Their moisture content (water weight/sample weight) averaged 41.5 percent. Four shallow cores representative of *in situ* conditions averaged 43.5 percent.

The pumped material was cohesive and readily formed cone shaped piles about 2 feet high with a slope of 9:1. When an attempt was made to fill a wooden form 18 inches high and 8 feet square, the material stacked up to the height of the pipe lip instead of flowing across the form like concrete. The pumped sediment was too stiff to be dragged across the form with a shovel. At one point, water was added to the hopper to increase the flowability of the discharged sediment.

The dredge also filled four 15-foot circumference geotextile tubes placed in a trapezoidal pattern in shallow water. Then the area inside the tubes was filled with pumped sediment to form a small island. The pipe was moved several times because the sediment was too stiff to flow to the sides of the containment. Within a week, researchers could stand on 18-inch-wide plywood on the sediment. After 3 weeks, the sediment had a crust and easily supported researchers.

The second demonstration was in September of 2002 at Lacon, Illinois (Marlin 2003a). A Putzmeister concrete pump truck with a 32-meter articulated boom and a 5-inch line was used. The excavated sediment was the same used for the conveyor demonstration described above. The pump and boom experienced no difficulty handling the sediment. It pumped easily and could be precisely placed as it exited the discharge pipe. When pumped on the field, it formed a cone that after 2 hours of settling was about 2 feet high with a radius of 10.3 feet. The pump boom also discharged sediment to the conveyor truck.

The hopper feeding the pump is designed to handle concrete and has a 2-inch grate. The stiff sediment bridged over the grate and was slowly drawn into the pump. In order to improve flow, the grate was removed. The pump operated at about 10 percent of its capacity because of the skidder's limited ability to load sediment.

For use in backwater restoration, existing concrete pumps could be placed on floats or work barges and fed with an excavator or crane. The material could then be pumped onto an island, to shore, into geotextile tubes, or into barges or trucks. A placing boom could be mounted on a barge or on shore to place the sediment in a specified pattern and depth. Equipment of this type could provide great operational flexibility, especially where shallow depths are desired and building containment berms is not an option.

iii. Barge Transport. Sediment was barged to a Chicago landfill site in the fall of 2002 in order to evaluate the feasibility of moving backwater sediment long distances using conventional equipment. The project is described in Marlin 2003b. Nine hundred tons of material dredged from Lower Peoria Lake was placed in a barge with a clamshell bucket. The bucket was heaped to minimize the amount of free water placed in the barge. The barge was towed 163 miles to a Chicago dock on the waterway and unloaded into trucks for the 1-mile trip to the landfill. The material presented no serious handling difficulty and the trucks and barge cleaned normally after the project.

When dumped from semi-trailers, most loads formed a mound about 32 inches high. The material was cohesive and kept its shape after placement. A load dumped on an 8 percent slope stayed in place.

iv. Mud to Parks. In 2004, the State of Illinois moved 68 barge loads of Peoria Lake sediments to the Chicago Lake front to restore a portion of the 100 acre former U.S. Steel site as part of the State's "Mud to Parks" demonstration. This project further demonstrated the potential feasibility of transporting river sediment relatively long distances to utilize these sediments as a resource

F. Placement Options. Dredged material from the Illinois River historically has come from the main channel, marina access channels, and small harbors. Most material from the main channel is currently placed in designated sites that are diked, especially for large projects. Small harbor and marina maintenance projects generate material that is frequently dewatered in a pit or cell and is then trucked away to a field or hauled away by contractors and homeowners. Before the importance of maintaining floodplains was recognized, a common practice was to fill floodplain and water areas with dredged material. Such placement is now regulated.

A limited amount of material can be used to develop islands and wind and wave breaks in backwaters. Such structures will restore some of the features of the original system that were lost when water levels were increased during the last century. Islands can be high enough to support native floodplain hardwood trees and provide relatively isolated areas for various birds and other animals to rest, forage, or nest. Another option is to build islands with low spots above normal pool elevation that may support aquatic vegetation. Islands can be oriented to minimize impacts on flood storage and conveyance. Smaller structures can break waves and provide some calm and sheltered areas for waterfowl resting. They will also reduce resuspension of the flocculent sediment layer by wave action, which will reduce turbidity and make conditions more favorable for aquatic plants and sight feeding fish and other predators. Breakwaters will provide some protection from wave erosion to both new and existing islands and the shoreline.

Portions of the floodplain can be elevated to allow the return of native plant species that cannot tolerate the altered water levels, caused by the current locks and dams, diversion, drainage projects, and land use changes. This can be accomplished by mounding sediment on existing islands as well as areas between the channel and bluff line that are currently mudflats or covered with willow. The mounds can be located so that they become islands during floods.

Sites capable of holding large quantities of dredged sediment either permanently or for later use exist in the basin, but not always in proximity to backwaters needing restoration. Potential placement options include gravel pits, strip mines, and fields. The material can be dewatered behind a dike or dried and piled to any desired shape. A mound could be several stories high and as long and wide as desired.

The bulk of the material in the backwaters is quite similar to topsoil. Clean sediment could be used for landscaping, landfill cover, restoration of mine land and industrial sites, amending agricultural soil, and as bagged soil. Some sediment is suitable for use as construction fill, levee repair, and other projects depending upon its physical properties. If options with commercial value are found, it may be possible to offset all or part of the cost of some restoration dredging.

i. Unprotected Island Plot Trials. In 1994, the Rock Island District built an island in upper Peoria Lake under the Environmental Management Program. The large island was constructed by a clam shell dredge that cut a channel through sediment and lake bottom as it built the island approximately a mile long and 7 feet high. The distance the crane arm could reach determined the width. The soft top layer of sediment was removed first and cast to the west of the island, creating a low berm known as the overburden or small island. It was expected to rapidly wash away. Both islands are still in place, although the overburden island has lost much of its length and height. Exposed tree roots on the top of the large island indicate that it has lost up to 2 feet of height. It also has a higher sand content than the overburden island, probably because it contains greater amounts of material from the original bottom. Observers are surprised at the longevity of the overburden island

and apparent strength of the larger one. A demonstration to determine the ability of the various sediments to serve as island building material is desired, but funding has not been available for a controlled project of reasonable size.

In the spring of 2001, a number of sediment piles were placed in shallow water and on the low EMP islands in Upper Peoria Lake. Some were built using the DryDredge™ and others were placed during high water using a clamshell bucket on a work barge. Portions of all piles that were above the flat pool elevation consolidated to the point where they supported the weight of researchers. The piles in the water and on the low end of the EMP "overburden island" washed away or were seriously eroded after one year. They were frequently subjected to waves striking at different elevations depending upon pool level. The piles on the east side of the large island lasted longer that those on the west that were subject to waves with a long fetch distance. By the fall of 2003, only a clamshelled pile about 2 feet above flat pool remained. It consisted largely of sand and had lost half its height.

These observations indicate that islands can be built with sediments in the area. However, the fluctuating water levels make it difficult for the shore to stabilize and vegetation to become established at lower elevations. Material containing sand or original hard bottom will make a better base than fine-grained sediment. A wave break can help protect an island, as could a geotextile tube, riprap or other armor.

Over 15 earth islands have been constructed in Pools 5 through 10 as part of the UMRS-EMP. These islands generally consist of a low sand base with fine sediments placed on top of the sand base. Shoreline stabilization of islands includes vegetative stabilization, riprap, and biotechnical methods such as groins, vanes, or off-shore mounds combined with a vegetative stabilization measure. Although there is significant variation from project to project, a typical distribution of shoreline stabilization methods is 20 percent riprap, 40 percent biotechnical, and 40 percent vegetative measures. More recent projects tend to have less riprap and more use of biotechnical and vegetative stabilization.

ii. Geotextile Tubes. Tubes made of geotextile fabric are in common use in coastal areas around the world for use in stabilizing beaches and constructing islands and wetlands. The tubes are filled with sand and allow berms, wave breaks, and containment areas to be quickly constructed. The tubes are also used to dewater sediment as well as sludges from wastewater and industrial facilities in situations where space for conventional dewatering is not available. Tubes filled with fine-grained sediment are in use at several projects and may prove useful for backwater restoration on the Illinois and Mississippi River systems.

The Corps' Nashville District used geotextile tubes at the Drake's Creek environmental restoration project near Hendersonville, Tennessee on Old Hickory Lake. The tubes separate a shallow area of a tributary arm from a recreational channel and open water. The tubes create a connected backwater protected from waves and suspended sediment. Fish and other organisms can freely enter and leave the area because the tubes do not extend all around the new backwater.

The Nashville District is experimenting with various options for vegetating the tubes and protecting them from ultraviolet rays that may cause them to deteriorate over time. Trees are planted in slits in some tubes and in other areas soil is placed over them. Vandals and boats have not damaged the tubes. The sediment in the tubes is consolidated and firm. The reservoir in not used for flood control and its water level is fairly stable. It is also not subject to freezing.

In Illinois, the Fox Waterway Authority in northern Illinois used geotextile tubes filled with sediment to form the perimeter of an island habitat restoration project. The tubes were filled using a hydraulic dredge in combination with a polymer that helped settle the solids. Sediment was then pumped into the ring formed by the tubes. Tubes suffered damage in a number of ways. Floating ice driven by wind and waves punctured several tubes. Snowmobiles ran over some tubes and cut the fabric, and recreational boats caused some damage. Duck blinds that escaped their moorings blew into several tubes and ripped the fabric. Waves eroded sediment from over 98 feet of one tube in 2 days. Riprap was placed over severely damaged tubes.

Four 15-foot-circumference tubes were placed in shallow water in Upper Peoria Lake in conjunction with the DryDredge ™ demonstration in May of 2001. They were filled with the DryDredge™. They formed an island about 50 feet on a side that was filled with sediment at near *in situ* moisture content. The tubes were about a foot above flat pool, and the island was frequently submerged by high water and lashed by waves.

Initially the tubes were pumped as full as possible and had no slack in the fabric. In 2001 the elevation of the ends of each tube was recorded with respect to a nearby reference point. Two years later, they were an average of 9 inches lower. The tubes were flatter and the fabric was not as tight. It is not clear whether the fine-grained sediment had consolidated, was passing through the fabric, or if the bags were sinking into the bottom sediment. These tubes suffered no ice or boat damage or vandalism during 3 years.

The tubes held the island in place while it consolidated. The sediment was initially mounded inside the island higher than the tubes. Grass seed planted on the sediment was consumed by geese and killed by flooding. Waves washed sediment from the top of the island until it was essentially level with the tubes.

Geotextile tubes will likely prove useful in Illinois River restoration projects. They can be used to hold dredged material in place while it consolidates, serve as wind and wave breaks, and as the edge of islands. In areas where ice, debris, or vandalism may be a problem, it may be necessary to use riprap or other protection in conjunction with the tubes. The tubes and their scour aprons could be used to reduce the amount of riprap required and to keep it from sinking in soft sediments. It will also be necessary to determine the best fabric for the sediment in a given area.

G. Beneficial Use

i. Dredged Sediments as Soil. Landscaping soil is a potential beneficial use of large quantities of sediment removed from water bodies, and the chemical and physical properties of the dredged material will largely determine its suitability. Sediment from the Illinois River valley has properties that indicate that it would make excellent landscaping soil. Much of the sediment found in the Illinois River valley originated from eroded fertile rural areas. Consequently, it contains less pollution in the form of heavy metals and other chemical contaminants than is typically found in sediments from urban or industrial areas. Some compounds found in sediments, such as ammonia, that are often toxic in an aquatic environment, may be beneficial to plants when placed on land. The initial problem with using dredged sediments as soil is that they are dispersed, have no soil structure, and may set up like concrete upon drying. This problem is generally overcome after weathering, i.e., wetting and drying, freezing and thawing, and exposure to microorganisms and plants. As the weathering progresses, the dredged material develops structure that enhances air, water, and root penetration. Tillage, or other means of mechanical disturbance, will accelerate the process. We have conducted a series of demonstrations and experiments that indicate that this scenario is generally true for the Peoria Lakes sediments.

Investigations to date show that fine-grained backwater sediments are similar in character to native topsoil (Darmody and Marlin 2002, Darmody et al, 2004 in press). The germination and growth of a variety of plants in sediment and central Illinois topsoil was essentially equivalent. The conclusion is that sediments can serve as well as natural, high quality topsoil as a plant growth medium in the greenhouse. Metal uptake by plants was elevated in some instances, but doe not appear to be a serious problem.

Peoria Lake sediment placed in a pit and on fields developed typical soil structure after weathering. A field at East Peoria was monitored after it was covered with sediment in 2000. When sampled in late November of 2001, the site supported a continuous stand of grass and other weedy vegetation. The sediments showed evidence of the development of soil structure. Moist consistence was firm in the sediments and very firm in the underlying fill. There was good root penetration in the sediment, and the internal soil surfaces were covered with common fine roots, which generally did not penetrate the soil's structural units themselves. Therefore, in about 15 months, the sediments developed much more favorable soil properties as they weathered. The site was revisited in December of 2003. Vegetation was still growing on the sediment. Soil structure was evident throughout the sediment, and live roots were found on the soil ped faces down to the contact with the underlying materials. Small insects and other soil-dwelling fauna were also found on the soil's structural units surfaces.

In another demonstration, fine-grained sediment from the same Peoria Lake location was placed in a gravel pit within a day after excavation in May of 2000. The wet sediment was over 8 meters deep in some locations. The site was visited in October 2002. By then there was a thick stand of vegetation on the sediments, including cottonwood trees and willow trees about 8 to 10 feet tall. This vegetation was all volunteer. A soil profile was exposed to determine the physical characteristics of the sediments. Good soil structure had developed to a depth of about 4.5 feet. Below this depth, there was little evidence of soil structure.

ii. Amendment to Sandy Agricultural Soil. Crop production on sandy soil amended with Illinois River sediment is under study by University of Illinois soil scientist Dr. Robert Darmody with funding from the state. The study plots are near Kilbourne in Mason County. Varying amounts of sediment were applied to standard plots as a top dressing or were incorporated by tilling. Otherwise, the plots were treated the same, including minimal use of irrigation. Corn and soybeans were grown on the plots. Current plans are to extend the study through the 2004 season and measure the uptake of heavy metals by the plants.

Preliminary results indicate that sediment moderates fluctuations in soil temperature and significantly improves moisture-holding capacity in sandy soil. Seed germination and plant growth were also greater on sediment plots. During the 2003 season corn yields were greater on all sediment plots. Plots with 6 to 12 inches of sediment produced over 3.5 times the yield of untreated sandy soil plots. Soybean yields were not as dramatic, although the 6-inch treatments produced statistically higher yields than the controls or other sediment plots. The 6-inch incorporated plots produced 1.6 times the yield of the controls.

Sandy soils are found in several counties bordering the Peoria and La Grange Pools. Given the nearness of some fields to the river and backwaters, it may be feasible to pump sediment directly to fields or transport it short distances by other means. This study will help determine whether sediment will improve soil conditions enough to warrant placement onto sandy fields. Placing a 6-inch layer on a 100-acre field would require about 80,600 cubic yards of sediment.

iii. Sediments Used for Greenhouse Applications. A proposed dredging project to improve wildlife habitat and recreation in the Peoria Lakes reach of the Illinois River will generate a large quantity of dredged sediment. The objective of this study was to investigate a possible beneficial use of the sediment as topsoil. Sediment was mixed with various amounts of biosolids, municipal compost, and horse manure. Barley and snapbeans were grown in the mixtures in the greenhouse. Plants grew well in all treatments, except snapbeans were stunted by salts in unleached biosolid mixtures. The highest overall yield for barley was obtained in the treatment composed of 50 percent sediment and 50 percent biosolid. For snapbeans, the highest yield was the treatment composed of 70 percent sediment and 30 percent biosolid. Heavy metals in plant tissues are within ranges considered normal, except for molybdenum (Mo) in snapbeans which is at a level of concern if the plants were used exclusively as animal fodder. Addition of biosolids to sediments decreased Mo plant availability. Based on these results, this sediment has no inherent chemical or physical properties that would preclude use as topsoil substitute.

In terms of standard agronomic parameters such as plant growth, results confirm previous work that established that sediments from the Peoria Lakes reach of the Illinois River make excellent topsoil material. Both legume and grass plants grew well in all sediment mixtures and improved the plant growth potential of unleached biosolids. Addition of biosolids to sediment mitigates some of the problem with growing plants directly in sediments or biosolids. Pure sediments may have poor physical characteristics, at least initially under some field conditions. Pure biosolids have excessive salts that inhibit plant growth, particularly legumes, as evidenced by the death of some snapbean plants on 100 percent biosolids. The sediments may experience improved tilth and higher plant nutrient content under field conditions when mixed with biosolids. The biosolids release less of their load of potentially toxic heavy metals and the injurious salt content is diluted by sediment addition. Mo uptake from sediments is decreased by biosolid addition.

An optimum sediment-to-biosolid ratio would be a range of 80:20 to 70:30 on a volume basis. This mixing ratio was also shown to reduce uptake of metals by crops, perhaps due to dilution as well as to modifications of soil properties, such as pH.

H. Conclusion and Recommendations. A number of technologies and innovative approaches show great promise in reducing costs and improving the current approach to remove and place sediment for restoration of Illinois River backwaters. Limited investigation of some of these techniques and the sediment's suitability for beneficial use have highlighted potential benefits. It is recommended that additional detailed evaluation and demonstrations of some of these concepts be implemented. These activities may be studied alone or conducted in conjunction with restoration projects. Some suggested lines of inquiry are presented below.

Lessons learned from past island projects constructed as part of the UMRS-EMP, along with information from other island projects (primarily in coastal areas) will be adapted to the unique conditions found in Illinois River backwaters. A demonstration of various ways to build islands with sediments would be useful. This could include the use of geotextile tubes and fabric, as well as sand and riprap where feasible. The evaluation should include different fabrics to determine whether sediment passes through over time, their overall durability, and their usefulness in combination with riprap. The use of geotextile tubes and other means of forming narrow windbreaks to reduce wave action and resuspension of sediments should also be investigated. The impact of frequent water level and presence of ice fluctuations on the structures requires particular attention.

Another investigation would be to test various options to place sediment on existing or potential islands in lifts to reach greater overall height. The areas would then be monitored to determine the durability of the material and the growth of various types of vegetation including mast-producing trees.

Various options exist for placing layers of sediment on farmland as a soil amendment. Investigations could include using small scrapers called soil movers that can be pulled by farm tractors to incorporate or shape sediments, directly dredging from backwaters to nearby fields with hydraulic or high solids equipment, or placement by trucks.

Further testing of transport options should be investigated. Displacement pumps are clearly capable of handling sediment typically found in the Illinois River. An analysis of the sizing and operation of pumps in relation to distance of the line is in order. This would include options where a pump located on a shallow draft platform pumps material through a pipe as well as to a placing boom. In addition, it would be valuable to evaluate the general design and operational feasibility of a shallow draft conveyor to move sediment from backwaters to islands, to the shore or to barges. If loaded onto barges, it would be important to demonstrate and determine the feasibility of quickly unloading barges of sediment with a slurry pump with minimal water added.

The best restoration option may involve a contractor removing incremental amounts of sediment from several locations in a river reach at different times during the first year and repeating the process over several years until the desired depths are met. This would allow the material at the placement sites to consolidate or be removed for use in more manageable quantities. It would likely require less land and construction at the placement site. This approach is similar in principle to some maintenance dredging contracts that cover river reaches.

In regard to beneficial use, the chemical and agronomic character of deposited sediment and the underlying original bottom in backwaters should be determined in order to identify restoration sites where beneficial use is a viable option. The initial work should require a few samples for chemical contamination and a larger number for characterization of suitability for use as soil or fill. A market analysis for sediment by itself or mixed with other material as a bagged or bulk soil would be useful.

The material on the deltas is sandy and is likely to be useful as fill or in some cases commercial sand. Cores of this material should be taken and evaluated. There is a need for such material at construction and brownfield redevelopment sites near the river and in the Chicago area. The feasibility of moving these deposits by barge, rail and truck needs to be investigated. In addition, sediment could be used as the basis for flowable fill, to be used in utility, road repair, and other construction applications.

Additional testing and use of innovative technologies and beneficial use options are recommended. This is justified based on the fact that restoration of depth diversity within the Illinois River Basin is a major goal that will require dredging and placement. In addition, a wide range of potential technologies and uses exist that merit further exploration.

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