SMA ROUNDTABLE

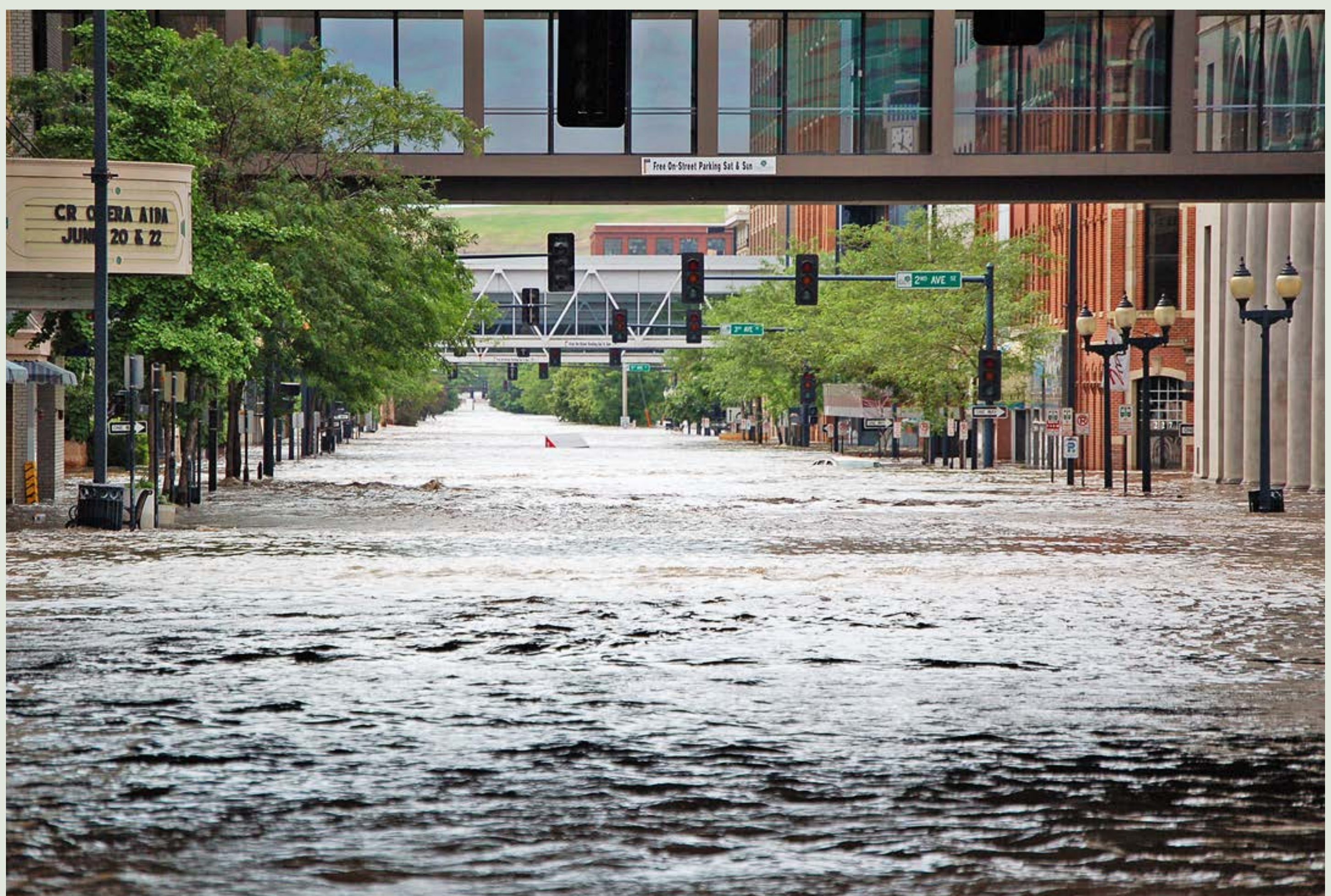
Flooding and Tree Damage: Lessons and Surprises

Contributors were asked to describe their flooding event(s), share which tree species fared well and which ones did not, and say what changes in plant selection and general management they made based on lessons learned.

On June 13, 2008, the Cedar River crested at its highest level in history, at 31.1 feet (9.5 m). The previous record reached only 20 feet (6.1 m). The flood waters penetrated 10 square miles (26 sq km) or 14 percent of the city. This monumental flood impacted 7,198 parcels, including 5,390 houses, dislocated more than 18,000 residents and damaged 310 municipal facilities.

Two prominent areas of Cedar Rapids, Timecheck and Czech Village, were hit especially hard. These two residential neighborhoods are now unrecognizable to people who last saw them before the flood. What were previously tree-lined residential streets have been replaced with block after block of open lots. The urban tree canopy in these areas, as well as the other flood-impacted locations in the city, has also changed.

Starting the year after the flood, trees began to decline. For the next several years, trees were removed as they succumbed to the effects of the flood. While most of the trees were older or had already been under some sort of stress, the losses occurred across all species. Each year, all dead and dying trees were removed from these areas. The following year however, trees that appeared to be healthy during the previous inspection were in serious decline or were dead. These losses continued for the next four years, with most of the removals occurring two to three years after the flood. The area finally stabilized in 2012.



Flooding in Cedar Rapids, Iowa in 2008 penetrated 14 percent of the city. USGS photo in the public domain.

Like many cities that had to replace much of their canopy after losing trees to Dutch Elm Disease, the most common street trees in the city are maple (*Acer* spp.) and ash (*Fraxinus* spp.). Together, they make up 70 percent of the urban canopy in Cedar Rapids. The overwhelming majority of the trees lost to flooding consisted of these species. If there is a silver lining to the flood and its aftermath, it is that we are now able to start to provide a better quality urban forest for future generations.

The looming threat of Emerald Ash Borer also affected these areas. Starting in 2009, the city began proactively removing ash. Since we were losing such a large number of trees from the flood and the majority of the homes were condemned and scheduled for demolition, these neighborhoods were among the first targeted for the ash tree removal program. Unlike other target areas, all ash in these neighborhoods were removed.

The City reforestation budget allows for 1000 new trees to be planted yearly. Replacement trees are pulled from an ever-changing list of 60 different species, a practice helping to create a more diverse forest. While diversity is the primary directive for reforestation, matching species to the site is also very important. This is especially true for flood-prone areas. While this method is now adopted as part of a city-wide management plan, it was initiated because of the flood.

Instead of rebuilding homes in these flood-affected areas, plans are in place for a levee system to protect the city from the river that runs through it. Seven years after the flood, and three years after the mass tree removals ended, new removals have begun in preparation for the coming flood protection system. These areas will be turned into recreational green space and trees will play a big part in the design. Species selection for these areas will be a careful consideration. Another flood event is likely to happen, but this time, we will be planning for it.

—Todd Fagan, City Arborist, Cedar Rapids, Iowa

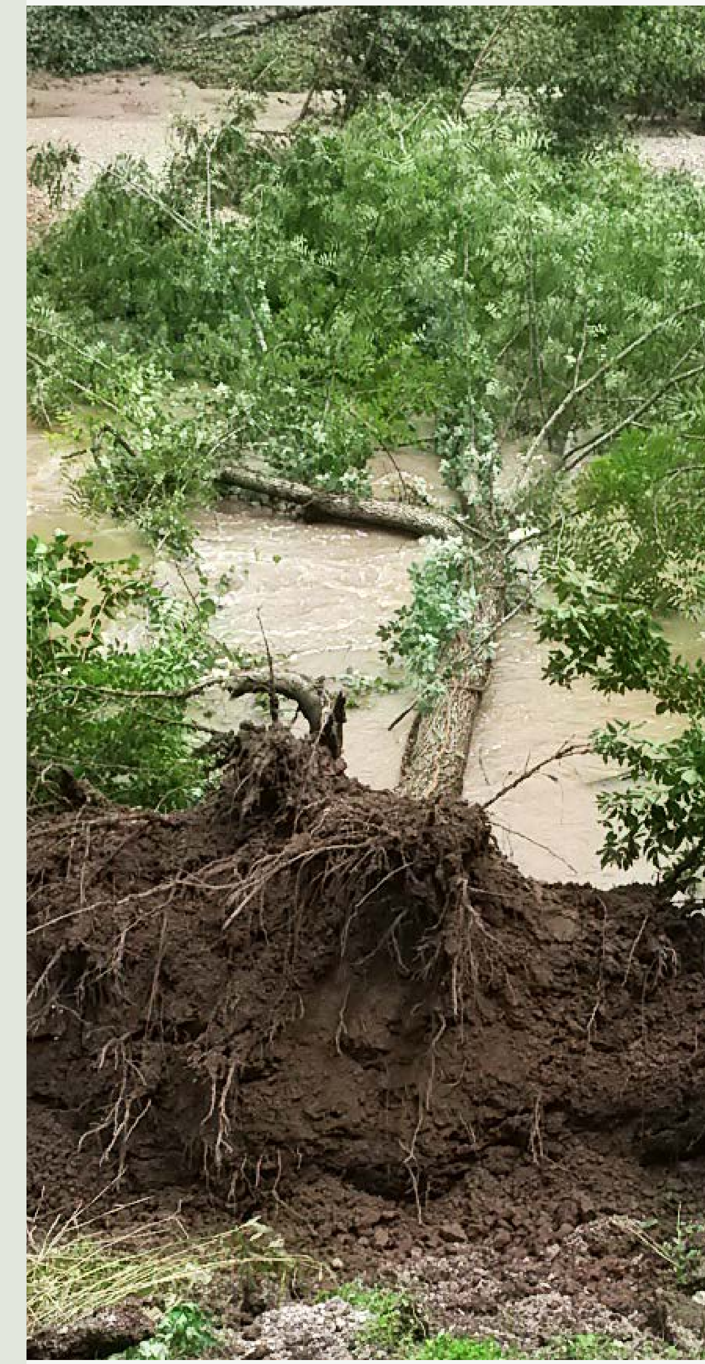
New York City lost at least 11,000 street trees (and an estimated more than 10,000 park trees) to storm damage from Sandy and shared with Long Island the experience of significant die-off of London plane trees. NYC Parks and Recreation prepared a report after Sandy related to flooding. With regard to London planes, more than 1500 failed to leaf out at all the following season and more than 2500 leafed out 50 percent at best, with further decline anticipated.

Part of that report asks, "How will we change what we plant because of Hurricane Sandy?"

Sandy highlighted that we as urban forest managers must continue to be vigilant in our efforts to specify trees that will be resilient to not only a diverse array of urban factors, but also changing environmental factors. For example, going forward, trees we choose to plant within the advisory flood zone for a one percent storm must be tolerant of both coastal conditions as well as inundation. To give you an idea of how important this consideration is, fourteen percent of NYC streets fall within the advisory flood zone.

What are the major reasons flooding is so punishing for trees?

Dr. Kamran Abdollahi, professor of forest ecophysiology in the urban forestry program at Southern University in Baton Rouge, Louisiana, explains that flooding fills soil pores, denying tree roots access to the oxygen they need for respiration and water and nutrient uptake. Dr. Abdollahi says, "In the urban environment where soils are already compacted by human activities, flooding exacerbates compaction and its negative effects. Flooding can also negatively affect root anchoring and tree stability."



The toppling of streambank trees is one of the classic symptoms of "Urban Stream Syndrome," a term that covers a number of ill effects of flooding on urban waterways.

Integrating what was learned from Sandy's particular toll, we identified a list of 75 tree species and cultivars that the City considers worthy of use in the advisory flood zone for a one percent storm. Every new tree planted within the flood zone will now be chosen from the refined palette to ensure our trees are long-lived and resilient. Those trees include species and cultivars of hedge and red maple (*A. campestre* and *A. rubrum*), birch (*Betula* spp.), hackberry (*Celtis occidentalis*), hawthorn (*Crataegus* spp.), coffeetree (*Gymnocladus dioicus*), elm (*Ulmus* spp.), oak (*Quercus* spp.), blackgum (*Nyssa sylvatica*), and zelkova.

—Matthew Stephens, Former NYC Parks and Recreation Director of Street Tree Planting

To give some background: our company, Valley Tree and Landscape, has planted more than 25,000 trees for greater New York City over the course of 25 years. In October 2012, Hurricane Sandy hit Long Beach, Long Island with several feet of salt water on land, bay to ocean, for about 12 hours, accompanied by high winds. That brief flooding event left dramatic damage to the region's trees, with some surprising victims.

The biggest shock was how poorly Long Island's many London plane trees (*Platanus* x *acerifolia*) fared. We had long thought them to be flood and salt tolerant and they had been widely advocated for seaside use. The damage manifested in stages; the following spring, an average of a third of the canopy was affected. It wasn't typical dieback, in that it didn't affect the whole crown. A large section of the crown on one side would not break bud, while the rest leafed out normally. However, over the 2013 growing season, the trees continued to show signs of decline, until by 2014 their bark started to peel off and the trees died.

In the summer of 2014, Long Beach took down more than 1400 dead trees. My guess is that 85 percent or more of them were London planes. We used to have our streets lined with allées of them, like American elms (*Ulmus americana*) back in the day. This was a huge blow to our city. Lesson learned: the city will avoid planting monocultures in the future, no matter how flood-tolerant any one tree species is thought to be.

Arborvitaes (*Thuja* spp.) in our area were instantly killed by the floods, as were blue atlas cedars (*Cedrus atlantica*). I had a job where I'd planted 200 blue atlas cedars at 4-inch caliper, and they were at 7-inch caliper when the storm came; they were dead within weeks. That was heartbreaking. Leland cypresses (*Cupressus* x *leylandii*) also were quick to die. Tulip trees (*Liriodendron tulipifera*) never put leaf on again. Every single Japanese maple (*A. palmatum*) died. Pine trees (*Pinus* spp.) and magnolias (*Magnolia* spp.) were a mixed bag. Across species, mortality was high for newly planted/younger trees.

There were happy surprises, though. Blue spruces (*Picea pungens*) never looked better; no one expected that! Junipers (*Juniperus* spp.) and red cedars (*T. plicata*) did fine, as did holly trees. The Kwanzan cherry trees (*Prunus serrulata* 'Kwanzan') did okay if they'd been in the ground at least three years. Honeylocusts (*Gleditsia triacanthos*) and pears (*Pyrus* spp.) did okay, and Norway maples (*A. platanoides*) and zelkovas (*Zelkova serrata*) did well.

—Joel Greifenberger, Owner of Valley Tree and Landscape in Long Beach, Long Island

Chile has certain geographical characteristics that make it particularly vulnerable to flooding from rivers. On March 24, 2015, an unusual storm in the driest desert in the world—the Atacama region in northern Chile—triggered a series of floods that devastated several localities, including the city of Copiapó.

The overflowing of the Copiapó River flooded the city with mud, dramatically affecting the local infrastructure and the lives of its inhabitants. Trees also suffered—the mudslide was a stroke of the sword through the heart of numerous woody warriors. Less than a year after the floods, palm trees (*Phoenix canariensis* and others), silver wattles (*Acacia dealbata*), oriental planes (*P. orientalis*) and peppers (*Schinus molle*) began to fall. Before the flood, they had already been weakened by age, heavy soils and arid conditions. After the flood, the accumulation of polluted, dried mud around tree trunks and over tree roots prevented water infiltration. Just eight months after the flood, the wind had dealt the final blow to more than 30 of these weakened trees, with more losses likely yet to come.

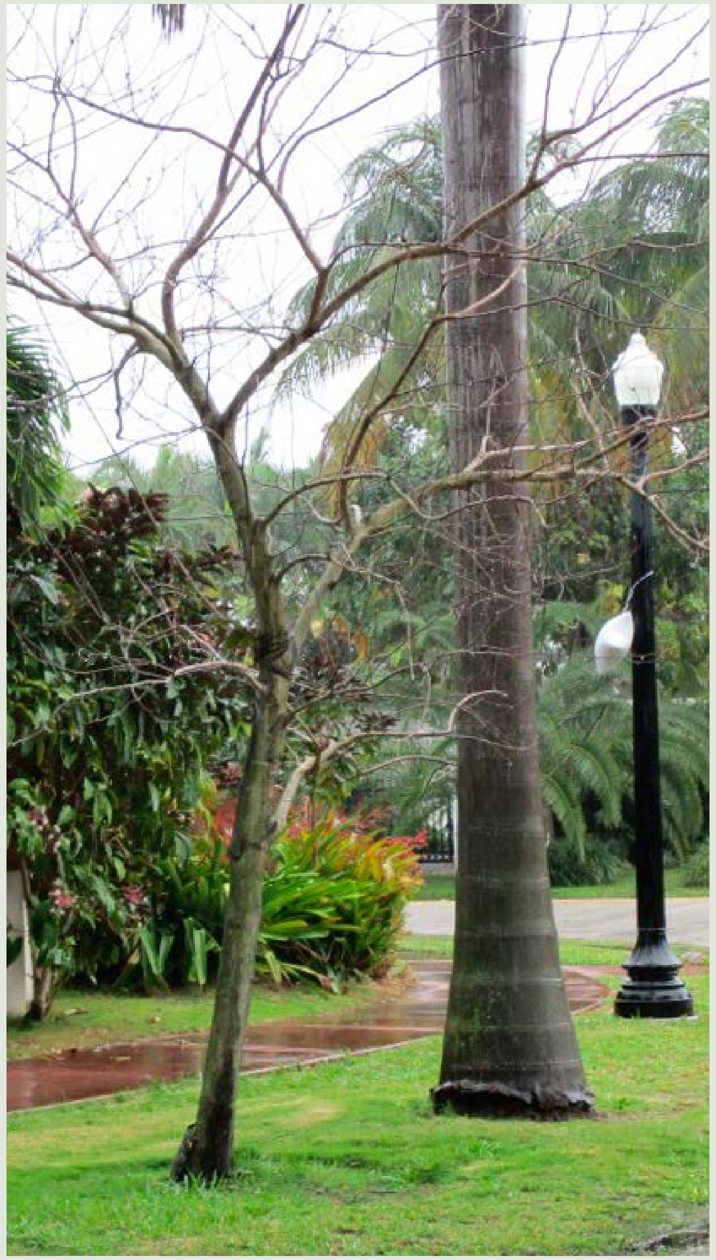
My colleagues in Copiapó and throughout Chile want to prevent this kind of disaster in the future. We can install water collectors and dikes and other barriers, forest the foothills, improve the urban design of settlements, avoid settlements in inappropriate places, plant species resistant to flooding, and promote green infrastructure. But sometimes, even with these preparations, irrepressible threats will come, and reverently we understand that nature manages to impose its terms.

—Felipe Fuentes R., Municipal Arborist for I. Municipalidad de Calera de Tango, Chile

When one thinks about the City of Miami Beach, vivid images come to mind: sparkling water, sandy beaches, significant art and cultural events, and palm-lined streets. However, some of the features that make Miami Beach such a prime destination also include some notable concerns. Geographically speaking, the City is a coastal spoil island (an island created by waterway dredging) with a fairly low elevation and high brackish ground water tables. This has led to a history of storm and salt water tidal flooding events most notably during the "king tides" (exceptionally high tides that occur a few times per year).

To address the significant issues caused by storm-related flooding, sea level rise, and high tides, the City has embraced a new comprehensive strategy. It includes additional storm water pumping stations, raised sea wall and road elevation projects, adoption of a robust climate resiliency plan, and revisions to the City's reforestation program, including planting standards.

Royal palm trees in Miami Beach, Florida, showing leaf burn due to salt water flooding. Photo by Mark Williams

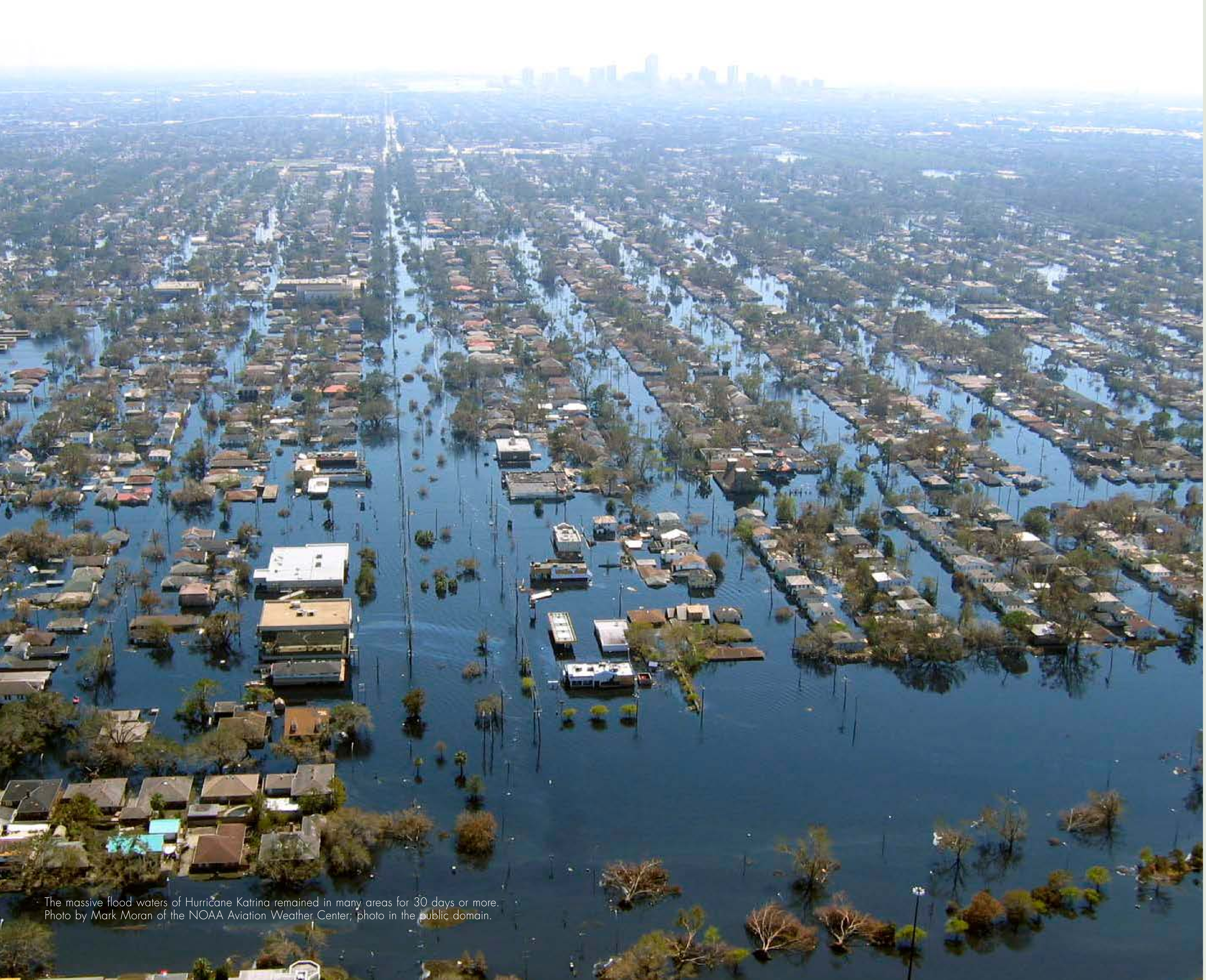


This Hong Kong orchid tree (left) in Miami Beach, Florida died after salt water flooding. Photo by Mark Williams

Certain tree species in Miami Beach have proven to be highly susceptible to damage from salt water flooding. These include but are not limited to trumpet trees (*Tabebuia* spp.), royal poinciana (*Delonix regia*), tree forms of privet (*Ligustrum* spp.), Brazilian beautyleaf (*Calophyllum brasiliense*) and Hong Kong orchid (*Bauhinia blakeana*). Common symptoms of damage include extreme leaf chlorosis, new foliage stunting, canopy dieback, sudden leaf drop, and—in severe cases—total tree defoliation and death. The trees that have proven to be highly tolerant of salt water flooding include pitch apple (*Clusia rosea*), seagrape (*Coccoloba uvifera*), green or silver buttonwood (*Conocarpus erectus* and *C. erectus* var. *sericeus*), gumbo limbo (*Bursera simaruba*) and paradise tree (*Simarouba glauca*). However, the City has observed situations where flooding that persisted for a week or more caused damage even to highly salt-tolerant tree species.

In anticipation of higher brackish ground water tables and more frequent salt water flooding events, the City has modified the reforestation program, emphasizing highly salt-tolerant Florida native trees and phasing out salt-intolerant material. Design changes are also being incorporated, such as bridged sidewalks, tree wells to protect existing trees from grade changes related to flood mitigation, increased use of bonded aggregate, and raised or mounded planting areas for new trees. Root aeration systems are also being explored. Continued outside-the-box thinking and attention to the latest research pertaining to trees and flooding/salt tolerance will help keep the City ahead of the curve.

—Mark Williams, Urban Forester, City of Miami Beach, Florida



The massive flood waters of Hurricane Katrina remained in many areas for 30 days or more. Photo by Mark Moran of the NOAA Aviation Weather Center; photo in the public domain.

Hurricane Katrina (August 2005) pushed huge amounts of brackish water on land that lingered for 30 days or more in New Orleans and greater southern Louisiana. Our company, Bayou Tree Service, is full-service but has specialized in historic tree preservation—especially that of live oaks—since 1980. Our crews were able to get into New Orleans starting four days after Katrina and worked many months, in extreme conditions, on tree clearing and hazard mitigation.

Everyone was predicting the demise of the live oaks, because although we know they are very tolerant of abuse, no one had observed these trees after they'd been inundated for 30 days or more! We were all worried. But the flooded live oaks did just fine. Because so many other species blew over or declined during and after the flood, the live oaks had little competition when it came time to rebound. The few other tree species that did well included various palms, baldcypress (*Taxodium distichum*), and slash pine (*P. elliottii*).

After the flood waters receded, lawns were completely brown and looked desert-like. Most of the ornamental shrubs and herbaceous plants were dead brown and then here were these live oaks with dark green and healthy leaves, looking like they had survived nuclear fallout. It only enhanced my deep reverence for this incredibly forgiving species with which we have worked so closely for 35 years.

Mass southern magnolia (*M. grandiflora*) mortality confirmed my longtime observation that "native" species aren't necessarily better prepared for extreme stress. It's all about whether the tree has been properly matched to the site. Southern magnolias, for instance, like to be on high, dry, mineral soils. Their being native is not reason alone to use them, at least not in low-lying areas. Meanwhile, crape myrtles (*Lagerstroemia* spp.), originally from Asia, weathered the flooding well.

Savannah hollies (*Ilex* x *attenuata*) and other hybrid hollies took a beating after the flooding; we were quite surprised to see that in mature, tall hedges of hollies, every single one died. Hollies grow natively in coastal and swampy areas, yet they were devastated by the flood waters. We noticed more insects in the wake of the flooding, in particular, scale insects. Of course, scale was most likely to hit trees that were already in poor health.

—John Benton, Owner, Bayou Tree Service, New Orleans and Baton Rouge, Louisiana

Advancing Urban Forestry Post-Katrina

Dr. Hallie Dozier (Louisiana State University) and Dr. Kamran Abdollahi (Southern University) found abundant evidence that those urban trees that had been categorized in poor condition by inventories prior to Katrina were the most likely to be wiped out by the storm effects. The trees that were hardest hit were the ones compromised by poor site conditions like soil compaction, root disruption, or inadequate rooting volume. This just makes common sense, but the fact that it was borne out so dramatically, with so much tree damage to deal with, has yielded a silver lining: more rapid advancement of arboricultural sophistication and urban forest appreciation in the region.

Dr. Abdollahi says that post-Katrina, educational programs for arborists and city leaders have intensified in southern Louisiana. City planners have been eager to learn more about how to better design infrastructure to make planting sites more hospitable for tree roots. The necessity of keeping tree inventories, hazard assessments, and maintenance up to date has received a lot of attention. And of course, the message of "Right Tree, Right Place" has been driven home. Abdollahi says that there has also been a growing focus on the need for arborists to be appropriately educated and licensed.

After Katrina, tens of thousands of native southern magnolia in southern Louisiana region were wiped out within a month. My colleagues and I studied the surviving tree populations. Wherever flood water from Katrina stood for more than five or six days, the southern magnolias died. I would say that in some spots where water lingered even fewer days than that, the trees were still lost within the next month or year. Southern magnolias are very wind tolerant but unfortunately very sensitive to standing water. It is challenging to find species to use that are both wind and flood tolerant.

I had a conversation with the New Orleans city forester about the wisdom of replanting southern magnolias. I said, "Well yes, you should, but not in such big swaths and not in low-lying areas." Because it's a tree with such cultural importance to us in the Southeast, not replanting it at all would be a mistake.

—Dr. Hallie Dozier, Professor of Forestry at Louisiana State University, New Orleans

Much of Texas, and especially the Dallas/Ft. Worth region, received record amounts of rainfall in spring of 2015. Flooding was severe for many areas for a prolonged period of time. All regional lakes were overfilled and many were not releasing water until downstream flooding subsided. This was especially true locally for the Trinity River system.

Under these circumstances many forested areas were flooded for over three months from April/May into July and even early August. I had always assumed that prolonged inundation of a tree's root system during the growing season would result in sure mortality. So far, that has not been the case; however, the full extent of damage is yet to be seen.

Thus far, river bottom species such as boxelder (*A. negundo*), sycamore (*P. occidentalis*), and cottonwood (*Populus deltoides*) have done the best. Cedar elm (*U. crassifolia*) have fared a little less well and some oaks species have suffered the most—Shumard (*Q. schumardii*) and Texas red oaks (*Q. buckleyi*) and especially post oak (*Q. stellata*) and blackjack oak (*Q. marilandica*) seem to have been hit the hardest.

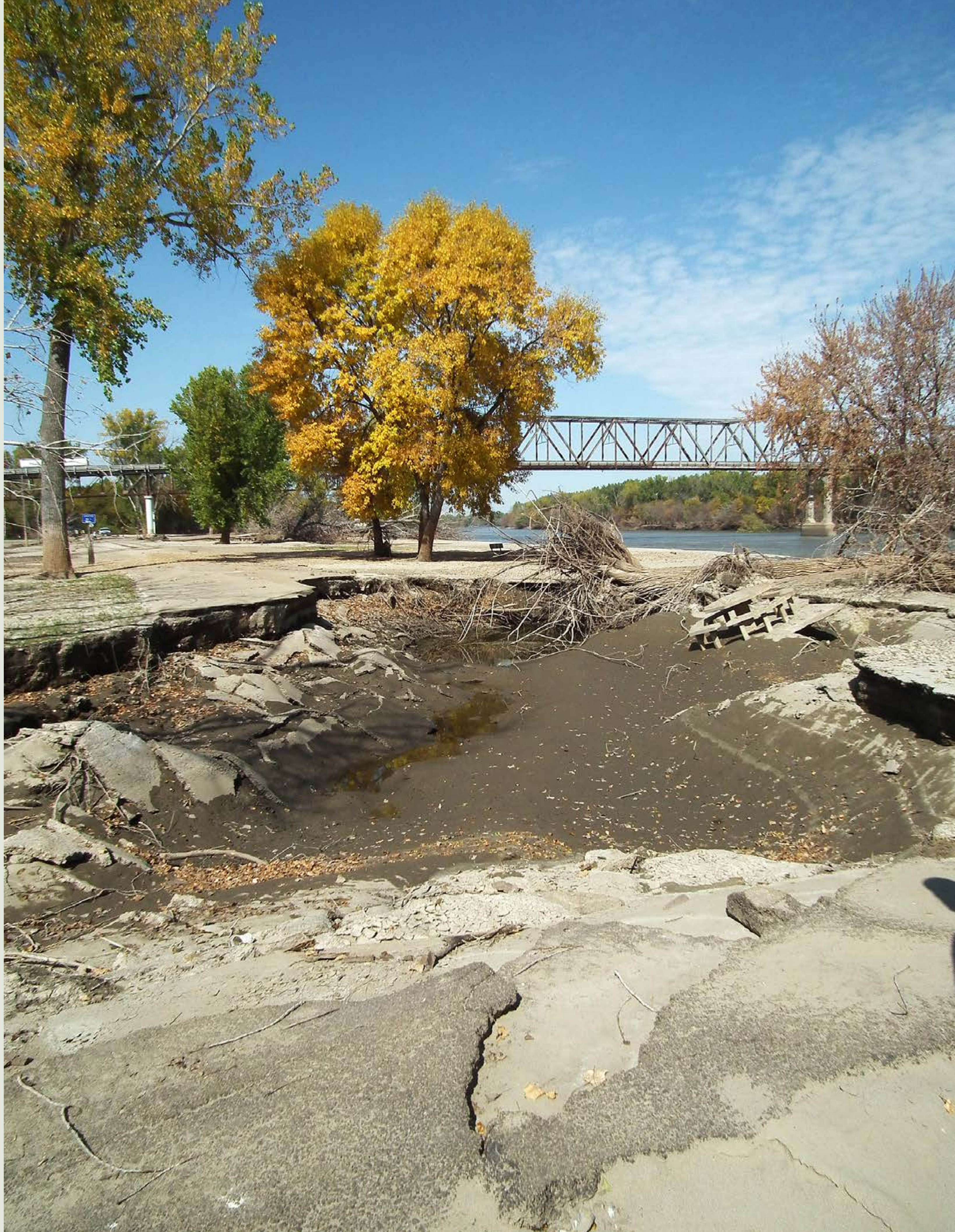
However for all species, the damage is hit-or-miss. There are trees of the same species growing right next to each other that were flooded for three months and one will be dead while the other looks just fine. Of course who knows what the future holds for these trees. I suspect just as with any other major stress to a tree, the resulting possible problems could take years to surface. For now, though, I've gained an appreciation for the way that certain trees seem to be able to handle severe flooding better than I'd expected.

—Courtney Blevins, Fort Worth Regional Forester, Texas A&M Forest Service

Flooding from the Mighty Mo (Missouri River) had major impacts from June through August/early September of 2011. In the Omaha area, the River swelled to over 36 feet/11 m deep (only 4 feet/1.2 m shy of the record set in 1952) and tripled in speed to nearly 12 miles per hour (19 km/h), eroding soil and washing debris downstream. The Garrison Dam in North Dakota doubled its previous water release record, sending 152,000 cu feet (4304 cu m) per second rushing downstream. That's equivalent to over 6000 average-sized refrigerators' worth of water every second. It is amazing that any trees remained standing after the reservoirs had drained back down to normal levels.

The flooding began the month after I began working as a Nebraska Forester, and I knew it was an opportunity to observe nature in action and share what I learned. The Bob Kerry Footbridge, which arches over the Missouri River, remained open to the public during the event. This gave me a front row seat from which to photograph and document flooding response from different tree species.

The force of the flooding deposited up to 2 feet (0.6 m) of sediment around some trees while leaving the buttress roots of others completely exposed at a comparable depth. Mature cottonwoods heavily eroded by the swollen river were observed to have two or three root systems at various depths—a response to past sedimentation events. Most cottonwood trees that died during the flooding fell over while still green due to unbalanced canopies and rotten smaller roots. One assessment I made for



Powerful flooding can erode soil from underneath concrete slabs and wipe out whole sections of paved road, like this one in Bellevue, Nebraska. Photo by Graham Herbst

In Nebraska, weeping willows responded to the prolonged 2011 flooding by forming massive aerial root masses from both the trunk and submerged branch tips. Photo by Graham Herbst

a flooded property had ten cottonwoods averaging 5 feet (1.5 m) in trunk diameter that needed to be removed. Those cottonwoods that had been caught in the cool, oxygenated river waters fared better than those growing inland where warm, shallow water was trapped at their bases.

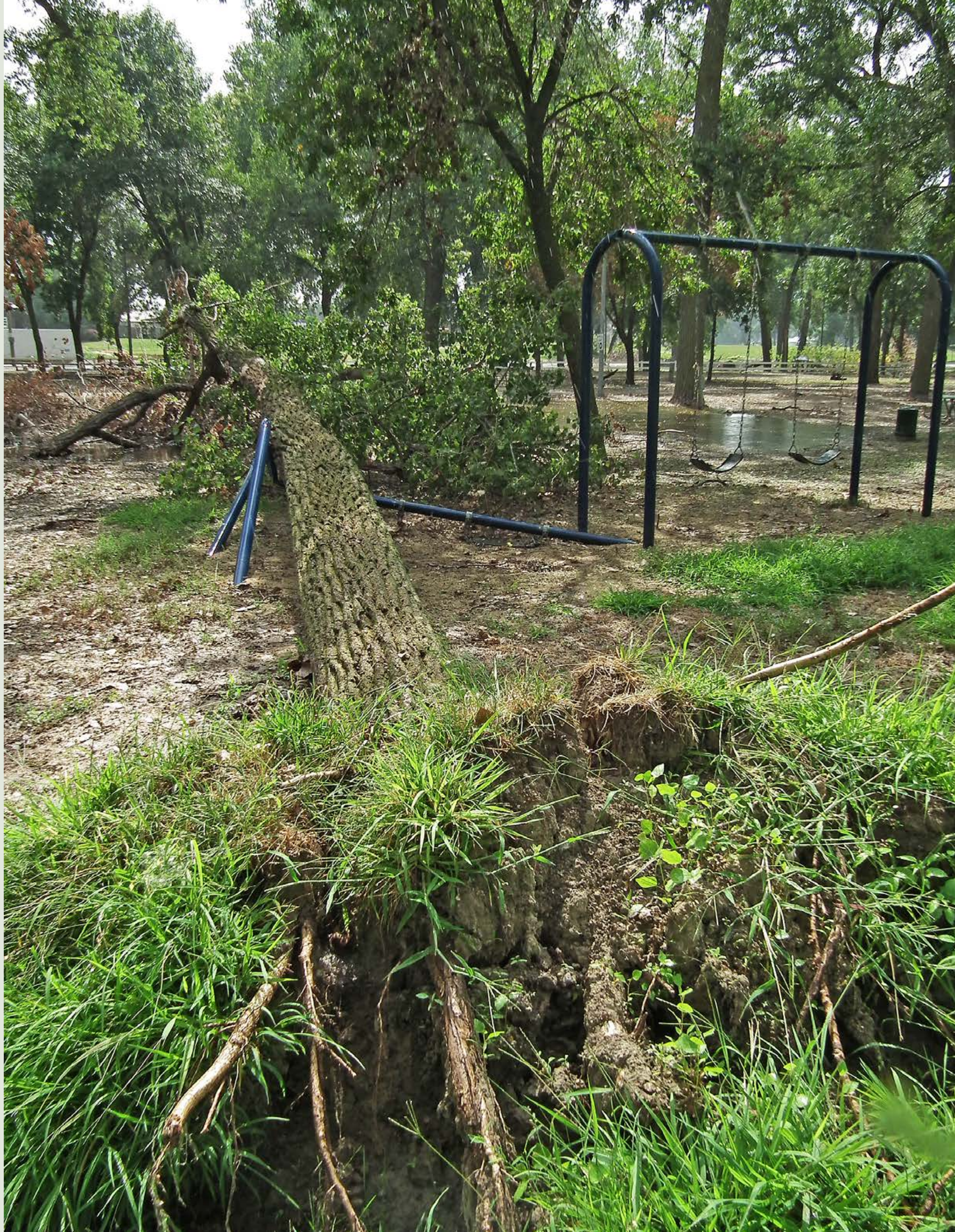
Willows (*Salix* spp.) had their own extreme flooding response. In N.P. Dodge Park they sent out large mats of adventitious roots like broom heads sticking out from the trunk and formed smaller root masses on those branch tips that hang into the water. The willows that died also sent out prolific epicormic sprouts from their root crowns. Some willows were able to break dormancy the following spring and grow, but the survivors all have significant dieback. Silver maple (*A. saccharinum*) had a similar sprouting response from the root crown as the willows, but survived in even smaller proportions.

Many other floodplain trees were unable to tolerate over three months of inundation. Green ash (*F. pensylvanica*), birch, sycamore, and silver maple took significant losses while mulberry (*Morus* spp.) seemed to have many individuals that hardly missed a beat. Swamp white oak (*Q. bicolor*) hardly noticed there was a flood aside from dieback on branches that were directly submerged; baldcypress was equally unscathed. Nearly five years later, many of the impacted species that survived the flood still stand, but insect and disease pressure is much higher, and signs of decline continue.

—Graham Herbst, Community Forestry Specialist, Nebraska Forest Service

Baldcypress tree standing tall in Omaha, Nebraska after the 2011 flood, with flood line visible on the nearby stressed cottonwood trees. Photo by Graham Herbst

Extended periods of flooding cause roots to rot, making large trees— like this cottonwood in South Sioux City, Nebraska—unstable. Photo by Graham Herbst



The astounding growth of Columbia, Missouri from a sleepy Midwestern college town of just 62,000 residents in 1980 to over 118,000 today has predictably led to some growing pains. The additional roads, roofs, and other impervious surfaces associated with this rapid urbanization have dramatically increased surface runoff and negatively impacted the ecosystems of our local streams and creeks.

The rush of storm water which now accompanies almost every downpour increases local stream flow or stream "flashiness" in our community, creating problems which directly influence the network of Columbia's multi-use trails located in the riparian forest corridors. Channel erosion and bank destabilization are the primary evils; however, logjams and debris piles are also a headache, especially around trail bridges and support structures.

A recent instance of costly channel erosion occurred in late June of 2015 after heavy rains. Approximately 150 feet (46 m) of the Hinkson Creek streambank collapsed, toppling trees and nearly severing access to Columbia's premier fitness trail, the MKT.

Almost 1400 tons (1270 metric tons) of boulders were needed to stabilize the bank, and over 36 tons (33 metric tons) of topsoil were spread along the crown of the bank before we replanted with a mixture of native tree and shrub species. Sandbar willow (*S. interior*) cuttings will be planted among boulders later this spring to complete the remediation.

The other aspect of channel erosion, dislodged streambank trees, has also presented challenges over the years. During a flash flood event in 2009, the remains of a massive cottonwood collided with a trail bridge over the Hinkson Creek (see photo at right). A large branch of this floating tree punched through the steel railing and became entangled with the bridge structure. Removal work proceeded with great care, since trees deposited in this manner are often under unexpected tension.

Predictions have Columbia gaining another 20,000 residents by 2025, so it's unlikely that storm water or flooding issues will be going away any time in the near future. Fortunately, a broad consensus among Columbia's community stakeholders makes enhancing our natural resources and mitigating storm water a top priority. See the following link for more on these local efforts:

http://helpthehinkson.org/CollaborativeAdaptiveManagement.htm

—Brett O'Brien, Natural Resources Supervisor, Columbia, Missouri

Streambed restoration on Hinkson Creek in Columbia, Missouri. The crest of the bank was seeded with river oats (*Chasmanthium latifolium*) and planted with stoloniferous (suckering) multi-stem native shrubs such as elderberry (*Sambucus canadensis*) and staghorn sumac (*Rhus typhina*) to quickly establish a network of anchoring roots. The creek has since been slowly depositing silt in the gaps among exposed boulders, which will allow Columbia to plant this rocky bank with sandbar willow cuttings this spring. Photo by Brett O'Brien

Dave Dittmer, forester with the Columbia, Missouri Parks Department, works to remove a large tree limb hung up on a trail bridge by powerful flood waters. Photo by Brett O'Brien