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ECOLOGICAL POTENTIAL OF THE GRAND CALUMET RIVER BASIN

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ABSTRACT. The Grand Calumet River and watershed have been severely degraded by industrialization and urbanization, and yet several high-quality natural areas remain intact. The degraded condition presents numerous opportunities for pollution mitigation and ecosystem restoration. In many areas of the river and watershed, biological communities are characterized by low diversity and pollution-tolerant organisms. By establishing programs of nonnative species control, prescribed burning, sediment removal, wetland establishment and extirpated species re-introduction, the Grand Calumet can be improved to reflect some of its natural history. The dredging plan for the river presents an opportunity to coordinate simultaneous improvement and restoration plans. Possibilities for each section of the river are discussed.

Keywords: Grand Calumet River, Calumet region, restoration, sediment removal

Other papers in this volume discussed the status of each major component of the flora and fauna of the Grand Calumet River study area. Here, we present an executive summary of the restoration opportunities found in the basin. These options were formulated at a meeting of all project authors and represent their collective vision for the Grand Calumet River and its associated ecosystems. This paper also includes a discussion of the impaired uses that serve as the rationale for river dredging as well as a discussion of the ways in which habitat restoration will reduce impairments.

The solutions were generated with two specific goals in mind. First, the flora, fauna and habitats need to be identified, restored, and protected. Second, pollution in the area needs to be abated. As far as possible, we hope to ensure that the watershed will possess the structural and functional attributes of a native, natural community, consistent with the Lake Michigan dune and swale ecotone.

The first step was to define the area under consideration, recognizing such an area would focus efforts to enhance the region's ecosystems but would not negate efforts to include suitable areas adjacent to the region as they become available. The second step will be to protect and enhance existing high-quality natural areas so that they can serve as biological refugia and as models to guide the restoration projects. Many other areas along the river should be enhanced and restored. These restored areas will serve as buffers for core natural areas and provide migratory pathways between natural and "least" disturbed habitats. Habitat heterogeneity and the control of exotic species are imperative for restoring and managing the watershed. To achieve our long-term goals, partnerships between the private sector and governmental agencies will be necessary to remediate degradation, to provide ongoing stewardship of lands, and to integrate ecological issues into the urban planning process.

THE STUDY AREA

The area covered in this report extends from the first dune ridge south of Lake Michigan to the ridge summit of Tolleston Beach (located to the south of the Grand Calumet River) and from the Grand Calumet Lagoons in the east to the river's confluence with the Little Calumet River in Illinois at the western end (Fig. 1). The purpose of our study was to examine functional relationships among habitat areas whose hydrology is connected to and dependent on the Grand Calumet River. Historically, the borders identified for our study

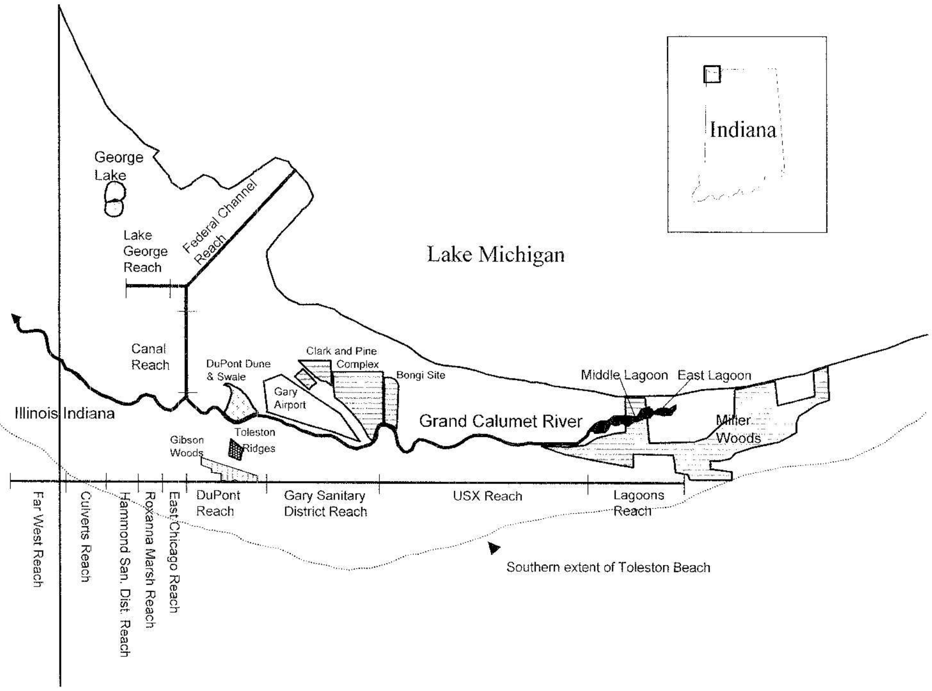

Figure 1.—Diagram of the study area. Reaches (sections) of the river referred to in the text are identified and delineated below the river diagram and along the channel leading to Lake Michigan.

marked the extent of the Grand Calumet watershed, but the hydrology of the region has been so altered by human activities that some areas have lost their connection to the river. The greatest focus has been on sites that retain some value as natural areas because these sites will benefit the most from preservation, restoration, and abatement.

The habitat quality along the shore of the Grand Calumet River is highly variable, ranging from contaminated Superfund sites to remnant natural areas that are globally significant for their rarity and diversity. The natural communities of the region were formed as the result of interaction of glacial, biotic, geologic and hydrologic factors. Industrialization has destroyed many of these sites and fragmented the rest, but those that remain retain a surprising degree of species diversity and community integrity.

The communities in the watershed formed through the mixing of species from four different biomes. The tundra species present after glacial retreat were slowly replaced by boreal forest species (Schneider 1989). Gradually, deciduous forest or woodland species replaced the boreal species in a series of changes dependent on the rates of seed dispersal and mobility. A period of warmer and/or drier climate followed, and grassland and savanna communities became established. These species invaded the region in numerous small waves as the glaciers that formed Lake Michigan receded northward (Bacone & Campbell 1983). The current communities reflect these changes. Relict species are still present in areas, but variation has occurred even within historic times. The prime communities in the current natural landscape are upland savannas, prairie remnants, and wetlands. Boreal remnants include bearberry, jack pine, white pine, and paper birch. Some woodland areas are also present. Relicts from other biomes, including tundra and deciduous forest, are located primarily to the north of the Grand Calumet River (Swink & Wilhelm 1994).

Slow landscape evolution resulted in the unique ecosystems present today. First, fluctuations in the level of Lake Michigan and currents in the lake alternately inundated and drained lake-associated habitats. These fluctuations controlled the formation and flow of the Grand Calumet River, making it a sluggish, almost swale-like watershed that drained only a small portion of the Calumet region. The wet, hilly dune and swale topography that characterizes the region is the product of slow sediment deposition on the nearshore lakebed and on the shoreline of Lake Michigan (Chrzastowski & Thompson 1992). Second, natural succession eventually changed beach formations into sand savannas and the many transitional systems in between. Migration and seed dispersal between areas was the third major process; it allowed disturbed areas to be re-colonized by native species from neighboring areas and helped to maintain genetic diversity within microhabitats. Finally, periodic fires burned across the land, clearing dead brush and preventing open areas from becoming overgrown and forested.

Industrialization and human settlement changed the ecosystems in the Grand Calumet watershed dramatically. During the past 100 years, the region's dune and swale topography has been greatly altered by sand mining, the draining and filling of wetlands, and the construction of large industrial facilities, roads, and commercial and residential areas on flattened dunes and filled swales. The Grand Calumet River has been deepened and channeled. Industries pump large quantities of effluent, greatly increasing the river's flow rate. Contamination made many areas toxic to sensitive native life forms and, in some cases, to more pollution-tolerant organisms as well.

Natural areas disturbed by industrialization and urbanization are susceptible to invasion by aggressive, exotic species. In some areas, these exotics have formed large monocultures that have choked out many other, more niche-specific species. Processes required for the creation and maintenance of local communities, such as periodic fires and migration, have been suppressed, allowing all of the communities to become overgrown. Some community types have all but disappeared from the region. Due to habitat destruction and fragmentation, the gene pools of many niche-specific native species have become dangerously small.

Despite all of the degradation that has taken place, a few high-quality natural areas remain (Swink & Wilhelm 1994). These areas are small fragments of the former landscape, which are often isolated both from each other and from the natural processes that formed them. Nevertheless, they have managed to persist relatively intact.

The Nature Conservancy, using Natural Heritage Network data, has identified the Greater Calumet Wetlands Site as an area that supports global- and state-significant biodiversity (Crispin & Rankin 1984). Eighteen natural communities exist at the site. Within these communities live more than 700 species of native plants, of which 85 are globally or state significant. More than 200 species of birds use the area, including 18 species confirmed to nest in the area that are globally or state significant. Over 20 species of reptiles and amphibians also inhabit the area, and eight of them are state significant.

Several federally-listed species are known to occur in the study area: Pitcher's thistle (*Cirsium pitcheri*), the Karner blue butterfly (*Lycaeides melissa samuelis*), and the Peregrine falcon (*Falco peregrinus*). Habitat appropriate for Indiana bat (*Myotis sodalis*) is also present, but this species has not been sighted in the area. Numerous state-listed species are found throughout the high quality habitats of the study area.

The highest quality natural areas of the study site are Miller Woods, the East and Middle Lagoons of the Grand Calumet Lagoons, Clark and Pine East, and DuPont Dune and Swale (Fig. 1). Miller Woods and Clark and Pine are the last and finest dune and swale remnants. These areas contain habitats that grade from mesic, sheltered forest into prairie and savanna. The Lagoons and adjacent ponds are some of the last local examples of potentially restorable palustrine wetlands. The Lagoons contain the most diverse macroinvertebrate fauna of any of the sites surveyed in the watershed. Clark and Pine East includes roughly 20 ha of remnant ridge and swale, which support a diverse range of habitat types, including sand savanna, sand prairie, wet prairie, sedge meadow, emergent marsh, and shrub swamp. DuPont Dune and Swale includes the largest remnant dune and swale area in the watershed (with 70 ha in the DuPont Property and additional partially degraded habitat sites in adjacent areas). Franklin's ground squirrels, declining in the state, still occur here.

The river channel itself is highly degraded and contaminated. The macroinvertebrate fauna is poor in all the reaches studied and is entirely absent from many stretches of the river. The fish are too contaminated to eat, and diving birds lose their ability to fly when the sediments coat their wings with oil. Silt deposited on the channel's banks has formed a nutrient-rich, cation-dominated sediment that favors common reed stands over native sedge flood plains. Homes, sewage disposal plants, industrial facilities and disposal sites line much of the bank; and thick growths of cattail, common reed and purple loosestrife choke out native plant and animal species in most of the marshes immediately adjacent to the channel. Dissolved oxygen concentrations in the water are often too low to support life, and nutrients released into the water support excess growth of blue-green algae.

Some improvement has occurred, and the macroinvertebrate community reflects the early stages in river recovery. A few species tolerant to some level of disturbance occur in high densities. The fish communities have also rebounded during the last decade. Abundance and diversity have improved, and these communities are primarily composed of invasive, tolerant species.

RESTORATION PHILOSOPHY AND SYSTEM-WIDE POSSIBILITIES

To evaluate the condition and restoration potential of the Grand Calumet River, we must examine every aspect of the watershed because neither organisms nor the river functions alone. Contamination of narrow river sections and/or specific organisms can have far-reaching effects on the rest of the river and its adjacent wetlands. Many changes to the watershed, such as an increase in flow rates due to industrial uses of the river, are unlikely to be reversed. For this reason, every decision about restoration must be made based on present conditions. The first goal is to restore the natural, integrated community's structure and function. When possible, certain areas may be enhanced to emulate historic conditions.

Lands adjacent to the Grand Calumet River historically consisted of a series of dunes and swales. For this reason, the species of the region are adapted to fill a wide variety of niches in both wet and dry habitats. Some species are adapted to move between different habitats in the dune/swale complex. Restoration of the area would involve recreating a complex array of contiguous habitats typical of the dune/swale system.

One method of enhancement mentioned throughout these papers is the creation of buffer zones around high quality natural areas. A buffer is a somewhat degraded, non-industrialized site adjacent to a high quality area. Although buffers are not sufficiently pristine to support diverse native communities, they can support some native species. The primary purpose of the buffers is to prevent contamination from residential and industrial sources from overflowing directly into the most sensitive natural areas. Also, they provide a surrounding habitat that is of higher quality than the polluted areas. Buffers can also be restored, when feasible, although they will usually be less diverse than high-quality natural areas.

Prescribed burning, exotic species control, and planting of selected native species are required management strategies. Burning, a natural ecosystem process, prevents succession from eliminating open, grassy habitats from the landscape (Bowles et al. 1990). Exotic species control opens areas for colonization by more diverse assemblages of species, and planting helps to ensure that disturbed areas will not simply revert to single-species stands of exotics or of invasive native species. An herbivore assemblage that is as natural as possible is also needed to maintain natural plant diversity.

Because of the presence of extensive stands of invasive and exotic species, any plans to create a continuous river corridor need careful consideration. A corridor created to facilitate migration of native, conservative plant species might easily become an invasion route for exotic monocultures. Any corridors that are created must be consistently monitored and actively maintained. Establishing diverse native species communities and avoiding exotics is an ongoing requirement for restoration efforts.

Reintroduction of extirpated species should play a role in restoration efforts. The river otter was present historically and could potentially be reintroduced to pond, lake and river habitats if these are sufficiently cleaned and protected. The American porcupine (*Erethizon dorsatum*), and perhaps the smooth green snake (*Opheodrys vernalis*), could be reintroduced into the Miller Woods area if enough good habitat is created.

Sediment clean-up would benefit the Grand Calumet watershed by clearing away large quantities of contaminants. To make moving them worthwhile, the sediments must be disposed of responsibly and have minimal impact on their disposal site's environment. After dredging (provided that all of the contaminated sediments have been removed or effectively capped) the benthic macrofauna again would have a non-toxic substrate upon which to grow. Variable banks, river depths, and bottoms should be created to provide habitat variation. Fish communities will probably return to the watershed, although it is unlikely that they will be edible.

Dredging and sediment-replacement should also be used to modify topography along the riverbanks. Banks could be dredged to recreate the shallow backwaters and marshy areas that were once present along the river. Dune replacement would help recreate the dune and swale topography. Such drastic alterations need to be carefully planned and supplemented by extensive planting and ongoing management. Further study is needed to determine the feasibility of habitat restoration in areas considered for topographic alteration.

Dredging also poses dangers to the habitats along the river and must be regulated if the benefit of dredging is to outweigh the risk. Contaminants and excess nutrients could, without proper precautions, migrate outward from the channel through aerial, side-channel, or groundwater transport of re-suspended chemicals and sediments. Some of the re-suspended chemicals may become more toxic when they are exposed to sunlight. Temporary weirs should be built as settling areas for re-suspended sediments. Dredging will create a greatly deepened, U-shaped channel, with an increased flow-rate. The increased flow will facilitate the sloughing of the river banks. Bank erosion could be minimized by adding clean sediment, planting native species, and constructing anti-erosion structures out of BioLogs(TM) or other materials. BioLogs(TM) could also serve as substrate for the growth of native plants and to create calm eddies. Micro-habitats for fish will probably be cleared away by dredging, and they should be re-created artificially. Lunker boxes, BioLogs(TM), half logs and other structures could be used to create artificially undercut banks and riffles for fish. Replacing dredged sediments with slag would be detrimental because contaminants can leach from the slag into the water and sediments. Instead, natural fillers such as gravel and cobble should be added. The new substrate will differ greatly from the current muck, but it would be far superior to the toxic sediments now present.

Every decision will need to balance desired benefit to the watershed with the possibility that restoration activities might actually harm the system. In many cases, these considerations may require that additional measures be taken in the course of restoration to protect against exotic species and contaminant spread, and habitat erosion.

Restoring natural systems of the Grand Calumet River can be viewed as a goal that is reached in many small many steps. Sediment restoration is one step toward cleaning up the watershed, but numerous steps must occur in this process, including wetland expansion, habitat creation, bank stabilization, and extermination of exotics. Further pollution from point and non-point sources will need to be assessed, and both average and peak pollution rates will need to be reduced. These steps could occur along with sediment clean-up, but they will be ongoing projects and cannot be performed in any meaningful and lasting way if they are considered only as an adjunct to sediment clean-up.

Continuous monitoring of all aspects of the system will be essential for charting the progress of restoration. Careful management and partnerships between involved groups will be imperative for making restoration an ongoing, rather than a sporadic and poorly planned, endeavor. Ecological considerations should be incorporated into all the steps in the planning process. Many sites, including terrestrial habitats, are indirectly affected by the river; and managing these areas is part of restoration. Furthermore, only by abating pollution and preventing re-contamination will restoration efforts be successful. Some areas may never return to historic conditions; but by decreasing pollution impacts and actively preserving and managing lands, progress can be made toward an integrated system of natural areas.

REACH-BY-REACH POSSIBILITES

The U.S. Army Corps of Engineers has divided the river into 11 reaches, or sections, corresponding to discrete dredging projects

(Fig. 1). The division between reaches is arbitrary from a habitat standpoint. The reach-by-reach possibilities for restoration will need to be incorporated into the entire study system. The possibilities for restoration at specific locations can be broken into reach-unit groupings. These, along with brief descriptions of the habitat found in each reach, are described below. These possibilities were developed in a meeting of all the authors whose papers are included in this volume. They reflect the joint effort of a group devoted to the improvement of the Grand Calumet River and the expertise of individuals in many fields of study.

Lagoons reach.—The Lagoons area contains two large tracts with high value as natural areas—the Grand Calumet Lagoons and Miller Woods, which border the Lagoons to the north and south.

Grand Calumet Lagoons: The Grand Calumet Lagoons are located at the eastern end of the Grand Calumet River where it once opened into Lake Michigan. The area immediately south of the Lagoons consists of mesic sand savanna interspersed with marsh and pond communities in swales. The area to the north borders Lake Michigan and includes unusual habitats, such as pannes. The ponds that are closely associated with the Lagoons are also valuable as rare remnants of the once-common panne-type community.

The Lagoons are divided into the West Lagoon, the Middle Lagoon, and the East Lagoon. The Middle Lagoon is considered to be the least contaminated of the three water bodies. The West Lagoon is highly contaminated and is currently under an enforcement action under the Resource Conservation and Recovery Act (RCRA). The clean-up mandated under this law will probably involve removal or capping of the contaminated sediments.

Clean-up or capping of West Lagoon sediments will probably stir up the sediment and cause contaminants to be transported into less-contaminated areas. To prevent this from occurring, before cleanup a weir could be built across the West Lagoon, near the boundary of the national park at the eastern end. After cleanup, the area should be monitored for water and sediment contamination. After contaminant levels have stabilized, the weir could be removed to allow organisms to pass between sections of the Lagoons. This process, and any other restoration activities, should be coordinated with the RCRA to assure that clean-up is efficient. If the migration of contaminants into the Indiana Dunes National Lakeshore is likely to occur, dredging and restoration efforts should be coordinated with the offices of the Indiana Dunes National Lakeshore.

Several smaller ponds associated with the Grand Calumet Lagoons also need protection. The two ponds north of the Lagoons are appropriate habitat for federally endangered plants. More research on water and sediment quality is needed to determine whether the nearby slag piles are causing contamination. Legal issues concerning the "taking" of the resident rare species need to be considered before dredging in these ponds. Contaminant concentrations should also be studied in the first row of ponds south of the Lagoons. Beyond these, the rise in elevation has probably prevented contaminants from spreading further south.

Dredging the Grand Calumet Lagoons may cause bank sloughing. This sloughing could destroy portions of the valuable Miller Woods tract. Clean sediment could be added to the dredged areas to minimize sloughing, and the banks of dredged Lagoons should then be stabilized with native vegetation in order to prevent habitat destruction.

Miller Woods: Miller Woods is one of the last and finest remnants of the dune and swale system in the watershed (Labus et al. 1999). The tract is located in a transition zone between mesic, sheltered forest areas in the east and more open prairie and savanna-dominated sites in the west. Miller Woods is the only part of the watershed containing large forest trees; and the tract is an important refuge for forest-dwelling mammals, including squirrels, voles, shrews, and bats. The area also contains high-quality amphibian habitat. Miller Woods, a large remnant area, can serve as a model for future restoration efforts. Preservation and management of this site must be a high priority.

Some of the areas surrounding Miller Woods are suitable for restoring oak savanna/hardwood habitat types, which would be valuable as buffer areas and as an addition to the isolated oak savanna habitat. Restoration efforts should include the ongoing removal of exotics, re-vegetation with native species, and the use of prescribed burning. The American porcupine (*Erethizon dorsatum*), and perhaps eventually the river otter (*Lutra canadensis*), could be reintroduced into the Miller Woods area. In the southern portion of the Miller Woods tract, the extensive illegal dumping of tires and other items is occurring. Stopping this activity would be a major step in cleaning up this valuable land. Restoration and management should be carried out based on the advice of local experts and land managers.

USX reach.—The USX (U.S. Steel Co.) reach is highly degraded along most of its length. The highest quality natural areas in the reach, both located at the far western end, are the Bongi site and a small portion of Clark and Pine. The Bongi site contains two borrow pits located north of the river. The northern pit, which is further from the river, is more contaminated than the southern pit, perhaps due to fly ash runoff from the steel mill.

Plans to restore the USX reach of the river are currently being formulated as part of a RCRA enforcement action against USX. The plans are currently on hold while the Indiana Department of Environmental Management decides whether or not to issue a water discharge permit for the river dewatering and discharge portion of the USX compliance plan. The plan for the reach's restoration, which will be paid for by USX, includes dredging within the reach to remove contaminants. Other restoration efforts may include the purchase and restoration of natural areas and the control of exotic species.

In addition to the efforts of USX, the U.S. Army Corps of Engineers plans to add deflector logs and submerged gravel weirs in this reach. Deflector logs will help to stabilize the shoreline before and after dredging. Stable shoreline and gravel weirs will provide fish habitat after dredging.

Several concerns remain. Dredging around the sensitive Bongi site at the western end of this reach may cause bank erosion, thereby destroying portions of this valuable property. Bank sloughing could also cause contamination of the Bongi ponds with sediment-laden waters from the river. The river bank should be stabilized with native vegetation to minimize this impact. The Georgia Pacific Lagoon, located south of the river, opposite the Bongi site, is also in danger of contamination due to sediment migration. One possibility is to build a levy to protect this area with tie gates to allow fish to move in and out of the Lagoon. These provisions are not included in the current restoration plans.

Restoration possibilities for the Clark and Pine property are discussed below in the section on the Gary Sanitary District reach.

Gary Sanitary District reach.—The majority of the Gary Sanitary District reach is highly degraded, but two high quality sites are located at its eastern and western ends—Clark and Pine and DuPont. An emergent marsh runs along the southern side of the Gary Airport for much of the Gary Sanitary District reach. The marsh is overgrown with cattails, which greatly limit floral and faunal diversity, and the macroinvertebrate community is highly degraded. Problems with high concentrations of PAH's (polycyclic aromatic hydrocarbons), PCB's (polycyclic biphenyls) and contaminated sediments plague the Gary Sanitary District area. The presence of a holding area for contaminated sediments probably contributes to this problem.

The Clark and Pine site has one of the highest concentrations of rare and endangered plant and animal species in the state of Indiana. The site has two main segments, separated only by Clark Street—Clark and Pine East to the southeast and Clark and Pine Nature Preserve to the northwest. The two sites are prime examples of dune and swale habitat, including extensive areas of pond, marsh, panne, sand prairie and open sand savanna. Several smaller natural areas also occur in close proximity to these sites; and they contain many of the same community types, including a jack-pine-dominated sand savanna. Within the Clark and Pine cluster, the most important restoration efforts are exotic species removal, buffer area creation and, where Clark and Pine East borders the river channel, bank stabilization.

In the rest of the reach, dredging would improve conditions by removing large amounts of contaminated sediment, thereby encouraging colonization by new species of plants and other organisms. Without ongoing habitat restoration and management, however, the shoreline is likely to refill with exotics; and no habitat diversity or connections with the broader ecosystem will be gained.

The marsh at the southern end of the airport has great restoration potential either as wet prairie or emergent marsh. Because the wetlands here are somewhat isolated from the river (and, therefore, from fish predators and the high contaminant levels present in the river water and sediments), they could serve as habitat for amphibians. To create a wetland in this area, input would be needed from the Gary Regional Airport to minimize the possibility of bird strikes by planes. Thus, the creation of open water might not be a good solution, but wet prairie or emergent marsh would attract birds that generally fly low enough to prevent problems for the airport.

The wetlands along the river might also be expanded using side channels. Dredging a channel through the abundant cattails surrounding the river and replanting with the appropriate vegetation would create a healthy wetland system, establishing an area of decreased water flow and shallow habitat ideal for turtles. The connections between the braided channels and the river would eventually close, leaving behind relatively protected wetlands. The plant species moving into the area would be influenced by water quality as well as physical topography. The ideal result would be to establish the hydrology of a sedge meadow and a conservative flora and fauna after the channel has closed. The drastic alteration of the local landscape carries with it a high risk of invasion by exotics. Careful planning, long-term continuous monitoring, and exotic species elimination would be essential to reestablish the native communities. Another alternative is to dredge the banks more shallowly than the main channel to create backwaters with the channel. These, like the dredged side channels, could potentially serve as turtle habitat; but they would also need to be actively managed to prevent exotic infestation.

In-stream restoration includes the creation of fish habitat in the river. Lunker boxes are structures built by embedding the ends of log platforms in the river banks and backfilling them with rock. These structures provide cover and shallow habitat by creating an artificial undercut bank. This approach might result in an increase in salmonids; and, because the boxes would be built in the open stream rather than in isolated backwaters and ponds, the amphibians would not be affected by the increase in salmonids. Altering river flow to establish large pool/short riffle sequences would also create new habitat in the river channel. The riffles would benefit the fish and macroinvertebrate communities by naturally aerating the water.

The top priorities for restoration in this area are 1) to abate pollution, 2) to protect and manage the Clark and Pine site, and 3) to create buffer zones and migration corridors that protect and connect the Clark and Pine and DuPont natural areas. Possible staging areas include the access road at the end of the Gary Regional airport and either side of the river at the landfill.

DuPont reach.—The largest intact dune and swale habitat in this region is in the DuPont site. Its preservation is a high priority. The DuPont site, located along the northern bank of the Grand Calumet River between Cline Avenue and Kennedy Avenue, is an example of a smooth transition between flat wetlands and the hilly dune and swale habitat. The DuPont site is one of the last places where high quality natural habitat is in direct contact with the river; therefore, the site's preservation is crucial. Wetlands, including marsh, flood plain forest, and a high quality tract of wet prairie, occur immediately adjacent to the river channel. Extensive areas of dry-mesic to wet sand prairie, dry-mesic sand savanna, and swales with sedge meadow and marsh are present slightly inland from the river's channel. A cottonwood stand grows at the bend in the river in a pond filled with dredge spoil, and this grove would be good habitat for Indiana myotis and northern myotis bats if enough trees are available. South of the river, the Toleston Ridges and Gibson Woods Nature Preserves are noteworthy; but these preserves are isolated from the Grand Calumet River by the Indiana Toll road, an effective barrier to all but the most mobile terrestrial animals. The habitat types included in this reach range from highly degraded, cattail-infested wetlands to high-quality wet prairie. Many relatively open areas remain because of accidental fires. The amphibian and semiaquatic mammal communities are quite healthy, and many birds forage here. Of all the reaches, the DuPont reach is the richest in nesting birds; and an egret rookery is found there. Creating a corridor between DuPont and Clark and Pine East would expand these high quality habitats, but functional limitations due to cultural land use would limit the corridor's success.

Contaminants are a major problem in the DuPont reach because their concentrations tend to increase as one moves further downstream. The fish are greatly affected, and oil-soaked birds are often observed in the area. Contamination affects shoreline plant habitat as well, but the depth to which the contamination penetrates the sediment and how much contamination is present in areas not immediately adjacent to the channel are unknown. The large stand of cottonwoods at the river bend probably indicates the disposal site of previous dredge spoil. Another major problem in this area is nutrient loading. Nuisance algal blooms have resulted due to deterioration in water quality. Nutrients, including nitrogen and phosphorus, probably enter from inputs upstream; but the resulting blooms first appear in the watershed in the DuPont Reach.

USS Lead currently has a cleanup proposal for this area out for public comment. One portion of the cleanup will probably focus on the channel from the river up to USS Lead. The plan for this cleanup could include stabilizing the channel's banks and preventing migration of contaminants into the adjacent, highly restorable savannas. The USS Lead property contains extensive marshy habitat that is overgrown with submergent plant species, including *Potamogeton*, *Redekia*, and *Elodea*. These submergents are useful because they extract pollutants from the water and concentrate them in their own tissues.

Because the DuPont Reach is relatively inaccessible, this area has not been studied as much as the other high quality sites in the region. More study is needed to determine the extent and impact of contamination in this reach. Difficult choices must be made between cleaning up the contaminants and/ or preserving current plant communities. The complete removal of the contaminants could mean destruction of current habitat; preventing destruction through creative engineering is a high priority in this area.

Minimal disturbance adjacent to the high quality areas (including dune/swale habitat) and the preservation of the wet prairie remnants would benefit the reach. Contamination along the remaining shoreline could be removed to the underlying sand—that is, deep enough to take out the seed bank and exotics. The banks would need to be stabilized with new vegetation and re-graded. Creating artificial wetlands by dredging side-channels (see above) would also be beneficial, provided that the natural river is not harmed.

The nutrient status of the river water must be considered when designing effective pollution abatement strategies. Excess nutrients fuel the growth of thick algal mats, which shade out other plant life. Nutrient loads in the Grand Calumet River might be reduced by bank flooding, which would allow shoreline plants to take up the nutrients. Historically, before the river was deepened and channeled, such flooding was frequent. The danger in this strategy is that contaminants can be deposited in shoreline soils. For this reason, water quality must be monitored and deemed safe before plans for riverbank flooding are made or implemented.

The removal of exotics will be important not only along the dredge channel but also within the high quality natural areas. In many locations on the DuPont property, micro-habitats exist with a limited exotic population that could be cleared manually. Ongoing plans for such removal activities would be beneficial.

A highly aggressive approach would have to be taken when dredging the channel in order to clean this particularly polluted reach. However, great care will be needed to protect sensitive habitats along the riverbank. Further study would determine the extent of contamination in areas that are associated with the river hydrologically but that are too far away from the channel to be dredged.

East Chicago Sanitary District reach.—This section of the river contains several small remnant areas of dune and swale as well as several very polluted areas. An upland meadow is present south of the river, between the Indiana Harbor Canal and the Roxanna Substation, which is located east of Indianapolis Boulevard on the north side of the river. The upland meadow at the Roxanna Substation shows great promise as a site for restoration because of its connection with the high quality DuPont Reach. Restoration could upgrade the site from a degraded remnant to a productive habitat.

Roxanna Marsh reach.—The Roxanna Marsh reach contains an open, shallow pond that was once a stopover area for shorebirds migrating between the Arctic and South America. Rising water levels over the last ten years have made the area unsuitable for these birds. The pond is now a large mudflat with very little vegetation. A number of large cottonwoods occur at several sites that had previously been filled with dredged materials. These sites are each approximately 12–15 ha in size. One is located near the Harbison-Walker property, and the other is near USS Lead. These stands might support bat populations, which are rare in the watershed. Dredging would increase the macroinvertebrate community, which would in turn provide an insect food source for bats inhabiting the area.

One option for restoring Roxanna Pond is to manage the water and vegetation levels in the spring and fall so that migrating shorebirds might use it for landing and foraging. Currently, no landing/foraging area exists in the entire Midwest, and birds that make long-range annual migrations need this habitat. This option would require that sediments in the Pond be dredged and replaced; capping the sediment is inappropriate because the added sediment could raise the bottom level to near or above the water level, making the pond unsuitable for bird landing and foraging. A dike or berm, with gates at the inlet to Roxanna Pond could be built. With the appropriate vegetation and infauna, the area would appeal to migrating birds. Some concern exists that regulating water levels in Roxanna Pond would impair salmonid migration in the river, but this concern could probably be addressed in the context of the suggested plan. A control structure around Roxanna Pond should not impede migration within the river channel; and if it did, water levels could be regulated in the spring and fall for shorebirds and left at natural levels in fall and winter to allow for unimpeded salmonid migration. Monitoring and management would be required to enhance food and shelter conditions for migrating birds. The location of a staging area should be further investigated before a final decision is made on its feasibility.

Two options are available for the cottonwood stands. They could be managed for use as bat habitat, or the trees could be cut and the areas dredged and managed as mud flats using the same proposal as for Roxanna Pond. These stands should be surveyed for bat populations and general ecosystem function before management strategies are formulated.

Hammond Sanitary District reach.—This reach is clogged with sewage refuse; and its waters are practically devoid of oxygen, making them toxic to fish. Areas adjacent to the channel are overgrown with exotic plants. Extensive dredging of both the immediate channel and the adjacent marshes will be required before any restoration can take place. Such extensive dredging will also reduce the stench that currently pervades this highly residential district. Further pollution must be prevented because currents here change directions with the seasons. Instead of flowing away from their source, the pollutants are flushed back to concentrate along the banks and in the riverbed.

One risk of dredging here is that altering the riverbed may also alter the hydrology of the area. The area is underlain by a bowl-shaped basin bordered by a brim from the expressway that causes the aforementioned reversals in current direction. If this area were leveled, the amount of water flowing to Illinois through the Grand Calumet River would probably increase. This change in flow direction might negatively impact salmonid migration. Engineers planning to dredge this reach should carefully examine the current riverbed to prevent a change in hydrology.

Culverts reach.—This area is highly degraded by an abundance of sewage. The river is practically impassable due to the depth of raw sewage. Nearby residences are subjected to unpleasant odors and an unsightly river. The water is anoxic and surrounded by cattail wetlands. Dredging most of the material from the channel will be an improvement; but contamination will persist if large portions of the riverbank, which is also highly contaminated, are not removed as well. Any removal activity will improve conditions temporarily, but re-contamination will occur without a change in sewage treatment capacity.

Far West reach.—The portion of the Grand Calumet River in Illinois was not part of our study. Nevertheless, this section of the river merits discussion in any paper concerned with the river's ecology. Burnham Prairie is located approximately 2 km west of the Illinois-Indiana border. Unlike the Indiana sites that are on beach or nearshore sand deposits, Burnham Prairie is on silt-loam soils that were deposited in somewhat deeper water. Burnham Prairie is one of the last remaining black-soil prairies in the region. The site contains marsh, wet-mesic and dry-mesic prairie, and a small dry-mesic savanna grove with burr oak. Northern leopard frogs and plains garter snakes, rare throughout our study area, are common at this site.

Canal reach.—The area around the Canal reach is principally industrial with a few scattered residences. A great deal of sheet piling, cement, and slag surrounds the river. Water flow is faster here than in the other reaches, and the channel is deeper. A steel wall crosses the river to control water flow. This reach is the only connection to Lake Michigan for migrating fish; and therefore, a channel that allows fish to pass should be maintained. A wetland complex exists near the Canal, and there is a dune and swale remnant at the site where the Canal meets the Grand Calumet River. This dune/swale area would be damaged if used as a staging area for dredging.

Lake George reach.—The Lake George reach was previously dredged to Calumet Avenue. After the Federal Channel is dredged, a decision on whether the Lake George Reach should be connected to the Canal reach will be made.

IMPAIRED USES

The following list of beneficial use impairments of the Grand Calumet River was developed by the Indiana Department of Environmental Management as part of their first Remedial Action Plan (Indiana Department of Environmental Management 1991), and this list serves as justification for the planned dredging activities. Below, we will discuss how each of the impairments to river system use will be reduced by dredging and by the implementation of the restoration options presented in this document.

i) Restriction on fish and wildlife consumption.—Removing the contamination from the Grand Calumet River will improve the health of fish and wildlife communities over several generations. After dredging, the best we can hope for is to reach Lake Michigan levels of fish contamination. At that point, the same restrictions on fish consumption would apply in both water bodies. Achieving Lake Michigan levels is possible for migratory species, but catfish and carp will probably never be safe to eat. Continuous monitoring of contaminant levels will indicate when river fish are safe under Lake Michigan guidelines. No appreciable hunting occurs in the area.

ii) Tainting of fish and wildlife flavor.—Assuming that dredging removes the contaminants, tainting would presumably be reduced as well.

iii) Degradation of fish and wildlife populations.—The fish and wildlife populations will be improved only with habitat improvement following contaminant removal. Dredging removes a great deal of allochthonous material and destroys shallow water habitats. Creating artificial fish and wildlife habitat, including shallow water areas and riffles, would encourage re-colonization. Minimizing habitat fragmentation by creating corridors between natural areas would prevent rare species populations that result from a shrinking gene pool.

iv) Fish tumors and other deformities.—Fish deformities would presumably be greatly reduced, if not eliminated, with contaminant removal.

v) Bird or animal deformities or reproduction problems.—Removing contaminants from the river will improve the quality of fish (over several generations) that the birds are consuming. Therefore, long-term improvement in bird health should occur, but immediate results are not likely. The present contamination can harm migratory bird and animal populations far from the river; this long-range influence might be eliminated with contaminant removal. Pollution abatement is essential to prevent re-contamination. Another potential threat is found in the dredge spoil storage areas. Birds and other animals that land, live, or feed there risk contamination; the construction of suitable storage facilities would benefit these animals.

vi) Degradation of benthos.—Dredging would eliminate a majority of the contaminated sediment that is limiting benthic species diversity. Pollution abatement is imperative since most contamination accumulates in the sediment. Also, re-contamination from slumping banks is possible if all of the contaminants are not removed. Adding clean sediment might promote colonization by tolerant species, provided that the appropriate sediment type is used and that water quality is improved.

vii) Restrictions on dredging activities.—The contaminated sediment brought up by dredging should not pose a threat if a proper disposal plan is in place. Because of the nature of the contaminants, phototoxicity is a possibility; but if proper precautions are taken, risks can be minimized. Lining and capping the disposal areas would prevent contamination of groundwater and air.

viii) Eutrophication or undesirable algae.—Eutrophication results from poor water quality. To address this problem, nutrient inputs need to be eliminated. Dredging will not impact the persistence of undesirable algae. Diversity will probably increase when algal species re-colonize, but blue-green algae will dominate the algal flora regardless of sediment condition.

ix) Restrictions on drinking water consumption or taste and odor problems.—The long-term effects on drinking water are not at issue since public drinking water comes from Lake Michigan. However, dredging may affect the quality of the drinking water temporarily due to the movement of contaminated materials from the river into the lake. Drinking water sources must be tested during this process, and a water source further from the outlet of the Indiana Harbor Canal should be used for a short time until disturbed sediments settle.

x) Beach closings.—Dredging the Grand Calumet River will increase the rate of water flow and, as a result, will increase the number of downstream beach closings. Bacterial contamination is a real problem due to heavy sewage input. Unless sewage treatment capacity is increased in the watershed, the same amount of sewage combined with a higher rate of flow will increase the transfer of bacteria to the beaches. With restoration of some of the marsh areas along the river (e.g., Roxanna Marsh), the resulting natural filtration system should help remove some of the bacteria.

xi) Degradation of aesthetics.—Debris scattered along the shore and in the channel will be removed by dredging. However, dredging will also release a great deal of oily sediment, and the oily sheen on the river will increase, at least temporarily. Over time, a noticeable improvement in the oily appearance of the river should occur.

xii) Added cost to agriculture or industry.—Shipping capacity and cost should improve with a decrease in sediment volume after dredging.

xiii) Degradation of phytoplankton and zooplankton.—The ecosystem is currently toxic to most phyto- and zooplankton, and removing the contaminants can only improve conditions. Phytoplankton community structure is determined by the nutrients present and the flow rate. A decrease in nutrient loading is essential for improving the phytoplankton populations. Zooplankton are greatly affected by toxic sediment, so dredging would be an improvement. However, more information on resident planktonic communities is needed before a thorough estimate can be made.

xiv) Loss of fish and wildlife habitat.—Fish habitat availability will decrease because of the smooth, U-shaped channel that results from dredging. Contamination should decrease and dissolved oxygen should increase, but fish will not be attracted to the watershed unless artificial habitats are created. For this reason, habitat enhancement in the river channel is an essential part of post-dredging restoration. Other animals would also benefit from less contamination; but again, suitable habitat is needed for them to remain there. Dredging along the banks to create shallow backwaters or to eliminate exotic seedbeds could, combined with active ongoing management, create such suitable habitats.

CONCLUSIONS

The preservation and restoration in the Calumet Basin are necessary to re-create viable natural ecosystems in the wake of contamination and fragmentation caused by human settlement and industry. The historic communities in the region were diverse and formed from the flora of several biomes. Despite extensive degradation, several rare and highly valuable natural areas remain, although they represent only fragments of the native landscape. For these natural areas to persist as viable, functioning ecosystems, extensive restoration is needed. Dredging and replacement of sediments in the Grand Calumet River are first steps in the process, but preservation and management activities are required to improve the chances of success.

Dredging will remove many contaminants from the river, but it probably will not fully clean the river and may have some negative effects. To minimize the negative effects of dredging, banks could be stabilized and fish microhabitats could be artificially recreated. Pollutant concentrations in the water and sediments of the river should be monitored after dredging to insure that they stabilize at low levels. For dredging to be effective in the long term, re-contamination of the river from point and non-point sources will have to be stopped.

The habitats of the Grand Calumet River basin have been degraded not only by contamination but by fragmentation, the invasion of aggressive species, and the suppression of natural processes. These problems will also need to be addressed. Buffer areas are needed to prevent further contamination of the remaining high quality natural areas. Corridors of semi-native habitat could be created between high quality areas to allow species to migrate between them. Populations of invasive species should be eliminated to the greatest extent possible and replaced with native species. Habitats that require fire to persist should be burned periodically. Extirpated species should, when appropriate, be re-introduced to the region. The watershed should be managed to create a variety of different habitat types, and habitat for rare species might be given priority in restoration. Restoration plans need to take current conditions, such as the unprecedented rapid flow of the present-day river, into account. We may not be able to return to presettlement conditions, but efforts should be made to create a diverse set of habitats that can persist over time and that, to some extent, mimic presettlement conditions.

To accomplish the goal of an integrated, viable landscape, a new land-use ethic will have to be established. Diverse groups will need to cooperate to make restoration a consistent, long-term project. All aspects of the system will require ongoing monitoring, and plans for preservation and restoration will need to be integrated into every stage of the land-use planning process. By acknowledging that the ecologic systems of the watersheds must be understood and maintained, we can move toward the goal of an integrated, functioning landscape where human inhabitants and natural communities can successfully coexist.

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