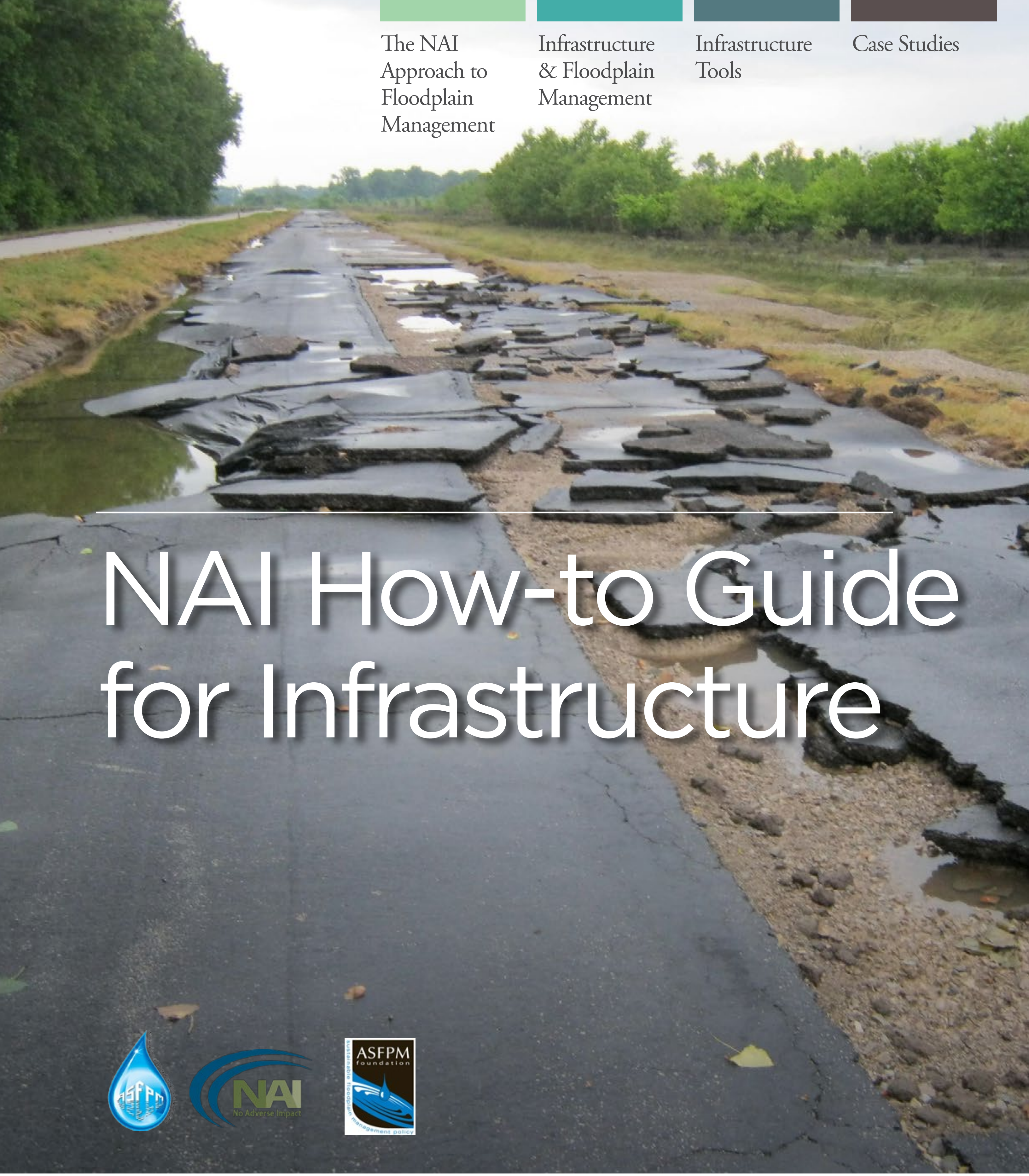


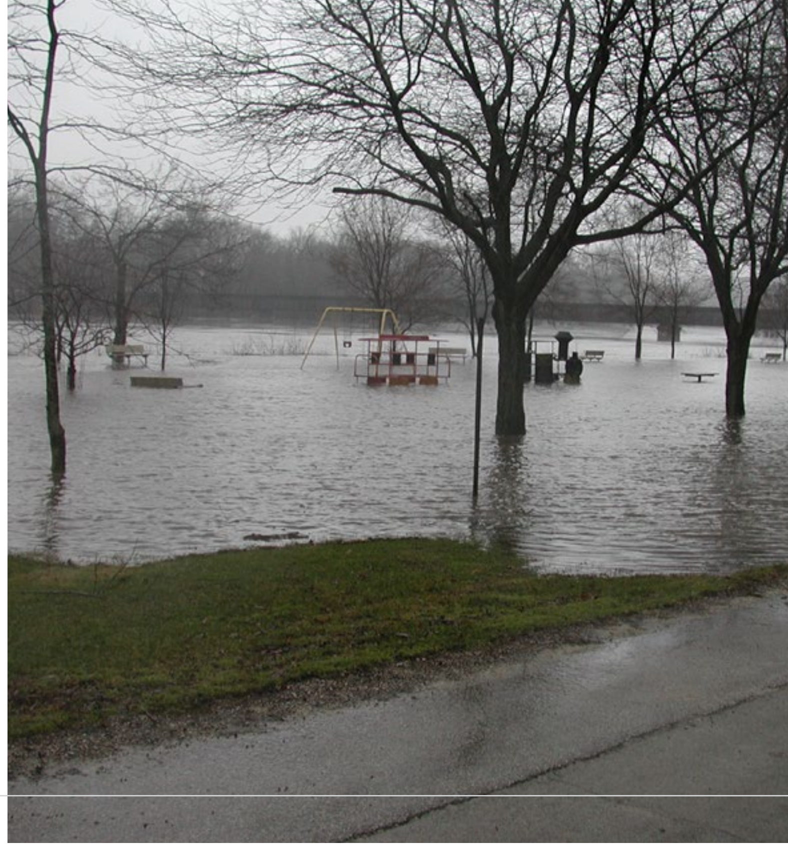
The NAI Approach to Floodplain Management | Infrastructure & Floodplain Management | Infrastructure Tools | Case Studies

NAI How-to Guide for Infrastructure

No Adverse Impact Infrastructure How-to Guide • July 2014/Updated 2016

Infrastructure

Infrastructure



This park in Aroma Park, IL, illustrates the NAI approach. Waterfront properties serve the community with open, green space, but damage is limited during a flood. Photo credits: “Dry” photo by French & Associates, “Wet” photo by Kankakee County Planning Department.

SECTION ONE
The NAI Approach

SECTION TWO
Infrastructure & Floodplain Management

SECTION THREE
Infrastructure Tools

ON THE COVER:

Photo courtesy of the FEMA media library.

This playground equipment was built using natural materials while providing fun features for kids to explore. Cedar River at the Charles City Riverfront Park, IA. Photo courtesy of the city of Charles City, IA.

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Introduction

As a nation, we continue to build at-risk structures in or near floodplains, yet we don't spend as much time or effort considering the adverse impacts of these developments on adjacent properties or elsewhere in the watershed. The minimum standards we follow today – if, indeed, there are standards being utilized at all – are resulting in increasingly difficult flood issues and higher flood risk to our nation's communities and its citizens.

Some of these persistent flood risk issues are historical. Towns and cities were settled near watercourses for transportation, while others, especially in the arid west, were settled where precious water was available as a resource. However, today, poorly designed and constructed development and redevelopment, and a changing climate, are increasing flood risk to these communities. Many communities are dealing with persistent flood problems. Some of those same communities have residents and business owners attending board meetings after a heavy rain, complaining of flooding and demanding that the flood problems be fixed.

Communities can get ahead of these flooding issues, avoid causing problems for themselves and others, and ultimately lessen their flood risk, by embracing a new approach to managing their flood problems – the No Adverse Impact approach. In essence, NAI floodplain management takes place when the actions of one property owner are not allowed to adversely affect the rights of other property owners.

continued on page 3

Who Should Use this Guide?

After a flood, damage assessments should be conducted to identify where changes can be made during repairs and reconstruction. Damage assessments are vital for a post-disaster plan, such as the ones discussed in Section 3, Tool 3, Estes Park, CO. Photo by Patsy Lynch/FEMA.

Anyone who wants a more resilient community that can withstand a major flood event should use this guide. That could mean anyone, from local officials, to elected officers, decision makers, floodplain managers, coastal managers, stormwater managers, emergency managers, planners, hazard mitigation specialists, public works and engineering staff, design professionals, concerned citizens, and various other groups in the community.

This *Guide* is one of a series of how-to guides that expand on the knowledge base within the No Adverse Impact Toolkit, a 108-page document prepared by the Association of State Floodplain Managers. The *Toolkit* is ASFPM's reference on implementing the NAI approach. It identifies tools for incorporating NAI floodplain management into local regulations, policies and programs; while the *How-to Guides* break down, by subject matter, that information into compact, usable information communities can apply.

This *Guide* reviews only five tools, but there are many more NAI tools for infrastructure, and for each of the other building blocks found in the *NAI Toolkit*. The Toolkit, additional references, and more information can be found by clicking on the NAI icon at the bottom of ASFPM's homepage: www.floods.org

When the *How-to Guides* series is completed, there will be one guide for each of the seven building blocks found in the *NAI Toolkit* (hazard identification and floodplain mapping; education and outreach; planning; regulations and development standards; mitigation; infrastructure; and emergency services (links below).

The *How-to Guides'* ultimate goals are to have communities take a different approach to managing development that prevents increasing flood risk, and to incorporate NAI concepts into other community activities. This *Guide* identifies just a few ways a community can incorporate the concepts into its infrastructure activities.

Users should view NAI as a continuum – every community is somewhere on the path between not addressing minimum flood standards at all, addressing only the minimum standards of the National Flood Insurance Program, and being 100 percent resilient and sustainable in the face of a flood threat. The more NAI steps a community takes, the better prepared it is for the next flood.

THIS HOW-TO GUIDE IS DIVIDED INTO FIVE SECTIONS:

SECTION ONE: The NAI Approach to Floodplain Management

SECTION TWO: Infrastructure and Floodplain Management

SECTION THREE: Infrastructure Tools

SECTION FOUR: Case Studies

SECTION FIVE: Resources & Fact Sheet

After reading this *Guide*, it is recommended that a community conduct an assessment of its infrastructure activities. A gap analysis would identify what is being done and what is not being done from an NAI perspective. It would lead to strengthening existing programs and implementation of new ones that can help reduce the community's flood risk. Similar assessments should be conducted after reviewing the other *Guides* in this series.

Link:
Mitigation How-to Guide: www.floods.org/NoAdverseImpact/NAI_How-to-Guide_Mitigation.pdf
Infrastructure How-to Guide: www.floods.org/NoAdverseImpact/NAI_How-to-Guide_Infrastructure.pdf
No Adverse Impact Toolkit: www.floods.org/NoAdverseImpact/NAI_Toolkit_2003.pdf
Education & Outreach How-to Guide: www.floods.org/ace-files/NAI/EdcOutHowToGuideSept2015.pdf
Planning How-to Guide: www.floods.org/NoAdverseImpact/NAI_Planning_How_to_Guide_Final.pdf

Common Terminology used throughout this Guide

This is an example of following the NAI floodplain management approach, letting nature follow its course with no threat to life or property. The waterfront is a community asset, of open green space and parks, where people can relax and enjoy the view. Photo from the CRS Coordinator's Manual.

NFIP: National Flood Insurance Program. Most community floodplain maps and floodplain management standards have been adopted to meet the NFIP's criteria. Learn more at www.fema.gov.

Community: The NFIP definition of a community is a political subdivision that has authority to adopt and enforce floodplain management regulations for the areas within its jurisdiction. The term usually means cities, counties, and Indian tribal governments. For the purposes of this *Guide*, a "community" also includes a neighborhood, unincorporated settlement, or other non-governmental subdivision where people live or work together.

CRS: NFIP's Community Rating System is a program that provides reduced flood insurance premiums for policyholders in communities that go above and beyond the NFIP criteria. For more information see www.FloodSmart.gov/crs or www.CRSResources.org. This *Guide* identifies how communities can receive CRS credits for implementing NAI tools and standards.

Floodplain: Nature's floodplain, which includes the Special

Flood Hazard Area (defined below), and other areas subject to flooding, includes:

- Areas subject to greater than the 1 percent annual chance flood, often referred to as the 100-year flood;
- Areas subject to smaller, more frequent, or repetitive flooding;
- Areas subject to shallow flooding, stormwater flooding, or drainage problems that do not meet the NFIP mapping criteria (but where 20 percent of flood insurance claims occur);
- Areas affected by flood-related hazards, such as coastal and riverine erosion or subsidence; and
- Areas that will be flooded when future conditions are accounted for, such as sea level rise and upstream watershed development.

For these reasons, "floodplain" is the term that best reflects a community's true flood risk, and is used in this *Guide* instead of "SFHA."

Natural floodplain functions: The functions associated with the natural or relatively undisturbed floodplain that moderate flooding, maintain water quality, recharge groundwater, reduce erosion, redistribute sand and sediment, and provide fish and wildlife habitat. One goal of NAI floodplain management is to preserve and protect these functions, in addition to protecting human development.

Resilient: "Able to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies," as defined in FEMA's National Disaster Recovery Framework.

SFHA: A Special Flood Hazard Area mapped on an NFIP Flood Insurance Rate Map that shows the area subject to the 1 percent annual chance flood caused by rivers, lakes, oceans, and other larger sources of flooding.

Sustainable: "Able to meet the needs of the present without compromising the ability of future generations to meet their own needs," as defined in FEMA's National Disaster Recovery Framework.

The *Toolkit*, additional references, and more information can be found by clicking on the NAI icon at the bottom of ASFPM's homepage: www.floods.org

SECTION ONE

The NAI Approach to Floodplain Management

Cleaning up a flooded home can be a long and expensive process. Cedar Rapids, Iowa, June 2008. Photo from FEMA library. www.fema.gov/media-library/assets/images/52962

The NAI Approach to Floodplain Management

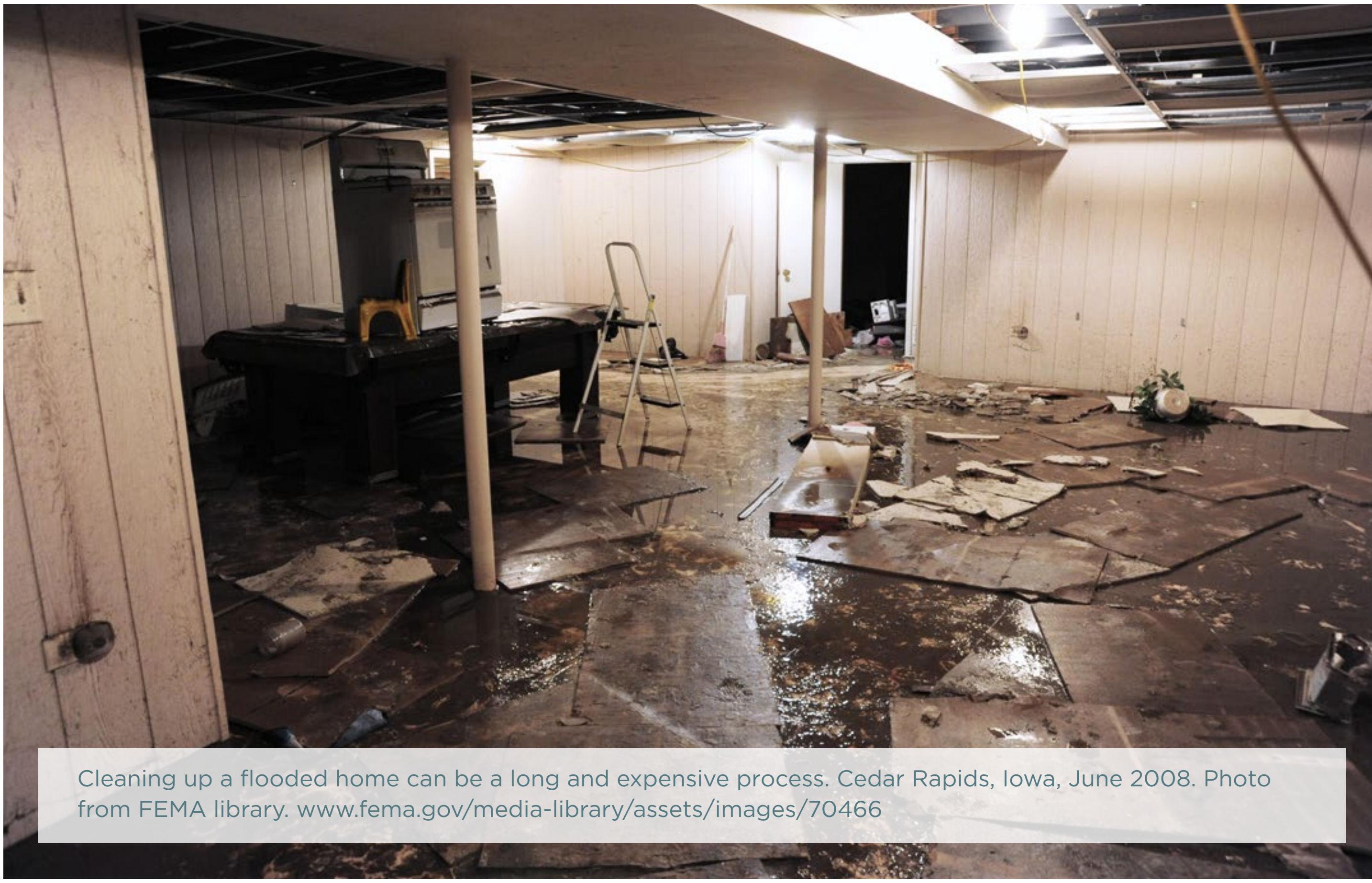
FLOOD LOSSES AT THE LOCAL LEVEL

Local flooding can have a much greater impact than is commonly thought. Consider that for every federally-declared flood disaster, numerous other floods never get declared – and little to no federal assistance is available. Studies show that communities experiencing a major flood take years, if not decades, to recover. For example, 50 percent of small businesses never reopen after a major flood, and those that do, fail at a higher rate within a few years.

For many communities that have not experienced a flood in recent years, it is only a matter of time until a major event occurs. When there is a flood in a developed area, any and all of the following impacts on communities and their residents and businesses can be expected:

- Decreased revenue due to loss of income, sales, tourism, and property taxes;
- Costs incurred due to post-flood clean up and repair of buildings and infrastructure;
- Loss of jobs due to businesses closing or cutting back on operating hours;
- Risk of injury or loss of life, including first responders rescuing those who did not evacuate or are stranded;
- Mental health and family impacts, including increased occurrence of suicides and divorce;
- Loss of historical or unique artifacts;
- Loss of programs or services that are cut to pay for flood recovery; and
- Deterioration of homes and neighborhoods as floods recur.

continued on page 9

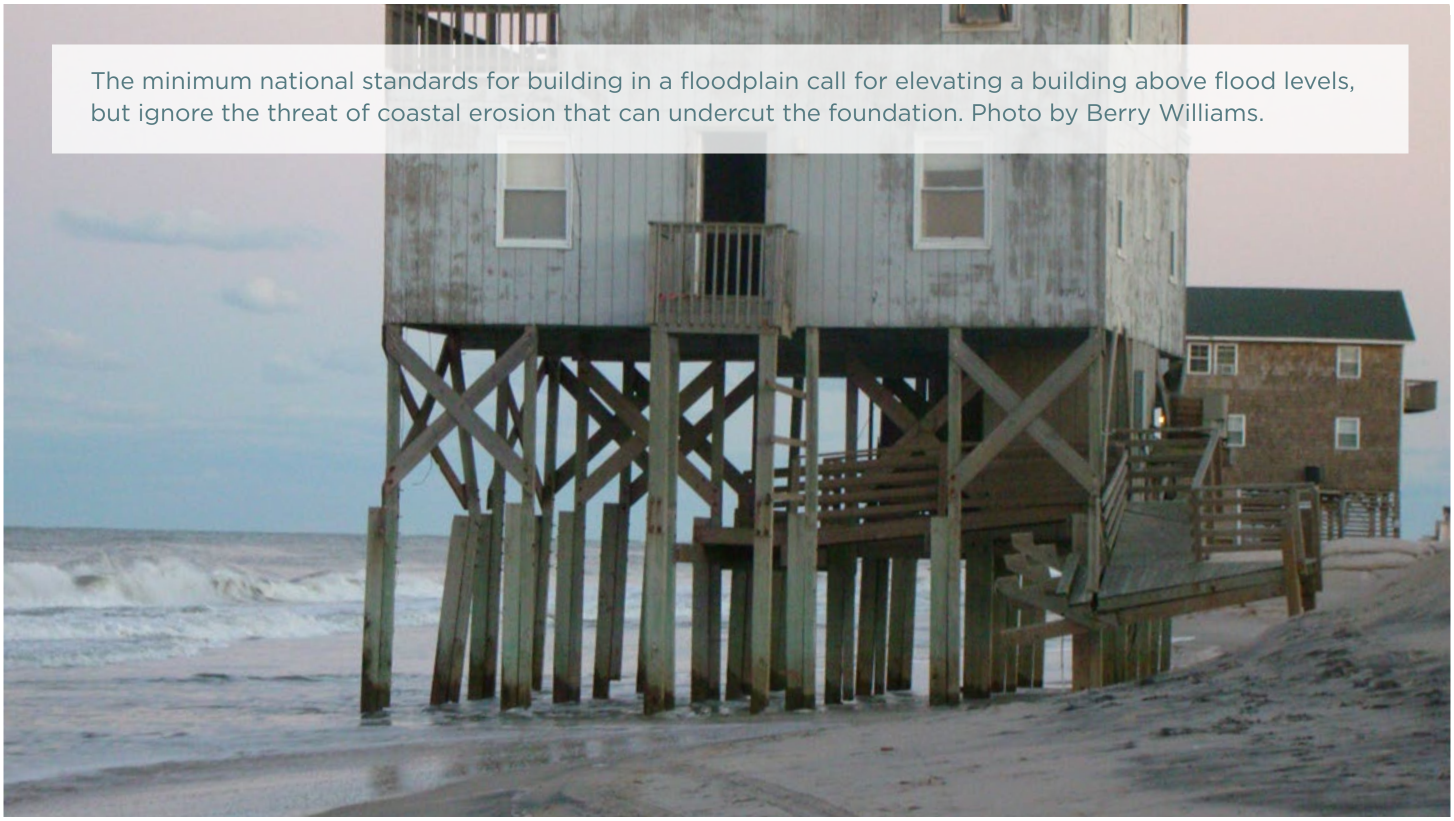


Cleaning up a flooded home can be a long and expensive process. Cedar Rapids, Iowa, June 2008. Photo from FEMA library. www.fema.gov/media-library/assets/images/70466

NATIONAL STANDARDS

The NFIP's *minimum* standards have been accepted by many as the default standards for communities' floodplain management programs. However, they were designed for the purposes of an insurance program and not to control our escalating flood losses. The NFIP sets minimum construction standards for communities' regulations in the mapped SFHA. These minimum standards are inadequate to stop and reverse the long-term trend toward increasing flood damage because:

- They do not address the entire floodplain. In other words, they neglect the potential for larger floods, other unmapped local flood hazards, or the effects of urbanization and a changing climate on future flood levels.
- They focus on how to build in a floodplain rather than how to avoid unsafe locations.
- They allow floodwater conveyance areas to be reduced, essential valley storage to be filled, and/or velocities to be increased – all of which can adversely affect others.
- The standards are flood-oriented and some construction techniques may increase exposure to damage from other hazards, such as wind and earthquakes.



The minimum national standards for building in a floodplain call for elevating a building above flood levels, but ignore the threat of coastal erosion that can undercut the foundation. Photo by Berry Williams.

- They assume the ground is stable, and that if a building is high enough, it will be protected from damage. This is not the case in areas subject to erosion or mudslides.
- There are no accepted national flood loss reduction standards for levees.
- While standards for dam safety are good as they relate to the protection level of the dam from failure or overtopping, there is a continued problem of increasing development downstream, necessitating a dam to be retrofitted to a higher protection standard.
- There are no commonly-applied flood loss reduction standards for infrastructure and critical facilities, such as wastewater treatment plants and emergency operations centers.
- Sedimentation, erosion, channel migration, ice jams in rivers, and coastal erosion, often cause flood hazards that are not adequately reflected in the NFIP's Flood Insurance Rate Maps.
- In areas subject to subsidence, floodplain maps lose their accuracy when the ground settles over the years.
- NFIP regulatory standards may not work adjacent to lakes where water levels may remain high for months or years.

For these reasons, relying on minimum national standards will not reduce flood losses or even stop the increases in flood losses.

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The NAI Approach to Floodplain Management, cont.

FLOOD LOSSES IN THE NATION

Local flood losses add up to very large numbers at the national level, and those numbers are getting bigger. Since the early 1900s, the nation's flood losses have increased five-fold. Since 2000, that figure has averaged $10 billion annually. Hurricanes Katrina and Sandy occurred within seven years of each other. They were the two largest flood-related disasters in U.S. history and together caused more than $200 billion in direct losses (see the graph on page 12).

This continued pattern of destruction has persisted despite the investment of billions of dollars in structural flood control projects during the last 100 years, as well as the development of many other flood protection measures. Yet, even in the face of increasing flood losses, development continues in high risk locations. For example, it is predicted that the U.S. population near the water will increase by 50 million more people by 2050 – putting more people and property in harm's way. The federal government's programs are not curbing the increases in flood losses as floodprone areas keep developing at what many believe to be an alarming rate. Consider the following:

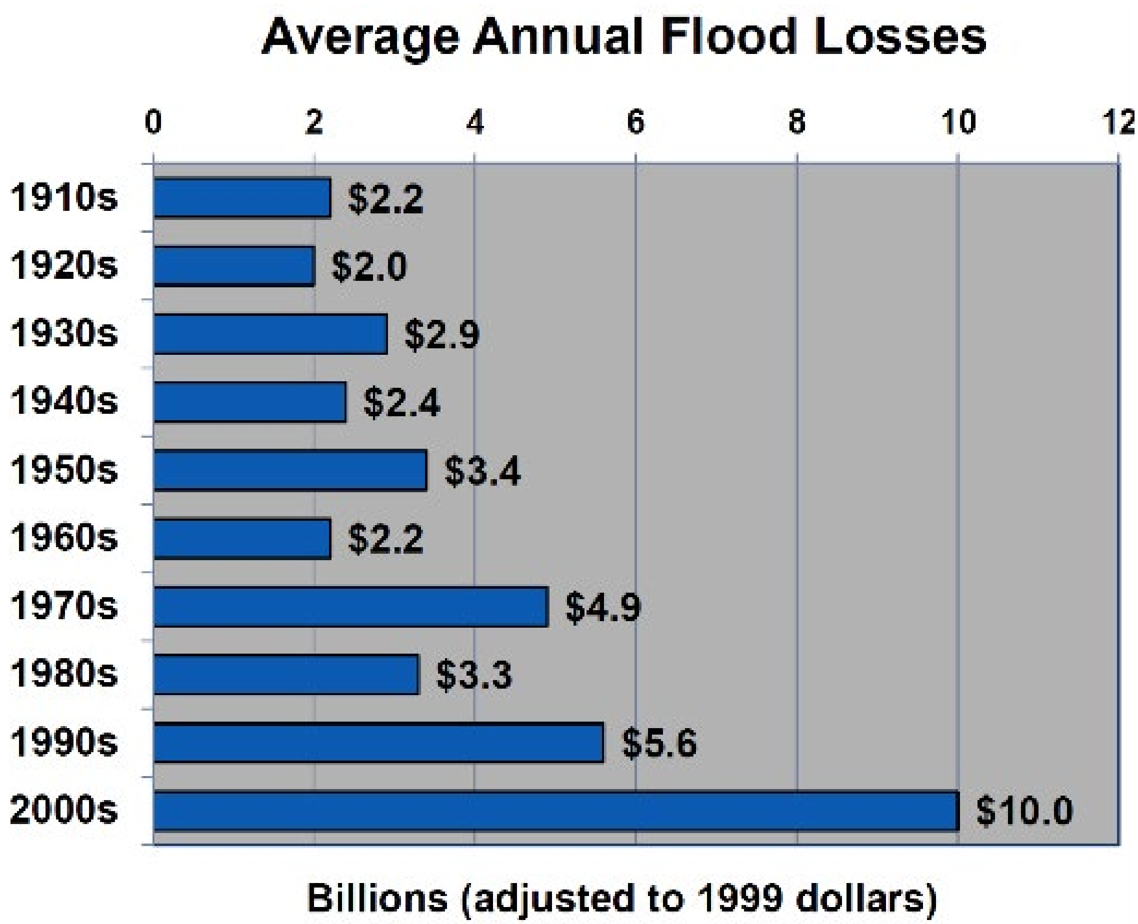
Comic created by Rob Pudim, and appeared in Natural Hazards Observer, May 2014.

- Funding for flood protection programs, especially structural flood control projects, has declined over recent years.

- Tax incentives and funding for disaster assistance have encouraged, and often subsidized, floodplain occupancy and development and reduced local and individual accountability for flood losses.

- The NFIP's national standards for managing floodplain development have not changed in more than 20 years and are assumed by many communities to be adequate for their floodplain management program, without regard to implementing other or higher standards that would address the hazard(s) they face.

The NAI Approach to Floodplain Management, cont.



Jeff Stone with ASFPM's Science Services Dept. created the graph above. Source: Flood Loss Data, National Weather Service, Hydrologic Information Center (www.nws.noaa.gov/hic/).

Further Information: Flood Damage in the United States 1926-2003 A Reanalysis of National Weather Service Estimates (www.flooddamagedata.org/).

The No Adverse Impact Approach

NAI floodplain management is a principle that is easy to communicate and, from legal and policy perspectives, tough to challenge. In essence, ***No Adverse Impact floodplain management takes place when the actions of one property owner are not allowed to adversely affect the rights of other property owners.*** The adverse effects or impacts of unwise community development decisions can be measured by increased flood peaks, increased flood stages, increased flood volumes, higher flood velocities, increased erosion and sedimentation, deterioration of natural floodplain functions, or other impacts to a community's well-being.

NAI philosophy can shape a community's floodplain management approach if the community:

- Identifies acceptable levels of impact;
- Specifies appropriate measures to mitigate adverse impacts; and
- Establishes a plan for implementation of multiple tools to reduce or eliminate those impacts.

> "…insisting that landowners internalize the negative externalities of their conduct is a hallmark of responsible land-use policy…" – Justice Samuel A. Alito Jr., in the majority opinion for the Supreme Court's ruling in Koontz v. St. Johns River Water Management, 133 S. Ct. 2586 (2013). The Koontz case is very important to floodplain management. For more information on it, see www.americanbar.org/content/dam/aba/administrative/state_local_government/land_use.authcheckdam.pdf

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The No Adverse Impact Approach, cont.

THE COMMUNITY'S ROLE

NAI principles give communities a way to promote *responsible* development measures through community-based decision making. Under NAI floodplain management, communities identify potential impacts of new development proposals, and implement actions to mitigate those adverse impacts before they occur.

A community's approach could be specific to flood damage or encompass related objectives, such as water quality protection, groundwater recharge, and protection of wetlands and riparian zones. NAI criteria can be extended to entire watersheds to support regional stormwater management methods to mitigate the adverse impacts caused by increased runoff from urban areas. At the community level, the NAI floodplain management approach and implementation plan should be comprehensive and address all the NAI building blocks:

- Hazard identification and floodplain mapping
- Education and outreach
- Planning
- Development standards and regulations
- Mitigation
- Infrastructure
- Emergency services

NAI ADVANTAGES:

Local empowerment: The NAI approach removes the impression that floodplain management is something imposed by federal or state government. Communities become accountable and accept responsibility for what happens. It also encourages development of a better informed public and a constituency for wise development.

More effective programs and projects: Floodplain management programs and flood mitigation projects are better tailored to local needs and conditions with the NAI approach. Communities are able to better utilize federal and state programs to support their own local initiatives.

Lower long-term costs: Over time, the NAI approach will reduce local government expenditures. For example: a mitigation project that relocates buildings out of a floodprone area not only can result in a community open space amenity, but in less maintenance of roads and public utilities, less risk to first responders who must conduct search and rescue operations when it floods, and lower disaster recovery costs.

Improved partnerships: Informed local officials can make the right decisions about protecting their community. Economic development organizations, transportation and public works departments, and local utilities do better when they work with planners and floodplain managers to implement an NAI based approach. This is especially true when everyone realizes that they have a role and a responsibility to address their own flood problems. Once people agree that flooding is a local problem and their department is affected, they are more willing to work together and share the workload.

continued on page 15

The No Adverse Impact Approach, cont.

Source: Natural Hazards Informer, July 1999, Natural Hazards Center, University of Colorado.

Reduced liability: NAI doesn't take away property rights – it protects them by preventing one person from harming another's property. One of the most important options a government typically has for reducing liability for flood losses is the prevention of increasing flood levels and erosion hazards due to government actions (or inaction). To do this, governments can adopt NAI standards for private development (through its regulations) and public infrastructure (through its design standards).

Meet community needs. NAI floodplain management is about communities being proactive toward understanding potential impacts and implementing preventive measures and mitigation activities. The NAI concept offers communities a framework to design programs and standards that meet their true needs, not just the minimum requirements of a federal or state governmental agency.

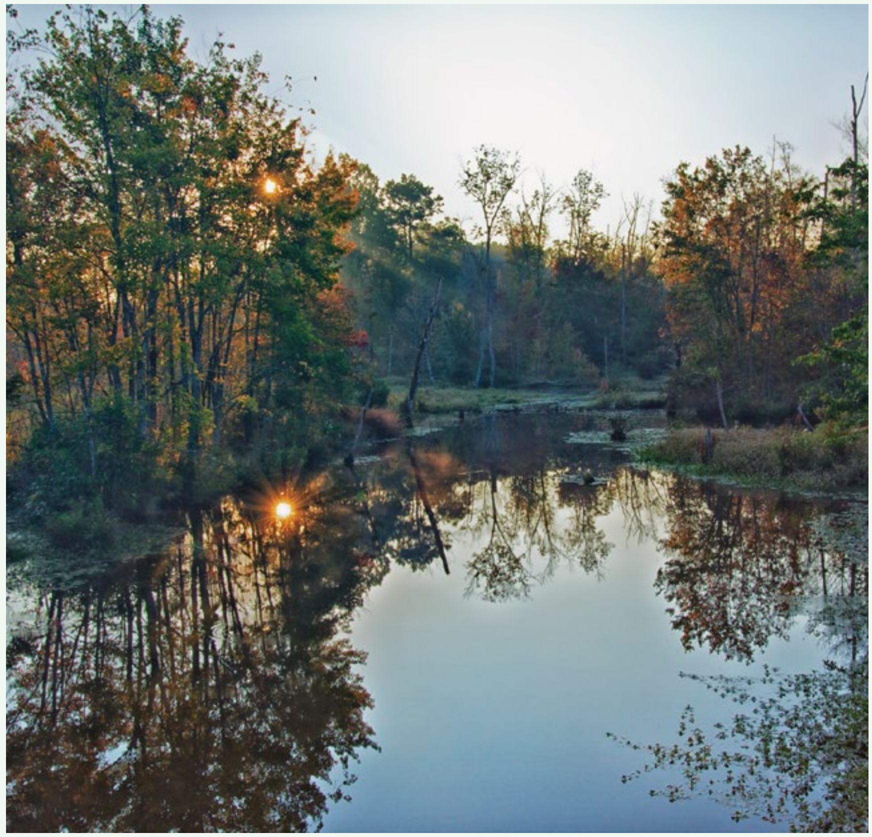
Greener floodplain: Flooding is a natural phenomenon and one goal of NAI floodplain management is to preserve and protect natural floodplain functions in addition to protecting buildings and infrastructure. An NAI emphasis will result in protection of natural buffers and environmentally sensitive areas, improvement in the biological, ecological and geomorphologic functions of riverine and coastal areas, improved water quality, more open spaces,

The No Adverse Impact Approach, cont.

protected fish and wildlife habitat, and similar benefits that come with maintaining an environmentally sustainable ecosystem.

CRS credits: By continually seeking to meet local needs, a community will implement programs and projects that are above and beyond the minimum requirements of the NFIP. Such activities are encouraged by the NFIP because they do a more effective job of preventing and reducing flood losses. This encouragement is accomplished through the CRS, which provides reduced flood insurance premiums in communities that implement NAI floodplain management activities.

On the whole, the NAI approach has many benefits at the local and national levels. With these benefits in mind, the remainder of this *Guide* explores how to take advantage of the NAI approach in a community's planning programs.



A wetland in Franklin County, NC. Photo by Jim Liestman via Flickr

SECTION TWO

Infrastructure & Floodplain Management

Photo courtesy of the Michigan State Police Emergency Management and Homeland Security Division

What is Infrastructure?

At its most basic level, infrastructure refers to constructed facilities that shelter and support human activities. These facilities are often organized into systems, including those for transportation, energy, water, waste and communications. There can also be social infrastructures such as those that support employment, commerce, education, recreation and housing. These systems can be fashioned to reduce environmental and economic costs of access to services and vulnerabilities to natural, accidental and willful damage.

Public infrastructure includes, but is not limited to, bridges, highways, causeways, sewer and water systems and shore protection projects. The ASFPM NAI Toolkit's definition of infrastructure also includes subdivision elements such as roads, sidewalks, utility lines, storm sewers and drainage ways. Also, infrastructure is itself an economic development activity. The planning, design, construction, operation and maintenance of infrastructure normally is about 1/8 of the nation's Gross Domestic Product.

What is Infrastructure?, cont.

WHAT IS NATURAL OR GREEN INFRASTRUCTURE?

Green infrastructure (also called natural or sustainable infrastructure) is the interconnected systems of natural areas and open spaces that are protected and managed for the ecological benefits they provide to people and environment. Although green space is often viewed as self-sustaining, green infrastructure implies something that must be actively maintained, and at times, restored. There is a growing recognition that natural systems can provide many of the infrastructure needs of communities, such as storing fresh water, absorbing stormwater, controlling flooding, etc.

Hurricane Sandy aftermath (Photo credit: John Miller, PE, CFM, CSM, Associate Water Resources Engineer; Princeton Hydro, LLC)

With green infrastructure, green space is considered a form of infrastructure in the same fashion as roads, water lines and sewers. It includes large metropolitan parks, neighborhood parks, riparian buffers, linear parks and greenways, trees and forests, farms, residential landscapes and urban gardens. It's a proactive, systematic, multifunctional model that views open space on a large scale and better integrates open/green space planning with other efforts to manage growth and development. It essentially uses stormwater storage areas, water conveyance areas and other natural flooded areas as part of the community infrastructure for stormwater management and flood damage reduction, as well as for parks, trails and other recreation areas.

Green infrastructure includes management approaches and technologies that utilize, enhance and/or mimic the natural hydrologic cycle processes of infiltration, evapotranspiration and reuse.

THE NEXUS BETWEEN NAI AND INFRASTRUCTURE

Several organizations have identified how deteriorated our nation's infrastructure has become. Transportation congestion is rising; the number of bridges, dams and levees at risk of collapse or functionally deficient is increasing; and our nation's electric power grid are not keeping pace with demand and are increasingly susceptible to natural hazards. Infrastructure, if planned and built or retrofitted based on the NAI approach, is not only more resilient, it will be much more sustainable for communities. Consideration of the many environmental benefits provided by nature needs to be kept in mind by developing and maintaining natural, green and resilient infrastructure systems. ASFPM has found many green infrastructure techniques are compatible with the NAI approach.

SECTION

THREE

Infrastructure Tools

Photo courtesy of the Michigan State Police Emergency Management and Homeland Security Division

Tool 1: Locating New Infrastructure

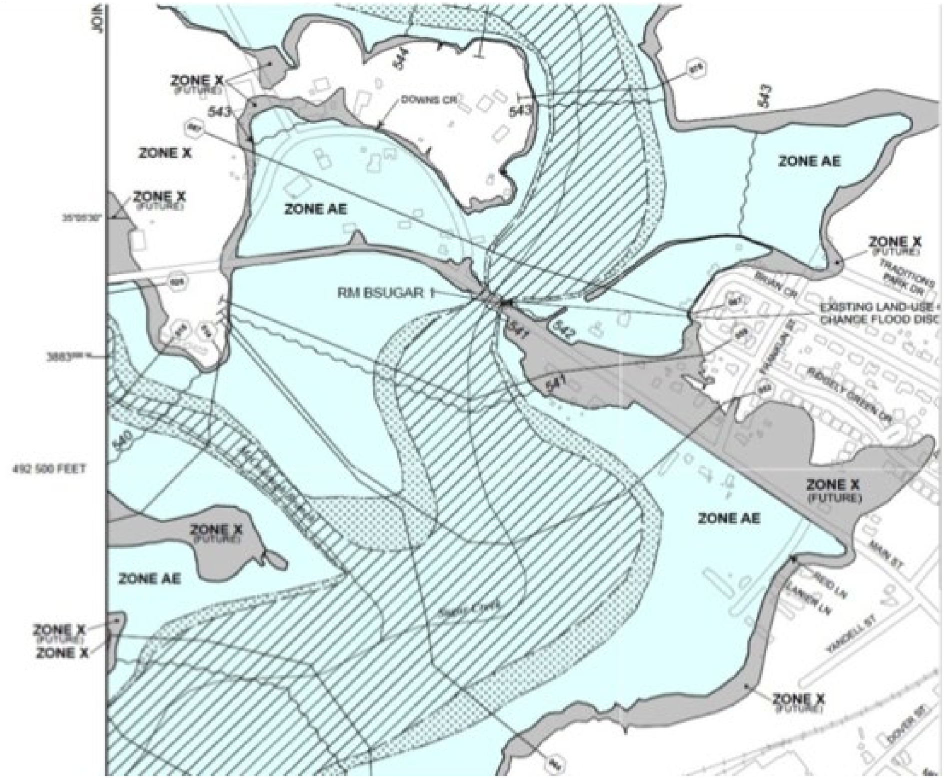
Very little development can occur in the absence of supporting infrastructure. Development generally follows infrastructure. A property's onsite infrastructure includes wells or septic systems, while the offsite infrastructure includes water supply, wastewater removal or the street system (roads, streets bridges, etc.) providing access, as well as electricity, gas, telephone and cable systems. It also includes society support systems like fire stations, police stations, schools, hospitals, water and wastewater systems and community buildings.

There is a connection between managing infrastructure in high-hazard areas and managing development. In most cases, responsibility for offsite infrastructure subject to flood damage lies with the public sector, and the vast majority of this investment is not eligible for flood insurance coverage. Even onsite investments, such as wells and onsite waste disposal systems, are generally not eligible for flood insurance coverage, are extremely susceptible to flood damage and expensive to repair or replace.

One way to better manage and protect infrastructure is to **ensure flood hazard areas are fully identified**. By requiring the developer to undertake a hydrologic and hydraulic analysis of any stream or watercourse on or adjacent to the site to be developed (if it has not already been identified on a Flood Insurance Study (FIS)), 1-percent- and 0.2-percent-annual-chance flood elevations can be determined. Based on this new best available data, the community's floodplain management regulations can be administered and enforced.

Tool 1: Locating New Infrastructure, cont.

Some communities, such as Charlotte-Mecklenburg, NC have incorporated **future conditions mapping** based on projections of fully built-out watersheds that encompass Mecklenburg County (right). This NAI principle takes into account the effects of climate change (more frequent and more intense storm events), and uses future flood elevations (in many cases well above the current Base Flood Elevations (BFEs) on the Flood Insurance Rate Map (FIRM)) and future-conditions hydrology to analyze the impacts any development in the watershed can have on increasing flood levels, velocities or erosion.



Charlotte-Mecklenburg future conditions flood hazard map

This NAI principle incorporates more frequent and more intense storm events based on the effects of climate change. Using this assumption, along with future land use based on community planned development, we can estimate future conditions flood elevations. In many cases, these elevations are well above the current BFEs on the FIRM. With this information, the community can determine in advance the effects of these conditions on future flood levels, velocities or erosion.

Some communities, such as Licking County, OH do not permit new building sites in flood hazard areas, unless there is a sufficient area of natural ground elevation above the BFE on which the development can occur. This includes room for onsite wells and waste disposal systems, as well as underground utilities and their aboveground supporting equipment and components. This is a preferred NAI approach.

Although keeping infrastructure (and therefore development) out of flood hazard zones is best, there will be times and circumstances when public and private infrastructure must, for practical reasons, be located in flood hazard areas. When this situation arises, it is imperative the investment be protected from flood damage. For example, wastewater treatment by nature must be located at the lowest point in the community's terrain, which often places the wastewater treatment lines within SFHAs. In these cases, it is essential that **watertight manhole covers** be used in any condition where the manhole may be affected by street runoff, rising water or floodwater velocities. **Watertight connections** are also imperative. This

continued on page 23

Tool 1: Locating New Infrastructure, cont.

requirement could also be regulated by communities in the 0.2-percent-annual-chance flood area and other areas known to historically flood.

All new infrastructure and facilities should be located outside of the 0.2-percent-annual-chance flood hazard area or the historical highest flood inundation area, unless locating them elsewhere is impossible. The destruction of or damage to infrastructure frequently affects the health and safety of persons well outside the initially inundated area. A prime example is the flooding of wastewater treatment plants, which can be affected by storm surge in coastal areas and by rising waters in riverine situations. Siting the wastewater treatment plant at the downstream end of a community and limiting development below or around the facility should also be considered if a new facility will be built. Although locating a new wastewater treatment plant outside of known flood hazard areas is certainly technically feasible, additional cost may be incurred if gravity flow is not attainable and one or more pump stations must be added. New infrastructure should never be built without first having an updated, detailed flood study of any watercourse in the vicinity of the proposed site.

Another similar strategy is the **removal (or separation) of combined sanitary and stormwater sewer systems** (CSSs). CSSs are generally used in dry weather or during light to moderate rain events. These systems work adequately to convey wastewater and storm sewer flows to the wastewater treatment plant (which must then treat both forms of water at an increased cost to the system). However, in large or prolonged rain events, the capacity of the CSS is commonly exceeded, causing back-up into the community's residences, businesses and streets and overflow discharges into adjoining marshes, wetlands, creeks, streams and other receiving water bodies. These overflows include untreated domestic waste, industrial waste and commercial waste, as well as untreated stormwater, which can contain a range of pollutants. The resultant contamination can cause issues with water quality, which may pose threats to aquatic species and habitat, become a nuisance for recreational uses, compromise aesthetics, and most importantly, produce threats to public health. Complete avoidance of hazard areas is particularly desirable for rapid onset and serious hazards, such as flash floods, earthquakes, mudslides and landslides where the public and first responders may be exposed to potential injury or death.

Tool 2: Retrofitting Critical Existing Infrastructure

The Department of Homeland Security defines critical infrastructure as "the assets, systems and networks, whether physical or virtual, so vital to the United States that their incapacitation or destruction would have a debilitating effect on security, national economic security, public health or safety, or any combination thereof."

Examples of critical infrastructure include electric grids and generation facilities; water and wastewater facilities and any associated structures such as pump stations; roads that provide sole ingress and egress to facilities such as hospitals, nuclear power plants, etc.; ports; dams and levees that provide some level of protection; and telecommunication centers. In the past, some of this critical infrastructure was located in flood-prone areas because it was deemed functionally dependent use and/or the technology did not exist to locate it elsewhere, or was built prior to the NFIP requirements. However, with today's standards, technology and good planning, most critical infrastructure can be located or relocated outside of flood hazard areas.

Critical facilities comprise all public and private facilities deemed by a community to be essential for the delivery of vital services, protection of special populations, and the provision of other services of importance for that community. Although there is some overlap between critical facilities and critical infrastructure, critical facilities also include those where individuals would otherwise have a difficult time escaping or leaving at the time of a flood (i.e., nursing homes, hospitals, schools). Critical facilities are addressed in the NAI How-to Guide for Mitigation.

Beyond the obvious impacts of critical infrastructure failure during flood events, another reason to protect critical infrastructure is that repair and replacement could be very costly. Although federal programs may provide some assistance (such as FEMA's Public Assistance program), that only occurs in response to federally-declared disasters. Many more flood events are not federally declared. Not only is the cost to repair a factor, but so is the cost to the economy as a whole if that infrastructure is disabled for any length of time.

The NAI minimum protection standard for new and relocated critical infrastructure should be to build outside of, or protect to, the 0.2-percent-annual-chance flood or flood of record, whichever is greater. For some critical infrastructure, any chance of flooding may be too great, and therefore a protection level exceeding the 0.2-percent-annual-chance flood is necessary. Also, in coastal areas the NAI protection standard for critical infrastructure is the 0.2-percent-annual-chance flood level plus a freeboard equal to the long-term sea level rise projection for the area. Recent data in the National Climate Assessment provide scenarios for sea level rise.

> The flood control system for the Miami Conservancy District (OH) was designed in the 1920s to provide protection against the Great 1913 Flood plus an additional 40% surcharge as a safety factor. This roughly translates today to between 500-year and 1,000-year protection.

STEPS TO ACHIEVING NAI:

1. **Officially adopt the NAI standard for critical infrastructure in appropriate regulations and plans.** Local regulations may include floodplain management, zoning or subdivision standards. Plans may include hazard mitigation, comprehensive or "master" plans and capital improvement plans. At the state level, there are often standards in addition to or instead of local regulations for certain types of critical infrastructure. Those standards should be upgraded. Officially adopting the standards will make it more likely that future critical infrastructure will be protected and gives a clear directive to engineers and designers who will be retrofitting existing critical infrastructure.

2. **Identify all critical infrastructure in the jurisdiction.** In the past decade, emergency managers have developed good base information on many types of critical infrastructure. Critical infrastructure inventories may also be found in local or state hazard mitigation plans.

3. **Identify all flood-prone areas in the jurisdiction.** Begin with any FEMA floodplain map, but don't stop there. Even if existing FEMA floodplain maps show

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the 0.2-percent-annual-chance flood hazard area, make sure the flood data are current. If the critical infrastructure is in an approximate flood zone or none is identified, conduct a preliminary investigation to determine whether the site may be flood prone. Use all available data sources, including U.S. Department of Agriculture soils maps, maps from other agencies, interviews from adjacent landowners, etc. If flooding is even suspected, the site should have a detailed flood study built into any project to fund improvements or retrofits. It makes no sense to invest hundreds of thousands of dollars or even millions in infrastructure when you don't have a detailed assessment of flood risk.

4. **Review existing capital improvement plans and projects slated for funding to ensure an adequate level of protection for critical infrastructure. Try to get it incorporated if not adequately protected.** This may be tricky because critical infrastructure funded by the jurisdiction may already be funded through multiple sources. However, one relatively minor flood can cause hundreds of thousands of dollars of damage to a new wastewater treatment plant.

5. **Analyze critical infrastructure to be retrofitted to determine whether to retrofit in place or relocate.** To perform this step, having detailed flood data, as previously described in Step 3, is essential. The analyses in this step should include a robust alternatives analysis, including relocation of the critical infrastructure outside of the floodplain. Relocation is often preferable because even if protected to a 0.2-percent-annual-chance flood event, a larger flood could occur that could damage the infrastructure. Also, when a piece of infrastructure is near the end of its lifespan, the cost difference between relocating and retrofitting in place may be small, especially when accounting for all costs (including costs to the community for maintaining protection).

If the critical infrastructure cannot be moved, evaluate component protection. For example, even if a community determines a wastewater treatment facility cannot be relocated, components such as digesters and ultraviolet disinfection units can be protected. Similarly, for a road that is the sole access to a critical facility, and therefore a piece of critical infrastructure that normally floods during a 1-percent-annual-chance event, elevating the road may not be enough. Drainage systems through the road (culverts, bridges, etc.) must also be able

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In the wake of Hurricane Sandy, where many homeowners and businesses were left without power for as long as 13 days, many communities are looking at relocating electrical substations to the 0.2-percent-annual-chance flood hazard area, or better yet, out of the flood hazard areas altogether. For those that cannot be moved, a plan to protect those substations from flooding may be developed.

Tool 2: Retrofitting Critical Existing Infrastructure, cont.

to withstand extreme flood events and ensure the road will not be compromised. Often overlooked are utility connections or switchboxes. Although the infrastructure may be resilient, components such as switches are often not elevated or flood protected appropriately.

One type of critical infrastructure where component protection should be incorporated is a levee. However, this protection is to ensure the resiliency and integrity of the levee itself in case of overtopping. Unlike high-hazard dams, where there is a planned overflow outlet in case an extreme flood event occurs, most levees in the U.S. do not have such resiliency measures built into them. A high-hazard levee protecting a critical facility or one that protects many households and businesses should have resiliency built into it. A study of the New Orleans levees after Hurricane Katrina identified this as a major deficiency, and the new levees are constructed in such a way to increase their resiliency. Some ways to do this are hardening the landward side of the levee in case of overflow, or installing intentional spillways to ensure the levee is not overtopped.

One other analysis that is useful is that of cascading or compounding effects. For example, what if during a flood a piece of critical infrastructure is at risk from catching fire? Does the community have the capability to combat such a blaze (yes, fires do happen during floods, and most fire departments are not equipped to handle them).

6. **Prioritize critical infrastructure retrofits**. There will likely not be enough funds to do everything at once. Retrofits should be prioritized based on potential impacts if failure occurs. A community's hazard mitigation plan should list these facilities as well as the contact for the local/regional power company for his/her review and prioritization in terms of various hazards.

7. **Develop and exercise emergency operations plans in case of flooding.** This is especially true for infrastructure that must be retrofitted in place. If a larger event occurs, appropriate processes and procedures must be in place. Or if the retrofitted infrastructure requires human intervention, then personnel must be trained in appropriate procedures for locating, moving and placing defenses in place, and all components must be maintained in good working condition. An operational plan should be part of the flood hazard operation plan for that facility.

Climate change and sustainability will need to be incorporated for infrastructure planning to ensure the quality of life expected by the residents of the community is maintained and the community's infrastructure is resilient in the long term. Discussions should include whether current flood protection is adequate, what impacts flood-induced economic and social disruptions are having in the community, and how risk-based approaches (including how the community spends its resources) can reduce loss of life and loss of property and lessen the human misery caused by flood events.

Tool 3: Effective Management of Local Road Systems

A local road system consists of all of the local transportation infrastructure—largely a network of components including roadways (paved and unpaved), road shoulders, drainage ditches, under-drains, storm drains, stormwater management facilities, shoulders, rights of ways, guard rails and signage. They are owned by local transportation agencies, and many of the nation's local road systems are rural.

Roadways often cross waterways and that intersection can spell trouble. In a 2005 report by the American Lifelines Alliance, among the given case study counties, the average number of waterway crossings ranged from 0.16 to 0.90 crossings per mile. Flood damage to these systems can be broken down into two general types:

1) River and stream flooding occurs when rainfall generates runoff so the volume of water conveyed in the channels exceeds the capacity of those channels and flows into flood hazard areas.

2) Heavy runoff occurs when intense rainfall generates concentrated runoff that either exceeds the capacity of drainage ditches and under-drains or flows into ditches without drains.

Tool 3: Effective Management of Local Road Systems, cont.

The nature of damage to roads and drainage elements can include any or all of the following:

- Saturation and collapse of inundated road beds;
- Loss of paved surfaces through flotation or delamination;
- Washout of unpaved roadbeds;
- Erosion and scour of drainage ditches, sometimes to the extent of undermining shoulders and roadbeds;
- Damage to or loss of under-drain and cross-drainage pipes;
- Blockage of drainage ditches and culverts by debris, exacerbating erosion and scour;
- Undermining of shoulders where ditch capacity is exceeded;
- Washout of approaches to waterway crossings; and
- Deposition of sediments on roadbed.

In addition to physical damage to the road system itself, there are other offsite adverse impacts. Vehicle-related drowning is the leading cause of flood-related deaths. According to National Oceanic and Atmospheric Administration National Weather Service data, over the past 10 years (2003 to 2012) 57 percent of flood-related deaths were vehicle related. Another adverse impact is the propensity of road systems to cause offsite property damage, which can lead to liability and lawsuits. As a practical matter, local governments are most vulnerable to liability suits because they are the units of government most often undertaking activities that result in increased natural hazard losses or approving development that may be flooded or cause damage to other properties (Kusler 2011). Filling and grading activities related to road construction, sizing of waterway passages such as undersized culverts, and other development-related activities can change how water behaves on neighboring properties. And while structures like levees and dikes are usually studied for flood-related impacts, roadway improvement projects usually are not. Finally, increased stormwater flows due to the inability of rainwater to infiltrate and increased pollution (the infamous pulse of pollution when the first stormwater reaches waterways) adversely affect adjacent properties and ecosystems.

Managing local road systems to achieve NAI is a multi-step process. Each of the following steps can be taken independently to move the local roads program toward NAI. However, to truly have an NAI-based local road management system, all steps are essential. Steps for achieving NAI:

1. **Improve Road System Data Management and Inspections.** Knowledge about the adverse impacts and issues with the existing road system is important. There will always be more issues than funds available, and having a system to identify, catalog and prioritize existing problems is extremely useful. A local data management system should not only store specific information about the inventory of the road infrastructure, but also have procedures and data fields in place to collect information of the road system's performance after a flood event, especially at waterway crossings. Because every local road department does some form of inspections, collecting this information can be efficient. For example, if a local road department is doing an inventory of culverts, they can record the size—diameter and length—when they check age and condition. These data can later be used to help determine if culvert

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Tool 3: Effective Management of Local Road Systems, cont.

size is the culprit if future flood damage occurs and help inform the department when it selects different mitigation options. By collecting specific performance information during/after a flood, chances increase that desired mitigation measures can be justified to FEMA inspectors after a federal disaster declaration.

2. **Improve Roadway Flood Resistance through Better Standards, Designs and Analysis.** This step involves multiple actions and has two distinctly different approaches: one for existing systems and one for new systems. With new systems, it's easier to get it right the first time.

- **Develop a goal, standard or target for hydraulic performance of structures and road surface elevations.** From an NAI perspective, a 10- or even 25-year design standard is insufficient. Higher standards such as the ability to convey the 1-percent, or even the 0.2-percent-annual-chance event are necessary, especially if the roadway is 1) the primary ingress/egress to a critical facility or 2) the sole ingress/egress to multiple homes or businesses. It is important that such a road not be compromised during a large flood event. Even if this is not easily done with retrofitting existing road systems, such standards should be clearly identified in local subdivision and other applicable regulations.

- **Take a watershed, future conditions and stream morphology approach to flood problems.** Future conditions are too often associated with coastal sea level rise, but inland watersheds are experiencing more intense rainfall and storms that need to be factored into design. After a flood event has washed out a culvert crossing a road, it may be easiest to replace it with what is available without consideration of what is going on in the watershed. The NAI approach is to not only consider the issue at the given location, but also consider upstream development and other changes in the watershed, climate change-related impacts (this is especially important for coastal road systems where sea level rise must be accounted for), and the stream's general dynamics. Understanding the dynamics and morphology of the watercourse is essential in proper design of a structure crossing a watercourse. For example, where there are high velocities or scour potential, headwalls and wingwalls may be necessary. For new road systems, accounting for the full impacts could be significant.

- **Ensure that roads for critical facilities and those that are the sole means of ingress and egress are at an elevation that will not be overtopped during severe events.** For new roads, this can be accomplished most easily by following standards in subdivision regulations, which are usually triggered when any road building occurs. For existing roadways, such areas should be inventoried and prioritized for retrofitting and for flood warning and evacuation, as discussed in Step 4 below. While building roads that have only minor overtopping may be considered a "better" approach, it is not an NAI approach because of the difficulty in determining flood depth over a flooded roadway. There is also the possibility that an overtopped road can be eroded to a point of failure that could lead to injury or loss of life. The standard for roadways serving critical facilities should be

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Tool 3: Effective Management of Local Road Systems, cont.

the 0.2-percent-annual-chance flood or the flood of record, whichever is greater, and the standard for roads serving as the sole means of ingress and egress should be at least the 1-percent-annual-chance level. Both should require warning and evacuation systems.

3. **Include Considerations for Stormwater Management for Quantity and Quality Management.** For example, enhanced ditches for rural roadways and subdivisions can be designed to convey stormwater, resist erosion and promote infiltration (Licking County 2016). Grassed swales with check dams do well in promoting stormwater infiltration. For existing road systems, retrofitting to enhance stormwater runoff can be done in several ways, including stormwater curb extensions, permeable paving, stormwater planters, rain gardens and vegetated swales. The EPA in 2009 produced Green Streets: A Conceptual Guide to Effective Green Streets Design Solutions, which provides descriptions and plan views of these actions.

4. **Include Provisions for Operational Mitigation.** Operational mitigation includes understanding potential adverse impacts to the existing road system or resulting from flooded roads and having plans/procedures to reduce or eliminate those adverse impacts in the event of a flood. The loss of roadway access has a cascading effect in a community, which can be at least partially addressed by having good operational plans and procedures. Such plans and procedures may include any or all of the following:

- Appropriate road closing signage and barriers;
- Effective outreach messaging when a flood event is imminent and roads may be closed;
- Individual plans for each critical facility related to transportation needs such as evacuation, resupply, and backup or secondary locations (i.e., identifying the location of the temporary fire station if the primary one is flooded or access is cut off);
- Identification of individuals, their special needs, and plans for addressing them in isolated areas where a floodprone roadway is the sole means of ingress and egress or where power, heat, or potable water may be lost due to the event; or
- Specific community evacuation plans, triggering mechanisms, and police/public safety needs for area-wide or community-wide evacuations.

When attempting these activities, it helps to have a robust road data collection system in place. After a 1997 flood event on the Ohio River, a community was unprepared for the flood's impact and had to call for a hasty evacuation in the Special Flood Hazard Area (SFHA), with no evacuation routes or plan for police escort of affected residents. Residents found it almost impossible to evacuate, as onlookers and spectators were crowding accessible roadways, making the evacuation more difficult. In another community impacted by the same event, residents who had mobile homes tried to quickly move the mobile homes out of harm's way. Some of them got stuck on the road and obstructed others trying to evacuate.

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Tool 3: Effective Management of Local Road Systems, cont.

5. **Increase Staff Training Related to Flood-resilient Best Practices.** The prominence of local knowledge and experience as an influence in design and road repair is significant. Also, local knowledge and experience with flood risk-reduction measures implemented and subsequently tested during an actual flood are also an important influence on subsequent decision making. Hence, there is a tremendous need for staff training related to best practices, not only locally or regionally, but to include learning techniques and actions that have been applied elsewhere in the nation. According to American Lifelines Alliance's "Flood-Resistant Local Road Systems: A Report Based on Case Studies" in 2005, specific important areas of knowledge and training include:

- Methods for determining the flood and runoff conditions that provide the desired level of flood resistance, allowing for differences based on local conditions and constraints. Unless already established in regulation, it is reasonable for Departments of Public Works to set a target for performance to guide decisions.
- Methods for estimating the flood conditions and evaluating hydraulic impacts (including erosion), especially in areas where there is insufficient existing information to define flood hazard areas and discharges.
- Capturing high water marks and other characteristics of actual flooding yields valuable information that can be used to improve post-flood recovery and mitigation decisions, even in the absence of flood hazard models or computations.
- Identification of direct and indirect costs, and direct and indirect benefits, associated with improving flood resistance. The intent is to provide a sound, albeit qualitative, basis on which to make mitigation decisions based on understanding the full range of future benefits (avoided damage). Since the initial direct costs of mitigation appear to be a limiting factor in many instances, decision makers should be more aware of benefits that may justify more investment.
- How taking watershed-based or stream morphology-based approaches can yield multiple benefits.
- Sources of technical assistance and funding.
- Examples of mitigation projects for local road system components that have qualified for funding under FEMA's Hazard Mitigation Grant Program (HMGP).
- Budget practices that support improving flood resistance, such as creating a dedicated fund and accruing year-end balances in a special fund.
- How organizations have successfully and efficiently incorporated flood-resistant measures in their road system-related recovery decisions.

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Tool 4: Bio-engineered Embankments

Community infrastructure is subject to nature's extremes and can be very costly to maintain, especially where watercourses have eroding embankments. The embankment above the toe zone of the channel is exposed to varied wet and dry cycles due to variations of stream flow frequencies above base flow. This can lead to slope failures, collapse of the bank, and settlement caused by insufficient compaction, lack of drainage and scouring.

Traditional methods of erosion protection usually include hard armoring of slopes, which include:

- **Riprap:** Involves placing erosion-resistant ground cover of large, loose, angular stone to protect slopes against erosion due to concentrated runoff. While it is simple to install, riprap is not as effective as vegetative practices in providing permanent protection. It is more expensive than bio-engineering methods without providing the same level of habitat functions and diversity. If not properly placed, the riprap can move downstream, actually increasing bank scour and erosion.
- **Gabions:** Are wire baskets filled with rocks holding them in place. While this method may protect the banks against erosion, it does not restore natural beauty and habitat functions of the stream. If not properly designed and sized for highly erosive flows, it may fail, causing an adverse impact to downstream areas.

Tool 4: Bio-engineered Embankments, cont.

- **Retaining walls:** Are used to replace stream banks with concrete bulkheads to hold the stream in place. This method does not restore natural stability nor allow the stream to naturally adjust to watershed changes. As a result, it may cause adverse impacts in downstream areas by increasing velocity and shear stress in the channel. Furthermore, retaining walls are extremely costly and prone to failure if overtopped or breached.

Road embankment failure due to flood on the Missouri River. Photo credit: Chad Berginnis, March 2012, Pierre, SD

Slope instability has adverse impacts on upstream and downstream areas, causing unnaturally high velocities, bank erosion, unnatural sediment deposition and flooding. The instability may be caused by "controlled" activities related to clearing of natural vegetation, an increase in impervious surface area due to development, and agricultural activities. By using bio-engineering methods to protect and stabilize bank slopes, adverse impacts are minimized or prevented for upstream and downstream property owners. To achieve the NAI goals, the bio-engineering methods should be implemented to restore the natural conditions of the stream and provide the shear strength required to hold the soil matrix intact. Monitoring is important to make sure the system becomes self-repairing and sustainable. Bio-engineered embankments use living and nonliving plant materials in combination with natural and synthetic support materials for slope stabilization, erosion reduction and vegetative establishment.

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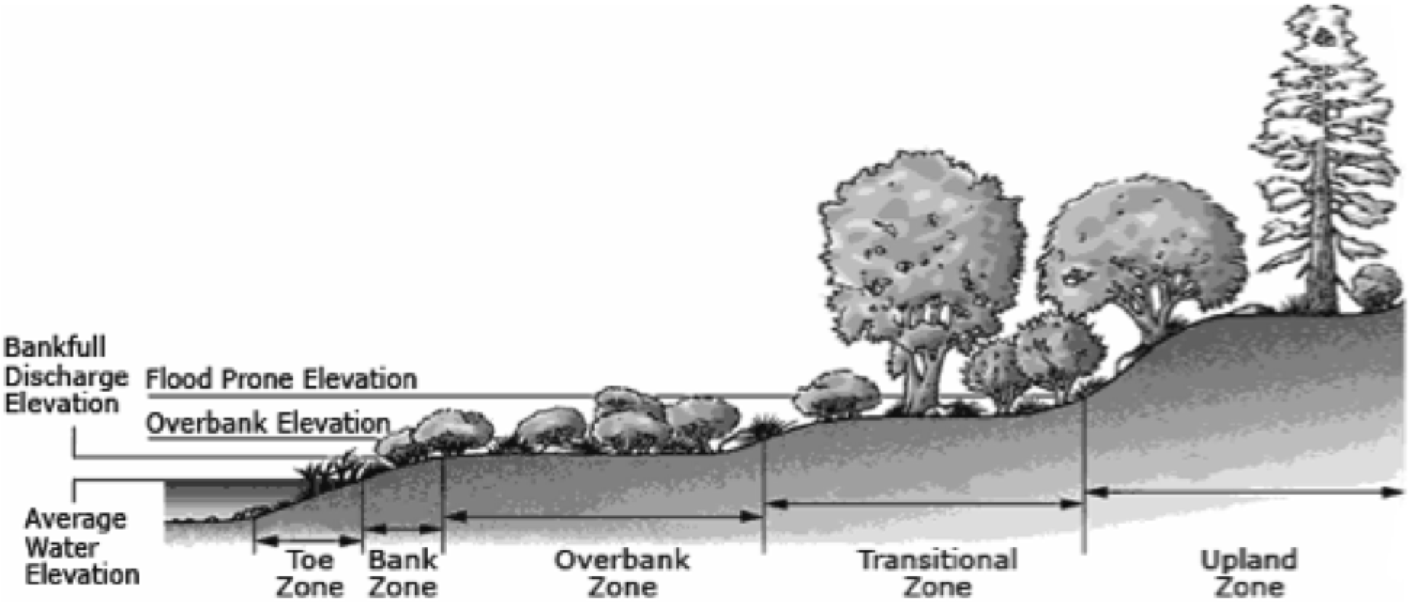
Tool 4: Bio-engineered Embankments, cont.



Bio-engineered embankment. Source: Streambank Soil Bioengineering, Technical Supplement 14I, Part 654 National Engineering Handbook, 2007

Benefits of bio-engineered slope protection: Provides long-term stability and natural resiliency by integrating aboveground biomass in the form of woody and herbaceous plants into the site-specific environment:

- Structural stability is enhanced through plant root reinforcement and energy dissipation due to roughness and evapotranspiration. Plants with dense root systems are more effective for erosion control.
- Ecological benefits are enhanced due to selection of native plants and the eradication of invasive plant species. Bio-engineering also improves habitat diversity and plant-induced slowing of water runoff, thus reducing erosion and flooding.
- Environmental quality is improved through the processes of evapotranspiration and infiltration.
- Improves the aesthetic, recreational and natural capital value.
- It is more economical than traditional methods, which require more construction, transportation of material, labor, etc.
- Bio-engineering is self-repairing due to the natural resilience of the biomass, but does require maintenance. How much maintenance will be needed depends on the environment in which it is installed.

Developing a planting plan: This is the most important step in creating bio-engineered embankments. The planting plan should be submitted by certified plant specialists, landscape architects, botanists, biologists and other ecologists.

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Tool 4: Bio-engineered Embankments, cont.

Types of planting methods:

- Permanent or temporary seeding and mulching.
- Live staking: Branches or small limbs cut from trees and bigger branches (e.g., silky dogwood and willows) are inserted into the soil. The growing plant root helps stabilize the embankment slope. The method of planting varies according to site-specific conditions. Live staking is relatively more labor-intensive but less expensive than containerized plants.
- Containerized plants: A hole is dug and the plants are placed in the ground along with their potting soil.
- Bare-root trees: The plant is placed into the ground with its exposed roots. Although this method of planting is less expensive, the plant survivability is usually less than for the containerized planting method.
- Plant quantity and density: Consult the Sound Native Plants website:
- Plant compatibility and selection: "VegBank" is a database sponsored by the Ecological Society of America's Panel on Vegetation and Classification. It allows ecologists to submit and share data for permanent documentation of plot data for plant communities.

Types of bio-engineered structures:

- **Coir matting:** Consists of biodegradable, erosion-control coconut/straw-fiber blankets rolled over graded surfaces and anchored properly, usually by live stakes, following the application of seed and mulch. The matting maintains slope stability as the vegetation grows and takes control before the matting biodegrades. The application of mulch helps maintain moisture and further protects against erosion.
- **Root wad structure:** Consists of logs, boulders and related geo-textile blankets, usually placed on the outer edge of stream meanders and pools to protect against the erosive flows around stream bends by diverting water away from the banks. They also support fish habitat and other aquatic life.
- **Brush and tree revetment:** Involves anchoring large woody debris, usually left over from construction, over slopes and stream banks to enhance soil stability and dissipate flow energy. This method is not recommended for high and erosive flows.
- **Brush mattress:** Very effective method of stabilizing stream banks and slopes by planting mattress-like layers of interwoven branches anchored with live stakes or twine.
- **Wattle fences/fascines:** Involves the use of long cuttings (e.g., willow) and vertical live stakes or rebar to form a fence. The vegetation and growing root creates sediment traps and improves soil shear strength, respectively.
- **Special Consideration: Special Flood Hazard Areas:** If the bio-engineering method is

Tool 4: Bio-engineered Embankments, cont.

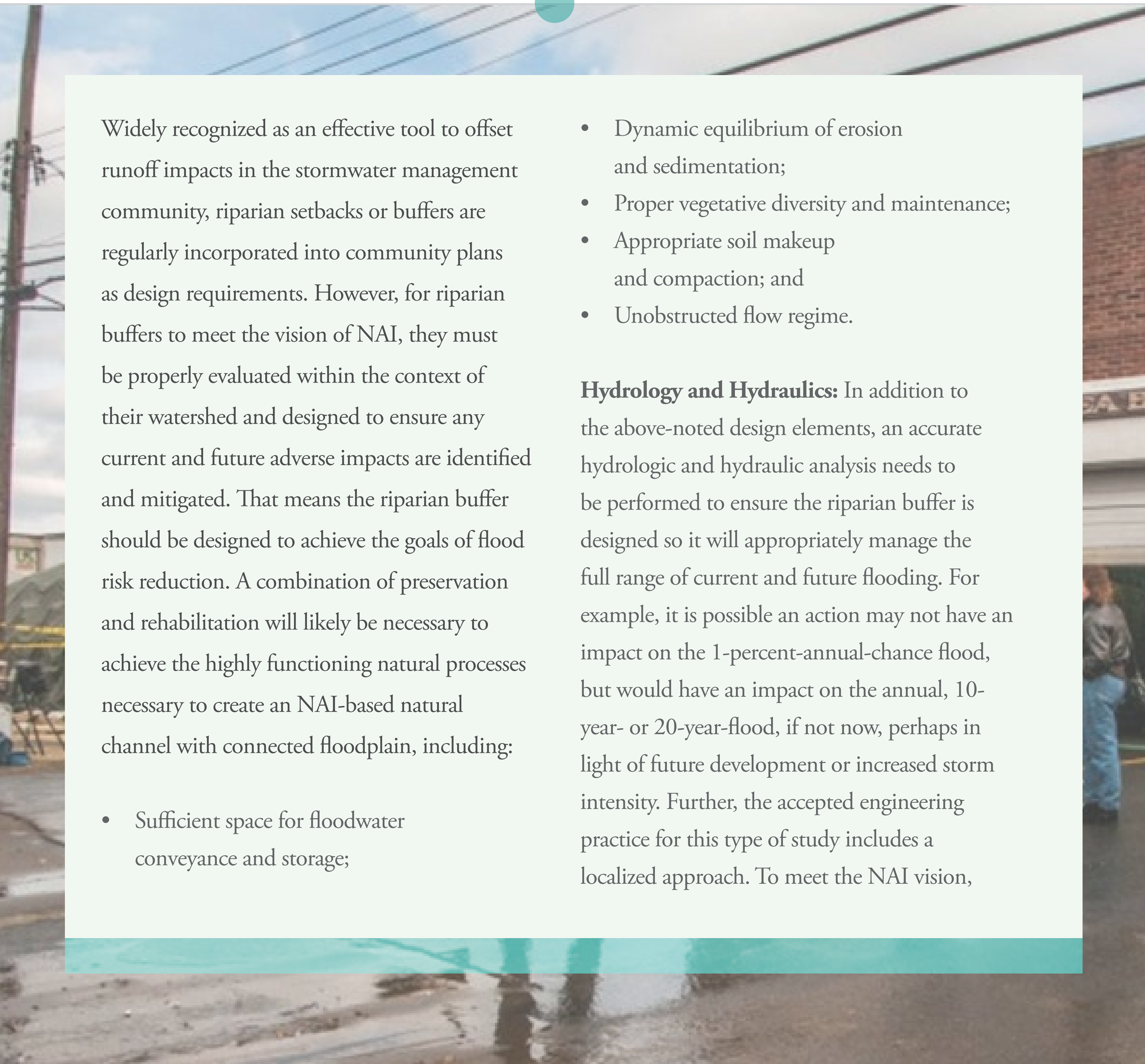
proposed on a stream located in an SFHA, a "no rise analysis" and possibly Letter of Map Revision (LOMR) or Conditional Letter of Map Revision (CLOMR) should be submitted to meet floodplain management requirements. State requirements vary and may be more restrictive than standard federal requirements. The proposed bio-engineering methods may affect the existing flood hazard area in the following ways:

- Roughness changes due to proposed planting methods need to be considered because it may involve the removal and replacement of existing brush and invasive species that exhibit different roughness values.
- In-stream structures such as root wads may cause stage increase. Any such changes must be mitigated or all affected property owners compensated before the changes occur.
- The proposed bio-engineering methods may be combined with other restoration proposals that should be collectively addressed in the hydraulic model to determine overall effects on the water surface elevation.
- Bio-engineering design and construction is a diverse and multi-disciplinary field requiring a high degree of coordination between engineers, botanists, horticulturists, hydrologists, soil scientists and construction contractors. Teamwork is essential.

Considerations:

- The causes of stream bank erosion should be thoroughly investigated and addressed prior to prescribing bio-engineering methods since the instability may be systematic and related to watershed changes, land clearing or straightening of channel.
- Planting should be done during the growing season.
- Protect plants from wildlife and other invasive plant species.
- Monitor plant survivability and water availability.
- Monitor toe protection and channel stability.

Tool 5: Riparian Buffers



Widely recognized as an effective tool to offset runoff impacts in the stormwater management community, riparian setbacks or buffers are regularly incorporated into community plans as design requirements. However, for riparian buffers to meet the vision of NAI, they must be properly evaluated within the context of their watershed and designed to ensure any current and future adverse impacts are identified and mitigated. That means the riparian buffer should be designed to achieve the goals of flood risk reduction. A combination of preservation and rehabilitation will likely be necessary to achieve the highly functioning natural processes necessary to create an NAI-based natural channel with connected floodplain, including:

- Sufficient space for floodwater conveyance and storage;
- Dynamic equilibrium of erosion and sedimentation;
- Proper vegetative diversity and maintenance;
- Appropriate soil makeup and compaction; and
- Unobstructed flow regime.

Hydrology and Hydraulics: In addition to the above-noted design elements, an accurate hydrologic and hydraulic analysis needs to be performed to ensure the riparian buffer is designed so it will appropriately manage the full range of current and future flooding. For example, it is possible an action may not have an impact on the 1-percent-annual-chance flood, but would have an impact on the annual, 10-year- or 20-year-flood, if not now, perhaps in light of future development or increased storm intensity. Further, the accepted engineering practice for this type of study includes a localized approach. To meet the NAI vision, a broader approach is necessary to ensure cumulative increases in flood heights are prevented. This broader study approach would fit within a watershed-based planning initiative that moves the community toward the NAI vision. This tool may need to be used in conjunction with others to achieve the flood risk reduction and additional goals of all the stakeholders.

Floodplain Encroachment: Traditionally, streams and their associated floodplains are altered to accommodate development in ways that reduce their ability to handle floodwaters. Alterations to the streambed may include placing the entire stream inside a culvert or pipe, channelization, dredging or erosion control measures to harden the banks. All of these common practices can increase the stream's ability to carry floodwaters, but can also transfer the risk up or downstream. In addition, the transition area between the channel and its floodplain may be altered in ways that cut off access to floodwater storage areas, as with the construction of levees, and can diminish or completely eliminate the stream's ability to carry or store floodwater. This activity amputates the natural floodplain, forcing the floodwaters that would normally be stored nearby to accumulate and exacerbate flooding downstream. Frequently, much of the floodplain is encroached upon with buildings and other development. Even the parts of a floodplain left as open space may have been altered by compaction or modified vegetation and lost their natural absorption and flood buffering capability. Development practices also often include stripping topsoil and compacting the ground to create a smoother, more useable surface. This is convenient for recreational purposes, and the remaining soil is perfectly serviceable to support sod or other standard landscaping features. However, the compressed soil reduces the ability of water to move through it, which effectively leaves soil in an impervious state. Often, the result is ponding or runoff similar to a paved area. These alterations to the natural stream and associated floodplain increase flood peaks, flood stages and flood velocities, as well as throw the erosion and sedimentation out of equilibrium. In turn, this creates a continuous battle against faltering banks and a sediment regime change that alters the flow and flood hydrology.

The Vegetated Corridor: In an undeveloped setting, most floodplains include a vegetated corridor alongside the watercourse that dynamically interacts with the stream through a set of natural processes. When allowed to function together, these processes can moderate peak flows and velocities while also balancing erosion and sedimentation. The frequency, extent and severity of flood events increase in severity as a direct consequence of elimination of the stream corridor's natural functions. These interactive processes between the watercourse and its natural floodplain can moderate flooding and minimize severe erosion-based meanders. Thus, the naturally beneficial functions of hydraulically connected floodplains have great potential to reduce flood risk. NAI-based riparian buffers can mitigate flood impacts if they include elements in Table 1 on page 40.

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Tool 5: Riparian Buffers, cont.

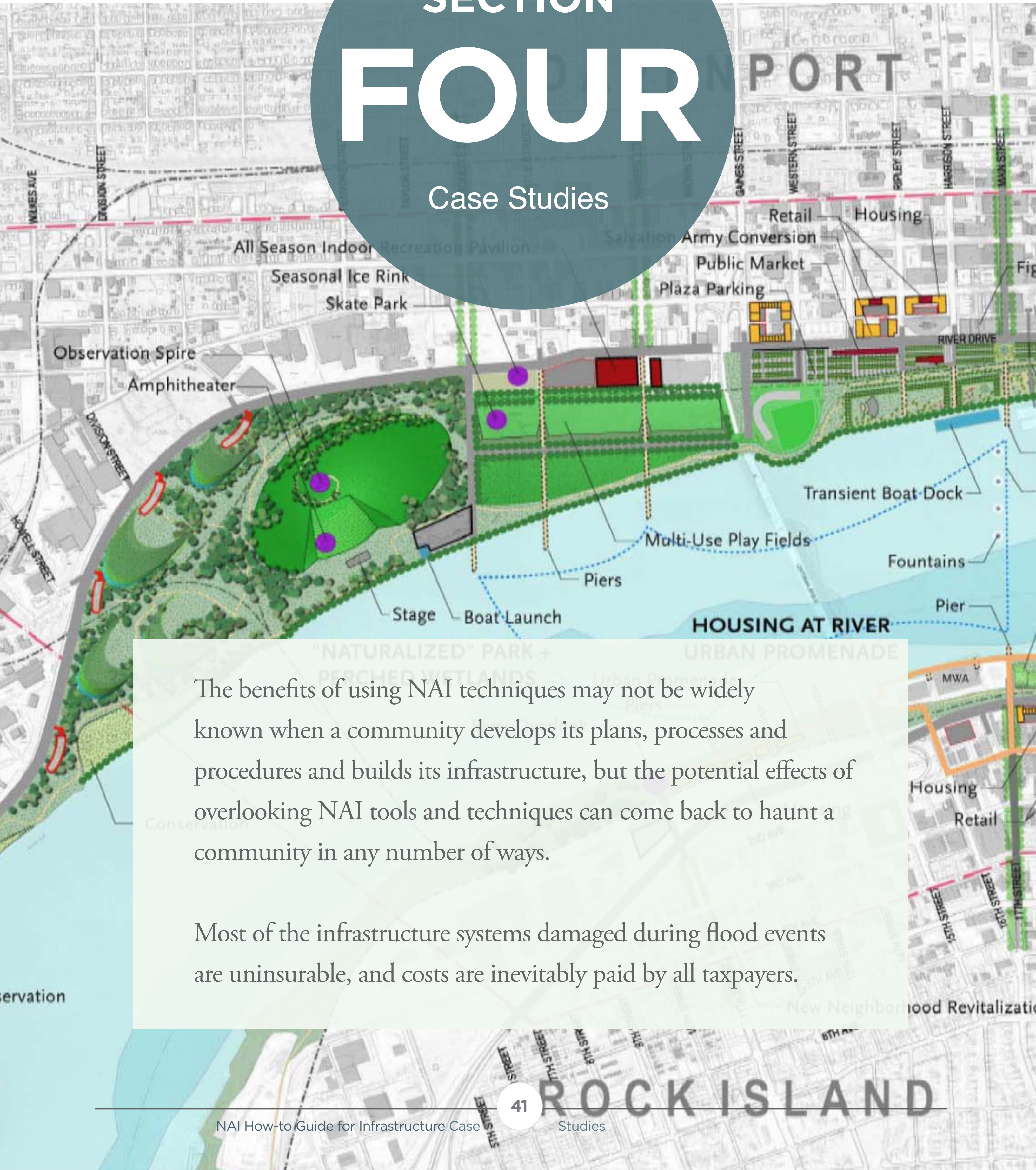
TABLE 1: ELEMENTS NEEDED FOR NAI-BASED RIPARIAN BUFFERS TO MITIGATE FLOOD

NAI-based Riparian Buffers	Elements Needed
Space for floodwater storage and conveyance	Provision of space for floodwater storage and conveyance is the most direct advantage of preserving a natural floodplain. Locating development farther away from the flood source will dramatically reduce potential damage. Cumulative reduction in flood storage and conveyance capacity through development can be mitigated with prioritized preservation efforts.
Achieve erosion/ sedimentation equilibrium	The combination of a naturally-meandering channel with a vegetated floodplain allows the water system to maintain a dynamic equilibrium. Dredged and eroding streams are in a state of disequilibrium due to an energy imbalance. Some benefits of a balanced system include reduced channel migration, less potential to undercut foundational elements of existing structures, as well as reduction in the shifting of flood risk downstream.
Vegetative maintenance	Dissipated peak flows and velocities are facilitated through a variety of natural processes provided by vegetated floodplains. Opportunities for evapotranspiration and absorption are provided as runoff makes its way through the vegetative network toward the channel. Appropriate vegetation holds soil in place, provides additional ground friction, dissipates the flood's energy and allows direct paths for infiltration through breaks in the ground surface provided by plant root systems. Natural landscapes facilitate slower movement of water toward the channel, thus altering the timing and lowering peak flows.
Soil makeup and compaction	Optimal drainage can only be achieved when soil particles have proper nutrients and enough space between them to allow air and water movement. Compaction and soil makeup issues may need to be restored to improve drainage and better support the vegetative diversity that will help reduce the amount of water that can be infiltrated and the amount that reaches the channel. Improving the soil characteristics enables several natural processes, including groundwater recharge, improved drainage, deep root growth and enhanced support for native plant populations that cumulatively reduce quantities of floodwater.
Unobstructed flow	Unobstructed, free-flowing rivers can provide considerable environmental and ecological benefits. Barriers like dams create impediments to aquatic species dispersal and reduce flow, sediment and nutrient transport. In turn, this can reduce the environmental quality and abundance of native species, not only within the river channel itself, but also in adjacent riparian, floodplain and coastal areas.

Balanced systems as mentioned above provide high-functioning, low-cost ecosystem services beneficial to communities by not only limiting the impact of floods, but also improving water quality and creating habitat and open space. As an overall NAI development strategy, green infrastructure is an effective tool for reducing flood risk while improving the integrity of the watershed.

SECTION FOUR

Case Studies



The benefits of using NAI techniques may not be widely known when a community develops its plans, processes and procedures and builds its infrastructure, but the potential effects of overlooking NAI tools and techniques can come back to haunt a community in any number of ways.

Most of the infrastructure systems damaged during flood events are uninsurable, and costs are inevitably paid by all taxpayers.

Case File 1: Infrastructure with NAI: Bad to Good Practice Example

Old restoration effort and eroded hill

Kenai River Center stairway to the Kenai River twisted by the force of the 2007 ice jam flood event. Photo courtesy of the Kenai River Center

According to the Kenai River Center's website, the River Center in Soldotna, AK is a multi-agency permitting, information and education center. The Kenai Peninsula Borough, state and federal agencies work together to protect the natural resources associated with Kenai Peninsula watershed. In addition to floodplain permitting and flood information, the river center provides information on many other topics—wetland delineation, fish habitat, guiding on area rivers and construction along salmon-bearing rivers—are just some of the subjects people find help with.

River Center Bank Restoration and Access Project.

The center is located on the banks of the Kenai River at river mile 22.7. This stretch of the Kenai River has high, steep and easily erodible banks. To protect the river and provide safe recreational access to the river, a re-vegetation and walkway project was undertaken in the spring and early summer of 2003.

Case File 1: Infrastructure with NAI: Bad to Good Practice Example, cont.

THE ISSUE

The bank behind the center is a popular river access point for anglers. Over the years, a number of trails have been created that crisscross the riverbank. These trails do not support vegetation and are prone to erosion, which in turn causes more vegetation to be lost, damaging water quality and fish habitat in the river. In June 2000, an initial effort was made to protect the shoreline at the ordinary high water line by fastening spruce tree revetments to the bank with cables. Although this succeeded in slowing down the erosion at the water line, it was prone to damage by trampling. Also, erosion of the bank above continued as people traveled up and down the steep bank to access the river.

THE PLAN

There was an obvious need to develop a solution that would address two issues: the need to protect riverbank re-vegetation and slow erosion, and to provide safe access to the river for anglers and other recreational users.

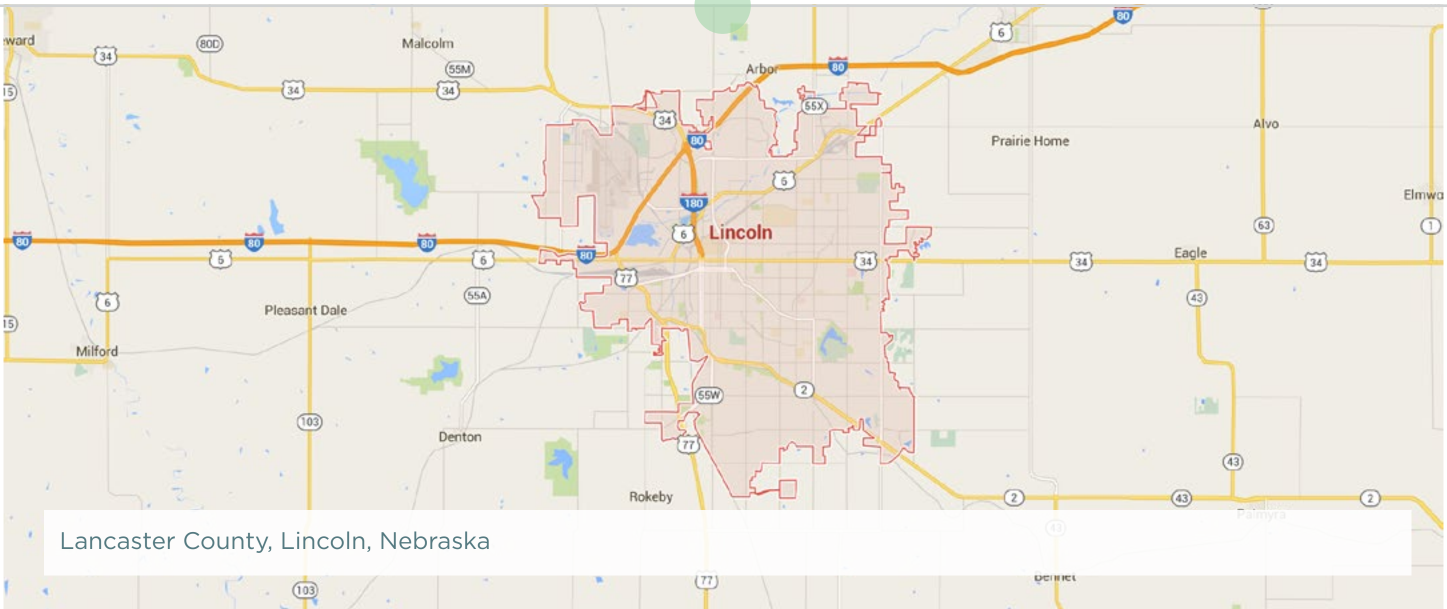
THE DESIGN

The completed project has four sets of stairs leading to the river from two access points on the upper bank, as well as a ramp that accommodates wheelchair access to a fishing platform. Established trails lead to each walkway. A clearing and gazebo on the upland section of the project provides an area to get out of the rain or have a picnic. This area is also used in conjunction with educational programs at the Kenai River Center.

THE ICE-JAM FLOOD

In January and February 2007, the Kenai River experienced an ice-jam flood event triggered by the release of the Skilak Glacier-Dammed Lake. The rise in water levels caused the winter river ice cover to break up and form ice jams and localized flooding in the Soldotna vicinity. Although built to withstand floods, the river center's fishing platform and stairs were no match for the strength of the ice, which twisted the heavy gauge aluminum stairs like a pretzel.
The stairs have since been repaired and rebuilt to allow access for anglers, but avoid the impacts of ice jam flooding. In combination with the NAI design and siting that avoids not only clear water flooding, but also ice jam impacts, the stairs, angler fishing platform and re-vegetation techniques enhance habitat by decreasing near-shore water velocities, allowing a win-win for the river and its riparian functions.

Case File 2: Infrastructure with NAI: Good Practice Example



Lancaster County, Lincoln, Nebraska

In January 2000, the Nebraska Emergency Management Agency approved HMGP funds for Lincoln's Waste Water Treatment Plant (Theresa Street location). The WWTP had requested funds to provide flood protection around an electrical substation and transformers that would be in danger of failing during a potential flood event.

The electrical substation was originally enclosed by a chain-link fence that could let in floodwaters from Salt Creek, which runs along the side of the plant. The HMGP grant helped pay for the construction of a 6-foot brick and reinforced concrete wall to enclose the electrical substation.

The entrance was engineered for stop logs (removable flood shields) to be inserted during a flood warning, completing the barrier and protecting the substation from floodwaters. The gates are tested annually to ensure proper fit.

On the west side of the WWTP, an electrical transformer was mitigated by raising it 3 feet above the 1-percent annual chance flood elevation. The transformer was set up on top of a brick and cement foundation structure effectively raising and protecting it.

The plant's sludge-processing tanks below-grade stairwells were susceptible to flooding. The stairwell was mitigated by being partially elevated with concrete and enclosed with approximately 12 inches of stainless steel. The stairwell entrance has also been designed using a similar technique used on the electrical substation, incorporating stop logs to prevent floodwaters from filling the stairwells.

The project cost approximately $298,000, of which $178,000 was awarded through the HMGP grant. The benefits of the project greatly outweigh the initial cost. These protective measures help protect vital components of the WWTP from Salt Creek.

Case File 3: Relocating Infrastructure before a Storm

File photo New Jersey.com

Sometimes you have to see it to believe it. "Resilience of NJ Transit Assets to Climate Impacts" was New Jersey Transit's first review into climate change effects in the New Jersey area. In 2012, the Federal Transit Administration awarded grants to agencies around the country to study climate change impacts on trains and rail systems. With the grant, New Jersey developed a $45,990 study that included a map showing the Kearny Meadows and Hoboken rail yards sitting in "storm surge areas."

However, prior to landfall of Hurricane Sandy, New Jersey's transit moved rail cars and locomotives into the previously determined to be flood-prone Kearny Meadows rail yard for storage just before the yard was inundated by Sandy's floodwaters in October.

Sandy floodwaters inundated the two rail yards, swamping locomotives and rail cars, including 84 new multilevel passenger cars, and even damaging spare parts. In those two yards, damage to railcars and locomotives was estimated at $100 million. The report urged the agency to begin planning for higher storm surges that could envelop rail yards, destroy track beds and corrode switches, gates and signals.

Case File 3: South Cape May, New Jersey, cont.

At the time of the storm, the authority apparently did not think it was going to flood, even though the report stated there would be flooding due to storm surge. It seems since the area did not flood during Hurricane Irene the year before, the authority did not think it was going to flood during Sandy. This shows how important it is for people to actually experience a flood event before they believe even a scientific study they paid for.

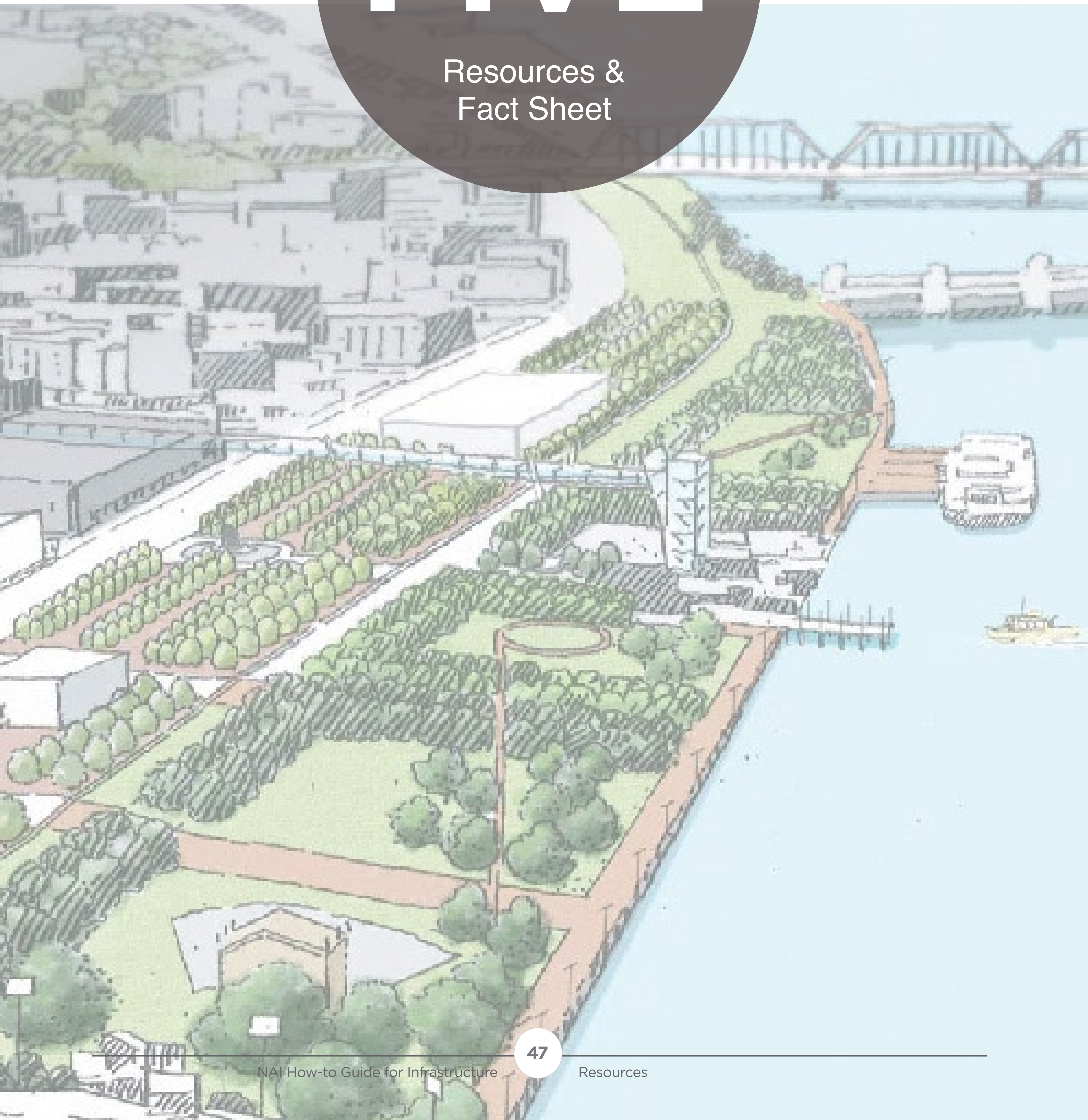
NJ Transit faced a torrent of criticism from state legislators, rail riders whose commutes were disrupted by the reduction in rail cars, rail advocates and its own employees, who questioned how the agency could leave equipment in flood-prone areas given the dire flood surge warnings weather forecasters had issued prior to Sandy making landfall.

NJ Transit is now seeking $450 million in reimbursement for system-wide damage and another $800 million for new projects to protect it against future floods.

The flooding at the Meadows Maintenance Complex in Kearny damaged 272 passenger cars and 70 locomotives. NJ Transit is hoping the repair costs will be reimbursed from its insurance and federal emergency grant dollars. The agency maintains the rail yards had never flooded before and that the agency's officials never expected the yards to flood.

SECTION FIVE

Resources & Fact Sheet



Resources, cont.

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Why Integrating NAI into Infrastructure is Important

"If we continue to encourage at-risk development and ignore the impact to others, can we accept the consequences, and are you willing to pay for it?"

-Larry Larson, ASFPM

"No adverse impact is an approach that ensures the action of any community or property owner, public or private, does not adversely impact the property and rights of others."

-NAI Toolkit, 2003

For case studies and specific examples of NAI success, visit http://bit.ly/1H5SeXL.

To speak to a No Adverse Impact expert, contact ASFPM at ASFPM@Floods.org or (608) 828-3000.

THE CONCEPT

At its most basic level, infrastructure refers to constructed facilities that shelter and support human activities. Several organizations have identified how deteriorated our nation's infrastructure has become. Transportation congestion is rising; the number of bridges, dams and levees at risk of collapse or functionally deficient is increasing; and our nation's electric power grid are not keeping pace with demand and are increasingly susceptible to natural hazards. Infrastructure, if planned and built or retrofitted based on the NAI approach, is not only more resilient, it will be much more sustainable for communities. While there are many flood risk infrastructure tools, five are reviewed in this Guide, and have shown to be particularly useful for floodplain managers.

TOOL 1: LOCATING NEW INFRASTRUCTURE

One way to better manage and protect infrastructure is to ensure flood hazard areas are fully identified. Require developers to undertake an H&H analysis of any stream or watercourse on or adjacent to the site to be developed (if it has not already been identified on a Flood Insurance Study (FIS)), 1-percent- and 0.2-percent-annual-chance flood elevations can be determined. Based on this new best available data, the community's floodplain management regulations can be administered and enforced.

TOOL 2: RETROFITTING CRITICAL EXISTING INFRASTRUCTURE

The NAI minimum protection standard for new and relocated critical infrastructure should be to build outside of, or protect to, the 0.2-percent-annual-chance flood

Fact Sheet, cont.

or flood of record, whichever is greater. Also, in coastal areas the NAI protection standard for critical infrastructure is the 0.2-percent-annual-chance flood level plus a freeboard equal to the long-term sea level rise projection for the area.

TOOL 3: EFFECTIVE MANAGEMENT OF LOCAL ROAD SYSTEMS

Some of the effective steps in this process include: improve road system data management and inspections; improve roadway flood resistance through better standards, designs and analysis; develop a goal, standard or target for hydraulic performance of structures and road surface elevations; take a watershed, future conditions and stream morphology approach to flood problems; ensure that roads for critical facilities and those that are the sole means of ingress and egress are at an elevation that will not be overtopped during severe events; and increase staff training related to flood-resilient best practices.

TOOL 4: BIO-ENGINEERED EMBANKMENTS

The benefits of bio-engineered slope protection is that it provides long-term stability and natural resiliency by integrating woody and herbaceous plants into the site-specific environment. Some considerations for this approach include: thoroughly investigated and addressed stream bank erosion prior to prescribing bio-engineering methods since the instability may be systematic and related to watershed changes, land clearing or straightening of channel; planting should be done during the growing season; protect plants from wildlife and other invasive plant species; monitor plant survivability and water availability, and monitor toe protection and channel stability.

TOOL 5: RIPARIAN BUFFERS

For riparian buffers to meet the vision of NAI, they must be properly evaluated within the context of their watershed and designed to ensure any current and future adverse impacts are identified and mitigated. That means the riparian buffer should be designed to achieve the goals of flood risk reduction. Examples include: space for floodwater storage and conveyance; achieve erosion/sedimentation equilibrium; vegetative maintenance; soil makeup and compaction; and unobstructed flow.

IN SUMMARY

Resilient infrastructure is the cornerstone of overall community resiliency. Also, infrastructure projects must be planned and completed in such a way to eliminate adverse physical impacts to adjacent properties. Given threats of sea level rise in coastal communities and more extreme storms everywhere, old ways of thinking of infrastructure must adapt to current realities. An NAI-based approach will ensure no level of flooding will impact critical infrastructure, and when existing infrastructure is repaired and replaced, flood factors will be incorporated into long-term plans and operations.

RESOURCES

For more information refer to:

ASFPM:

www.floods.org

NAI Toolkit:

http://bit.ly/23VSf1n

NAI How-to-Guides:

http://bit.ly/1Ei2r19