



Great Lakes Protection Fund



Muskegon Futures: Erosion & Sediment

Muskegon Watershed Research Partnership

Bulletin 3

Sand, Sand, Everywhere...

Eroding banks and sandy bottom channels are a common sight along much of the Muskegon River, but to what extent are bank erosion and the sandy riverbeds a priority problem in Michigan's scenic rivers? Past research has clearly demonstrated that sand bed channel segments produce less food for fish and are often avoided by trout. At a 2002 Muskegon Watershed Research Partnership (MWRP) stakeholders meeting, questions were raised about the ecological efficacy of bank stabilization work and sediment erosion controls. Historically these management techniques have consumed the lion's share of the energy and resources expended in protecting the Muskegon and many other of Michigan's valuable rivers. Is progress being made and is the effort well spent? MWRP studies and Mega Model simulations are providing important insights into the history and future of erosion and sediment transport in the Muskegon River system. It is true that sandy riverbed deposits are biologically less productive than areas of cobble, gravel, or even large log and debris jams. Never-the-less, MWRP studies suggest that bank stabilization work may not be the most effective way to reduce sediment erosion and transport in the Muskegon River?

Why Rivers Erode and Carry Sediment

While it is tempting to think of rivers as pipes made to carry water, and of sediment as the useless stuff that clogs up the pipes, this simple household plumbing analogy is really quite misleading when applied to rivers.

All rivers are earth-moving machines. River channels themselves are formed over time by many cycles of storm flow, channel erosion, and sediment transport and deposition. This happens because energy is always being released as water flows down hill. Some of that energy erodes material from the landscape, and even more is used to pick up the eroded sediment and carry it along with the flowing water. Part of this *sediment load* is carried in suspension (usually smaller particles of clay and silt) and is therefore called *suspended load*; and part is rolled along the channel bottom (usually sand, sometimes gravel, and occasionally boulders) and is known as *bedload*.

The amount of sediment load carried in a river channel ultimately depends on two things: the energy of the flow (its volume and velocity distributions), and the availability of sediment along the channel margin that can be moved. Sand requires the least energy to initially erode and relatively little energy to transport. As a result sand is the most



easily and commonly transported sediment in rivers. Clays require the least energy to transport once they have eroded, but need a lot of energy to initially erode because they are so sticky. Big rocks and coarse gravels require a lot of energy both to erode and to transport.

If river flow increases while moveable sediment is available, more sediment will be transported. If flow decreases, some of the sediment in transport is dropped which results in local sediment accumulation. So ultimately, sediment transport always varies systematically with stream flow. A key task for MWRP researchers was to quantify this relationship between flow, channel character, and sediment transport so that sediment and erosion issues could be represented in

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Why Rivers Erode and Carry Sediment (continued)

the Mega Model scenario simulations.

The bank erosion we see along the Muskegon occurs when either (1) water flows increase in a reach with the result that increasing available energy is used to move sediment from the stream bed margins; or (2) when sub-soil water seepage or foot/boat traffic mechanically undermines steep sandy slopes. Sediment from these bank slumps fall down to the channel margins and will be transported downstream only when and if there is sufficient flow energy available.

When flows increase and there is not enough readily moveable (bed) sediment available, sediment will be eroded from the river margins and the river channel will grow in size or cut meanders to decrease its slope. If river flow doesn't change but sediment input is reduced (by bank stabilization, for example) local sediment transport will decline. However, the energy of the flow remains and is available to erode wherever material is available further downstream. In either case the water is said to



be "hungry" for sediment. If river flow declines or sediment inputs increase, sediment in transport will be deposited and the river channel will fill in, rise in elevation, and/or cutoff meanders to increase its slope.

Ultimately, a balance between flow energy, sediment transport, and channel size and shape is reached, and the river channel settles into a more-or-less stable configuration. This stable size and shape of a river channel is thought to be set to hold at bankfull what is called the **dominant discharge**. The **dominant discharge** is the flow rate that over time (years) does the majority of the sediment transport work. The "right size and shape" channel is the one that at bankfull is just able to carry the dominant discharge. Simply put, a river erodes until it has an adequate size and shape to carry its typical sediment load! Or, to go back to our pipe analogy: rivers are landscape plumbing systems that continually build and re-size their own pipes out of the sediment they erode and carry! Their pipes don't clog with sediment; they are sediment! If we don't like the way channels are being adjusted, the cause is usually changing hydrology or sediment availability.

A History of Increased Flow, Erosion, and Sediment

The MWRP's reconstruction of the watershed's historical landscape and hydrology indicates a clear long-term trend of increasing flows, and as a consequence, of increasing sediment transport and channel erosion. Beginning with the logging era (1860-1900), the rate at which the river system eroded and delivered sediments to Muskegon Lake dramatically increased. While many people imagine that the logging period was the most severe period of erosion and hydrologic change on the Muskegon River, our analysis indicates that equally large increments in flow and sediment transport took place during 1960s and will likely occur again in the 21st century. Regardless of the future scenario chosen, the trend of increasing erosion and sediment transport seems likely to continue.

Increasing river flows require the river to adjust both its channel shape (depth, width, and sinuosity) and sediment transport in response (Fig 2.). Systematic re-adjustment of river channels involves both erosion and deposition as the river seeks a new balance between its flow energy and the sediment transport work it can do. These changes are characterized in the MWRP modeling as changes in the dominant discharge that each channel reach will be adjusted to carry. For example, the expected size of the lower river in the State Game Area increased after logging, then in the 1930s following a post-Depression boom in agriculture, and then again more slowly during 1960 -1980

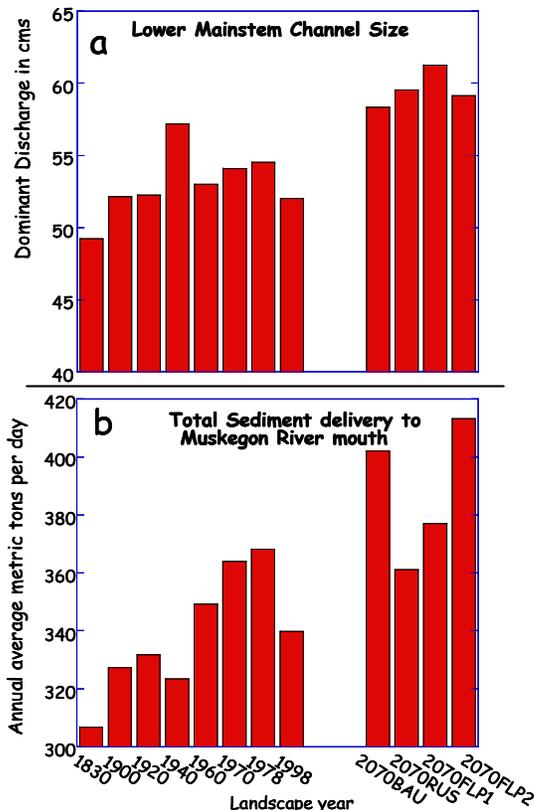


FIGURE 2. a. MREMS estimates of changing channel size (as dominant discharge in cubic meters per second) for the lower main stem Muskegon River. b. Estimated average daily sediment delivery to river mouth at Muskegon Lake.

In both plots the four right-most bars are computer projections for the year 2070 under different land management scenarios. Scenarios are coded as BAU= business as usual; RUS= reduced urban sprawl; FLP1 & FLP2 = Farmland Preservation scenarios.

A History of Increased Flow, Erosion, and Sediment Deposition (continued)

period (Fig 2a). MWRP modeling indicates periods of channel infilling in the 1940s, and again in 1980-2000 as agricultural land reverted to shrub and then forested land cover.

The actual amounts of sediment being eroded, transported, and eventually deposited are truly mind boggling. Yet, careful comparisons with data from other rivers around the country suggest that sediment transport rates in the Muskegon River are certainly normal in the sense of being typical for rivers with flows of this magnitude and watersheds of similar geology. Sediment loads being transported at various points in the Muskegon River vary depending on discharge rate, channel slopes, and substrate composition. Given the 1998 landscape, and the average climate for 1985 - 2005, the MREMS modeling suggests an average annual delivery of 124,000 metric tons per year of sediment to Muskegon Lake (equivalent to about 2,205 pounds). Hard to imagine, but this is enough sand to fill a football field to a depth of almost 50 ft each year. This amounts to about .07% of the total volume of Muskegon Lake, so there is no immediate danger of filling the lake!

In both field measurements and in the modeling studies for current conditions, the highest rates of sediment transport occurred on the main stem above the B-31 Bridge in the Maple Island Road area. Transport rates were greater than 233,000 metric tons. This represents the load being delivered to the broad lower river valley which is dominated by the State Game Area. The difference between this input (and ignoring smaller tributary contributions) and the output to Muskegon Lake gives an estimate

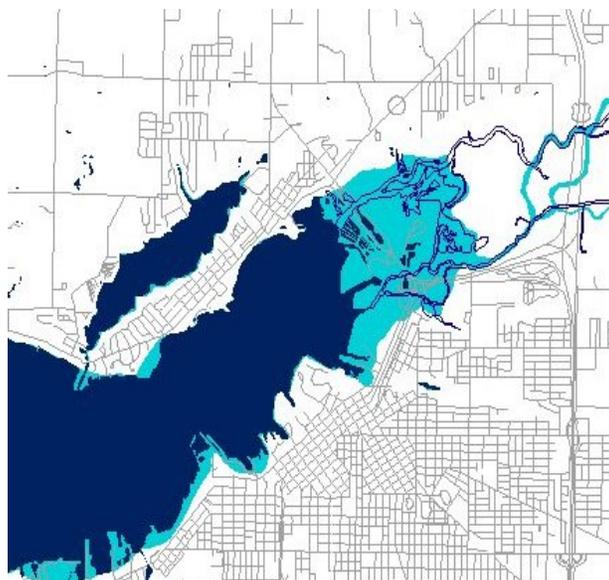


FIGURE 3. Changes in lake edge and wetland positions at the Muskegon River confluence with Muskegon Lake. Lighter blue represents the edge of the lake in 1830 which has been filled to the darker blue (from 1998 air photos).

of the rate of deposition across the Muskegon's delta wetland complex; it amounts to about 100,000 metric tons a year (Fig. 3).

Planning for the Future

In MWRP modeling studies all of the future landscape scenarios result in substantially increased channel erosion. This is the result of changes in landscape vegetation cover that will release less of the rain back into the atmosphere.

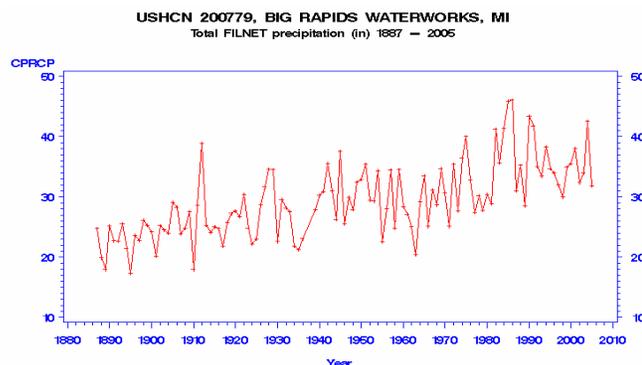
The amount of channel erosion varies with landscape management scenario (see Fig. 4, back page), but in all scenarios the extent of expected erosion is large. For the Business As Usual scenario nearly 26% of the river's length is predicted to be severely eroding by 2070. The total cost to attempt stabilization would exceed \$75 million dollars. **Because land use patterns affect river flows, and flows affect erosion, changing the way we develop the land has serious implications for bank erosion.** The Reduced Urban Sprawl scenario reduces channel erosion by almost half and represents savings of almost \$32 million in damages. In the Mega Model simulations rigorous setback restrictions on development also reduce bank erosion up to 2% at a potential cost savings of \$6 million.

Is the Mega Modeling analysis exaggerating the risks of future erosion? No, the MWRP analysis likely underestimates future erosion! Recall that the scenario modeling includes the assumption that climate (temperature and precipitation) is constant and similar to what the watershed experienced from 1985-2005. The predicted increase

in river flows and erosion are the result of land-use changes alone. In reality the effects of land use change are compounded by changes in climate. Since the late 19th century annual rainfall on the Muskegon River Watershed has slowly climbed (see Fig. 5).

Climate change predictions for the future suggest this trend will continue throughout the 21st century with more total rainfall concentrated in heavier storms. Our expectation then is that the Mega Model flow and erosion estimates are in fact, low.

FIGURE 5. Long-term trend in rainfall at Big Rapids .



Source: CN Williams Jr., MJ Mennis, RS Vose, DR Easterling, NOAA, National Climatic Data Center, Asheville, NC

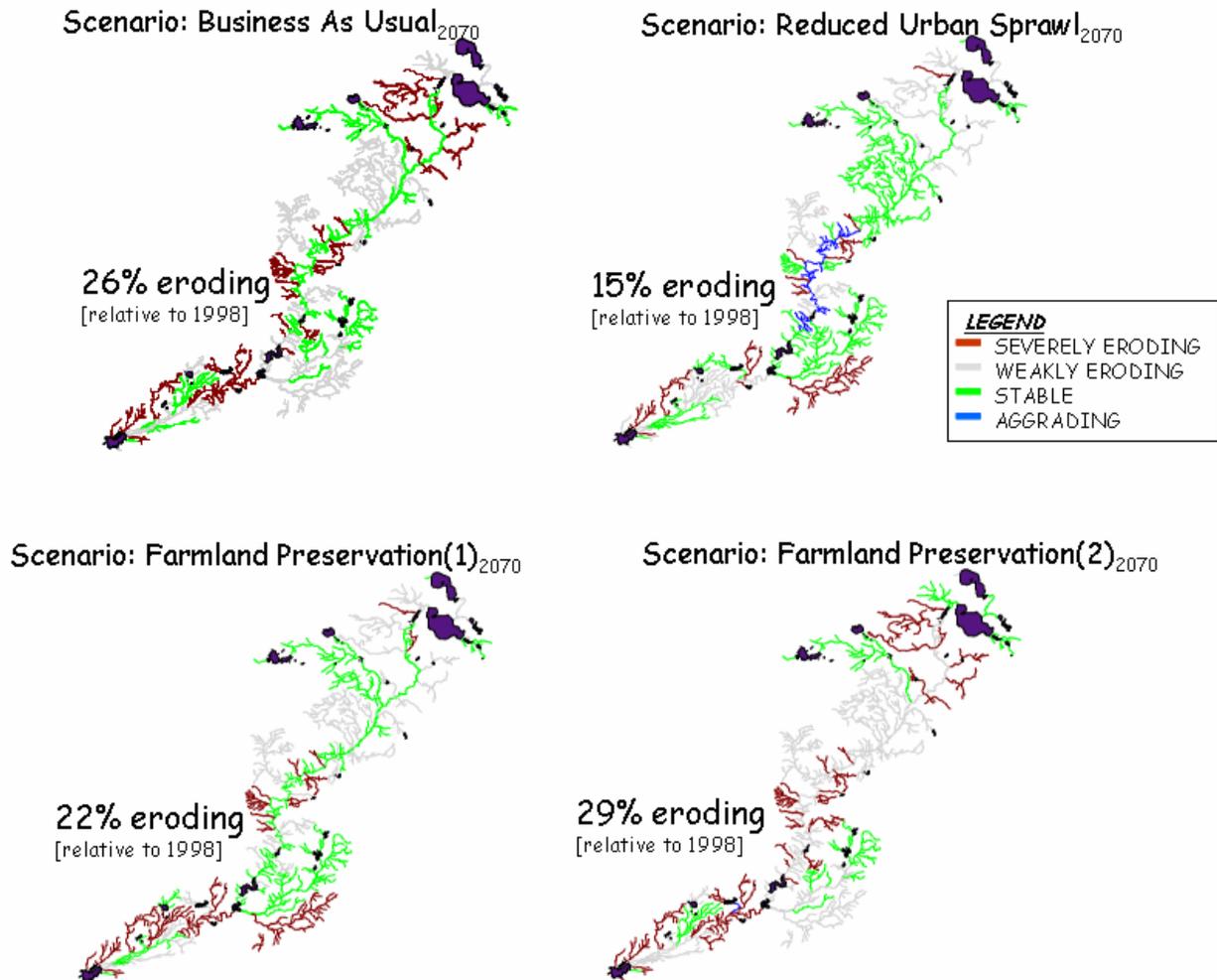


FIGURE 5. Predicted channel stability under four MWRP major landscape management scenarios. Percentages given are of entire Muskegon River channel system predicted to be severely eroding by 2070. Based on modeled changes in effective (dominant) discharge rate between 1998 and 2070. For scenario definitions see the MWRP Land Management Bulletin.

The Bottom Line...

MWRP modeling suggests that the Muskegon River faces a future of increasing flows, channel erosion, and sediment deposition in the lower delta and reservoirs; even if climate remains unchanged. Sensible land management can significantly reduce, but not eliminate this prospect. Using standard U.S. Environmental Protection Agency estimates (\$50 per linear foot of channel stabilization plus \$55,000 per damaged road crossing) a relative cost for the predicted channel erosion in each scenario can be assessed. Over the next 70 years the Business As Usual (BAU) scenario results in \$75 million worth of channel destabilization. Even the “green” Reduce Urban Sprawl (RUS) scenario, which gave the lowest erosion rates, produced at least \$42 million in erosion impacts. Given a worst-case land development scenario (continued sprawl, no further forest recovery) 29% of the entire river system would be facing severe bank erosion, with the cost of stabilization estimated at over \$82 million. The magnitude of these costs make clear the futility of a system-wide strategy of bank stabilization in the face of systemic channel adjustment to rising water budgets. Does this mean all bank stabilization and sediment trapping in the Muskegon River should be abandoned? Not necessarily, but any project must be justifiable in terms of total cost and local benefits. And, projects should be designed keeping in mind that the future includes a widely destabilized channel system. The general argument that localized bank stabilization or sediment removal will necessarily improve the river and its fishery is no longer reasonable.

Land management choices, especially (1) the reduction of urban sprawl, (2) the promotion of forest cover, and (3) the establishment of rigorous riparian setback rules are the only really efficient ways to reduce the impacts of systemic erosion. We need to begin to plan now for a future with significantly higher flows, and wide spread channel re-configuration all along the Muskegon main stem.