BANK REMEDIATION & STABILIZATION ALONG THE TITTABAWASSEE RIVER

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BACKGROUND

The Tittabawassee River is located in central Michigan. Starting in the mid-1800s, a logging and then an agricultural boom led to increased sediment loads to the Tittabawassee River, resulting in the formation of levees along the banks of the river.

In the early 1900s, Dow, like other manufacturers of the time, discharged wastewater directly to the river. The discharge contained graphitic carbon particles from electrical conductors used in the chlorine extraction process. Unknown at that time, these particles contained furans, which belong to the dioxin family of chemicals due to their similar chemical structures. The contaminated particles mixed with moving river sediments; some of this material deposited in newly forming levees along the banks.

Today, these deposits have the potential to erode and serve as a secondary source of furans and dioxins to the river and its adjoining floodplain. One objective at this site was to identify, screen, select, and implement effective strategies for remediating the contaminated banks.

IDENTIFICATION OF BANK MANAGEMENT AREAS

Approximately 42 miles of banks along the Tittabawassee River were evaluated. Areas targeted for remediation, called bank management areas (BMAs), were identified based on a multicharacteristic evaluation of the bank properties.

This evaluation incorporated a review of geomorphological features, a multiple lines of evidence evaluation of bank stability, and delineation of relative bank toxic equivalency (TEQ) levels. Bank stability surveys and modeling were conducted to characterize the erosion potential of the banks during normal and high flow events.

Bank stability surveys included the following:

- *Quantification of bank angle*
- *Beneficial vegetation cover*
- *Bank height*
- *Presence of undercutting*
- *Level of exposed roots.*

The empirical lines of evidence are bank characteristics that provide visual indications of past or ongoing erosion (e.g. evidence of undercutting and/or high level of exposed roots) or are indicative of possible future erosion (e.g. low vegetative cover and/or steep bank angle). This weight-of-evidence approach was used to categorize river banks as either high/moderate stability banks or low stability banks.

In addition, cores were collected along the banks of the Tittabawassee River to understand the distribution of furans and dioxins in the river banks. Measured furan and dioxin concentrations in the banks, along with the bank heights, were used to identify the banks containing the highest contaminant mass. Next, the banks with the highest probability of contributing furan and dioxin mass to the river (i.e. unstable banks with high concentrations) were identified for remediation. Stable banks with high concentrations will be monitored to ensure continued stability or to identify future BMAs.

REMEDIATION ALTERNATIVES AND STABILIZATION TECHNIQUES

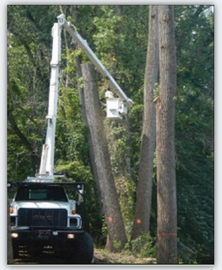
Potential bank remediation strategies included bank soil removal or bank stabilization.

Bank soil removal involved the targeted removal and off-site disposal of the bank furan and dioxin deposits. Reconstruction following bank removal involved additional removal or shaping of adjacent upland soils to construct a stable slope. As part of bank removal, all existing vegetation was removed. The Tittabawassee banks are often heavily forested; the work areas were revegetated following the completion of the removal and reshaping activities, but mature forests will take decades to restore.

Stabilization primarily relied on green technologies and included some or all of the following techniques:

Canopy management

The canopy of targeted trees is cut back to provide more sunlight to the bank areas, fostering growth of deep-rooted vegetation.



Bank clearing, smoothing and shaping

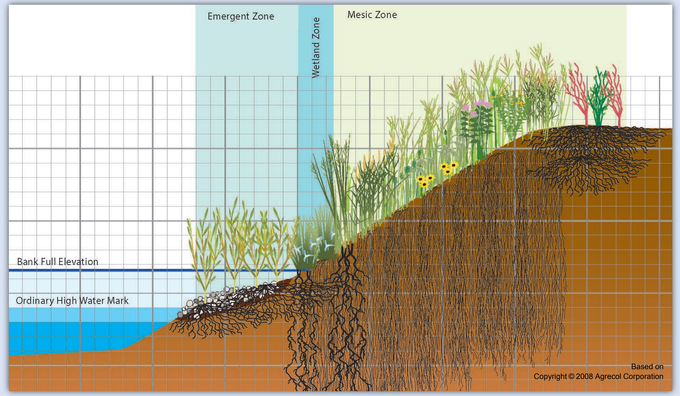
Bank clearing and smoothing involve removing the existing non-beneficial vegetation to implement treatments. Limited bank reshaping with earthmoving equipment may be needed to achieve an appropriate bank angle for stabilization.

Native vegetation and erosion control products

Stabilization always uses native, deep-rooted plants to enhance the bank's stability applied by hydroseeding and live planting of plugs. As needed, treatments through the placement of geotextiles, geocells, turf reinforcing matrices (TRMs), and erosion control blankets, are used to provide protection from short- and long-term erosive forces and allows deep-rooted vegetation to be established.

Toe armoring

In bank areas where routine river fluctuations prevent vegetation growth, thus reducing the stability of the toe and bank, toe protection may be applied.



Bank stabilization relies on deep-rooted, native vegetation.

RESULTS AND LESSONS LEARNED

As of the end of 2018, more than 4 miles of banks (more than 22,000 feet) in over 30 bank areas along the Tittabawassee River have been prioritized and remediated.

Establishing the native vegetation can take a couple of years, so short-term maintenance (e.g. irrigation, reseeding) may be needed. Long-term monitoring of the remediated banks is being conducted and is used to identify ongoing maintenance requirements, as needed. In isolated instances, small areas have required maintenance or modifications to the treatment, mostly due to localized conditions, such as steep slopes that were not smoothed/shaped or localized scour around tree stumps.

In general, these projects have demonstrated bank stabilization techniques to be an ecologically friendly and cost-effective approach to addressing contaminated banks as compared to traditional soil removal strategies.