Post-Hurricane Erosion Protection

By Lauren E. Haworth & Ernest Fields

Hurricanes are some of the most expensive and dangerous natural disasters we face. In late summer 2017, Hurricane Harvey slammed into the South Texas shoreline, causing $150 billion to $200 billion in damages and 82 deaths. It remained in the Houston vicinity for approximately four days after landfall, and some areas experienced as much as 1.52 meters (60 in.) of rainfall.

Along with the obvious damages to buildings and infrastructure, erosion causes extensive damage that can have far-reaching consequences. Many people are familiar with the coastal erosion that accompanies hurricanes. Storm-induced waves can move large quantities of sand both out to sea and further inland, causing widespread damage to the built and natural environment. However, hurricanes can also cause extensive inland erosion with similarly serious consequences.

In general, waterborne erosion is caused by water with a high enough capacity for sediment transport to dislodge and pick up sediment from its natural state. Water's capacity for sediment transport is affected by three factors: velocity, soil type and existing sediment load. Water that is moving at a higher velocity than usual, such as the runoff from an extreme weather event, has a greater capacity to move sediment, resulting in increased erosion potential from events such as hurricanes.

Soil type also affects erodibility. Highly cohesive soils such as clays or coarse-textured soils such as those high in sand content are less prone to erosion. Soils that have a high silt content are more rapidly eroded. In the Houston area, much of the soil is clayey, although there are areas of more diverse soils, including loam and sand. While these clayey soils are somewhat more resistant to erosion, their low permeability means that they do little to absorb runoff.

Clear water scour is another factor in sediment transport. When water with little sediment load, such as water from urban storm systems or discharges from lakes or ponds, enters a stream, it has a very high capacity for sediment transport. In the course of a lengthy, extreme rainfall event such as during Hurricane Harvey, the amount of low-sediment flow from urban storm sewers is increased.

What makes the erosion that occurs in the aftermath of a hurricane different? One of the factors that increases erosion following a hurricane is increased sustained outflow from regional detention facilities. Sustained high velocities can be detrimental to vegetation, stripping leaves from trees and shrubs, and unearthing many plants entirely, removing what is considered the most effective natural form of erosion control. During and after Hurricane Harvey, the Addicks and Barker reservoirs, which were built in the 1940s to control flooding along Buffalo Bayou, released sustained, high-volume flows of clear water with high erosive capacity. Even after the hurricane ended, six weeks of controlled release was required to empty

(Opposite) Buffalo Bayou experienced extreme erosion during and after Hurricane Harvey. (Top left) Long-duration high flows can undermine bridge abutments, such as this bridge at Saunders Road in Houston. (Top right) Structures can be undermined by sustained flows, as seen here on Spring Branch. (Bottom) High flows around an outside bend greatly affected existing erosion control measures on Spring Branch.

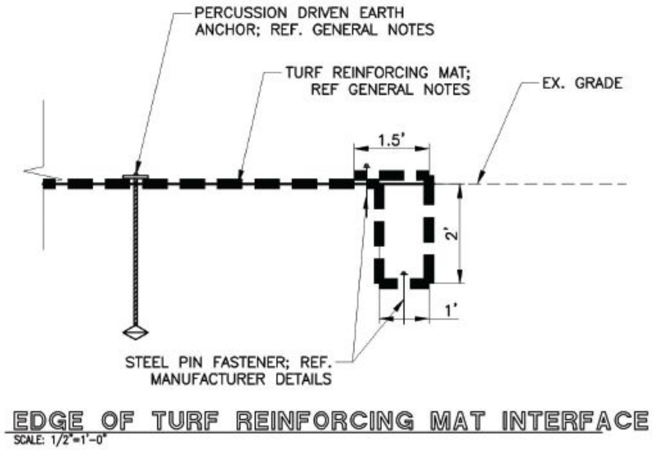
the reservoirs, meaning that Buffalo Bayou experienced higher flows for a sustained period. The release rate was high in order to make room in the reservoirs in case other major storms followed, as often happens in the Gulf hurricane season.

In addition, both reservoirs overflowed in an uncontrolled manner in the days after Harvey, resulting in another frequent cause of erosion following an extreme weather event like a hurricane: the presence of water where it is not expected. This was the first time the reservoirs had overflowed since they were built. The overflow introduced not only the extreme flows associated with floodwaters overtopping a reservoir, but also high rates of runoff to areas not accustomed to these conditions. Flows in areas that have not previously experienced them are often not armored against the potential erosive force associated with them, and can see rapid erosion that causes widespread damage to infrastructure. It can be especially dangerous for residents who may not expect flooding in their area. Along with damage to property, flooding in unexpected areas brings with it the increased risk of injury or death.

It is easy to assume that the spreading out of floodwaters that occurs when watercourses rise above their banks will result in slower flows and less erosion. While this is sometimes the case, preferential flow often means that water moves very slowly through the floodplain due to obstructions but velocities in and near the channel remain high. These isolated areas of increased velocity can experience extensive erosion as well. This erosion is often out of sight during the flood event and is not identified until floodwaters subside.

Along with erosion comes sedimentation. The soil and beach sand that are picked up by increased flows and storm surge are deposited once the flows spread and slow. This can endanger vegetation nearly as much as high-velocity flows; if deprived of light and air by extensive sedimentation, vegetation dies off and is susceptible to being washed out with the next large rain event. In this case, slopes are left vulnerable to erosion in the future. Protecting against erosion also protects against sedimentation, in that there is less sediment available for water to pick up, move and deposit.

How can we protect against the erosion that is often experienced inland following a hurricane? While these storms may be exceptional events, many of our standard treatments for erosion are also applicable in these situations. The best natural protection against erosion is vegetation. We can use turf reinforcing mats (TRMs) extensively in order to protect the root systems of vegetation from being swept away in high-flow events. TRMs have come a long way; newer varieties with percussive anchors can withstand velocities more than 3 meters per second (10 ft per second). Some anchored TRMs can be used for erosion control on slopes as steep as 1:1 (H:V), though slope stability should also be considered. TRMs are often a far more cost-effective



Detailing effective end treatments is vital to the longevity of a turf reinforcing mat.

alternative to hard armoring streams. It also can provide aesthetic and environmental benefits not achieved with a concrete channel.

Expanding the area protected with TRMs is a relatively inexpensive way to protect against increased velocities and extended flows. Confirming that the area protected by TRMs is large enough for the potential runoff is vital to protecting against extreme flows. Sizing TRMs is, like many engineering problems, a question of balance between cost and efficacy. In order to determine which locations would most benefit from TRM protection, it is important to consider stream geomorphology. Outside bends are always more susceptible to erosion and should be considered for extra protection. Areas of turbulence, such as aerial crossings, bridges and culverts, are vulnerable to scour and should be protected. Take steps to identify areas that are currently experiencing stream degradation, as this degradation may accelerate when subjected to the long-duration, high-flow conditions associated with hurricanes.

Comparing several years of aerial photography data can be crucial in identifying areas that are currently experiencing stream degradation. If successive years of detailed regional LiDAR data are available, the data can be compared to check for existing areas of degradation. Consider protecting likely breach areas. In the Harvey example, this might mean applying areas of TRMs at the ends of the Addicks and Barker reservoir levees, as those areas were logical points of overflow if other outfall areas were overwhelmed.

Also, be aware that as floodwaters subside, water flows in areas and directions that are not typical. In all cases, consider extending protection above the expected design stormwater surface elevation; extending a TRM-protected area by a few meters or yards is far less expensive than repairing an undermined bridge in the case of an extreme event like a hurricane.

Above all, it is key to remember that an extreme weather event such as a hurricane affects an entire region. If possible, individual designs should take into account regional characteristics and needs. Although municipality budget constraints may limit improvements to areas that are in greater need of repairs, it is good practice to identify, if possible, areas where erosion control now can prevent the need for major infrastructure repairs in the case of a severe weather event.

Equally as important is appropriately detailing end treatments that can protect the TRMs from being undermined if water levels rise past design levels. Manufacturers will provide requirements for anchoring the edges of their particular products, but it is good practice to view these as minimum requirements. Engineering judgement is required to determine if a particular area might experience greater turbulence than might normally be expected, or other factors that might endanger the edges of the TRMs. It is also important to remember that the engineer should take into account the entire design life of the project; while a less robust edge treatment may suffice when the product is initially installed, what if large events occur in succession? What if the edge treatment is exposed during an event, but budget constraints prevent a municipality from performing repairs before the next event? A more robust edge treatment can reduce the chances that these common situations and others like them will cause a failure. The main risk to any erosion treatment is unraveling at the edge interface between treated and untreated areas. Design engineers must consider the risks posed by conditions in their regions and by the specific project sites to prevent rolling and subsequent TRM failure.

The extreme rainfall that accompanies hurricanes can cause extensive erosion inland as well as to the coast, contributing to damage to the built environment. Erosion from hurricanes is typified by high velocities, increased flow rates over long durations and the presence of water in areas that are normally dry. Many of the strategies that can combat more typical stream degradation problems can be applied to hurricane-related erosion as well. The key is planning and designing with the possibility of an extreme storm in mind.

About the Experts

Lauren E. Haworth, P.E., LEED AP BD+C, has diverse civil engineering experience, including erosion control, streambank stabilization and site structure design. Her water resources engineering experience includes flood studies, hydraulic impact analyses and water rights assessments. She is a graduate of the University of Texas at Arlington and is a licensed engineer in the state of Texas.

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