INFRASTRUCTURE

How-To Guide for No Adverse Impact

July 2013
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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 are following 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 once settled near watercourses for transportation, while others, especially in the arid west were settled as water represented a vital drinking source. However, today, new development is also increasing this flood risk. 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, and ultimately lessen their flood risk, by embracing a new approach to managing flooding – the No Adverse Impact (NAI) approach!

Who Should Use this Guide?

This “How-To Guide” serves as a resource primarily for local officials, including 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 within the community.

The Guide’s intent is to expand on the knowledge base within the previous No Adverse Impact (NAI) Toolkit and to provide specific tools for incorporating NAI floodplain management into local regulations, ordinances, requirements, design, standards, and practices.

The NAI Toolkit identified seven community “building blocks” or functions that every community performs or has the ability to perform. Consistent feedback the Association of State Floodplain Managers (ASFPM) has received from the Toolkit, since its inception, is “What are the tools that a community needs to implement NAI?” Based on that feedback this series of NAI How-To Guides was developed. It is important to note that for usability of this particular Guide, based on the Mitigation building block, only five tools are identified; however, there may be many more NAI level tools for Mitigation and for each of the seven building blocks found in the NAI Toolkit. Additional tools and information can be found by clicking the NAI icon at the bottom of ASFPM’s website homepage at www.floods.org.

How-To Guides will be developed for each of the other six building blocks found in the NAI Toolkit (Hazard Identification and Floodplain Mapping; Education and Outreach; Planning; Regulations and Development Standards; Emergency Services; and Infrastructure – which is being developed concurrently with this Mitigation How-To Guide). Additional How-To Guides may be developed for special topics such as Legal Issues and Funding. Each of the How-To Guides developed by ASFPM will enhance one another and may be used stand-alone, or in conjunction with one or more of the other How-To Guides, dependent on the community’s flood risk, needs and desired outcomes.

The Guide’s ultimate goal is to have communities take a different approach – a NAI based approach - to managing all development in the community that can contribute to an increased flood risk and
incorporate the NAI concept into all ongoing local community activities. This Guide identifies just a few of the many ways a community can accomplish this. Furthermore, the identified tools should be included into community plans, and specific regulatory or policy language can be adopted to include NAI principles or specific projects can feature NAI. It is important to 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 (NFIP) and being 100% resilient and sustainable in the face of its flood threat. The more NAI steps a community takes the less flood risk it faces both now and into the future.

**How to Use This Guide Effectively**

**An Overview**

This How-To Guide is divided into six sections:

- **Section One** – What Is Infrastructure?
- **Section Two** – Why Is NAI Important?
- **Section Three** – Infrastructure at the NAI Level
- **Section Four** – War Stories
- **Section Five** – Resources

http://www.floods.org/index.asp?menuID=349&fir

- **Section Six** – Fact Sheet

The six sections are meant to build upon one another. While it is not necessary to read the entire Guide, note that Sections One and Two lay the foundation for the tools presented in Section Three. Sections One and Two are the “why” and the “what” to the “how” presented in Section Three. Sections Four and Five contain information on lessons learned and provide the “where”—that is, where to find community success examples and referenced materials. Finally, the Fact Sheet ties this Guide together into one tidy, all-encompassing package. This Fact Sheet focuses on the “who,” meaning the individuals, community officials, developers, and others committed to reducing the impacts of flooding and who seek increased community resiliency, improved quality of life, and enhanced floodplain resources.

**The Sections at a Glance**

**Sections One and Two** define and summarize infrastructure and the role of NAI, and explain the importance of floodplain management and applying NAI considerations to infrastructure.

**Section Three** is the focus of the Guide and discusses five NAI tools selected by the project team because they are among the most effective and common tools for enhancing floodplain resiliency:

- **Tool 1** – Locating New Infrastructure and the 0.2-percent Flood Hazard Area
- **Tool 2** – Retrofitting Existing Critical Infrastructure
- **Tool 3** – Effective Management of Local Road Systems
- **Tool 4** – Bio-Engineered Embankments
- **Tool 5** – Riparian Buffers
Section Four provides examples of where NAI considerations for infrastructure worked, and also where it should have worked if the community had embraced the “do no harm” philosophies of No Adverse Impact Floodplain Management.

Section Five lists resources for finding the information contained in this Guide and additional information on NAI and infrastructure.

The Fact Sheet makes up the final section of the Guide. The Fact Sheet contains the core NAI message and condenses pertinent information from the Guide into a two-page synopsis suitable for distribution to the public, developers, planners, public officials, governing bodies, and others wishing to approach development in a way that reduces or eliminates negative impacts on the community or surrounding areas.

After reading this Guide, it is recommended that communities conduct a comprehensive flood-hazard assessment in relation to each NAI building block. A “gap analysis” should identify what is currently “not” being done and should also analyze, from a NAI perspective, activities/policies/programs that would fit under each building block were ever an adverse impact can occur. By doing so, the flood-hazard assessment will naturally identify what new activities should be undertaken by the community, from both short- and long-term perspectives. Next, identify potential tools or solutions, secure the necessary technical and/or financial resources, and implement a NAI based solution.
Section One: 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 (PERSI 2010). Public infrastructure includes, but is not limited to, bridges, highways, causeways, sewer and water systems, and shore protection projects (ASFPM 2003). The ASFPM Toolkit’s definition of infrastructure also includes subdivision elements such as roads, sidewalks, utility lines, storm sewers, and drainage ways (ASFPM 2003). 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 (PERSI 2010).

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 the environment. Although green space is often viewed as self-sustaining, green infrastructure implies something that must be actively maintained and, at times, restored (ASFPM 2003). 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. (PERSI 2010).

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. Green infrastructure is 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 (Environmental Protection Agency 2008).
Section Two – The NAI Approach

No Adverse Impact (NAI) Floodplain Management Defined

“No Adverse Impact (NAI) Floodplain Management” is a managing 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 can be measured in terms of increased flood peaks, increased flood stages, increased flood volumes, higher flood velocities, increased erosion and sedimentation, or other impacts the community considers important. The NAI philosophy can shape the default management approach if it:

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

NAI criteria can be extended to entire watersheds as a means to promote the use of regional retention/detention or other watershed-based stormwater management methods to mitigate damages caused by increased runoff from urban areas.

NAI floodplain management also offers local governments a way to prevent the escalation of flooding, flood damage, and other negative impacts from irresponsible community development. Although some State and local governments may have abandoned their responsibilities for protecting public health, safety, and human welfare in the face of flood hazards, many simply have assumed that the Federal programs represent an acceptable standard-of-care. They perhaps do not realize that these very approaches can induce additional flooding and damage within their communities. More simply, NAI principles give communities a way to promote “responsible” floodplain development measures through community-based decision making. With the NAI approach, communities are able to put both Federal and State programs to better use; thus, enhancing their local initiatives to their own advantage. NAI floodplain management empowers the community (and its citizens) to build better-informed and “wise development” stakeholders at the local level. Simply put, it is a step toward community accountability because it prevents the increase of flood damage to other properties. NAI floodplain management also helps communities identify the potential impacts of development and implement actions to mitigate those adverse impacts before they occur.

The NAI approach will result in flood-damage reduction; however, the true benefits become realized when proposed development actions that would have increased local flooding, or impact the property rights of others, are permitted only when adverse impacts are identified and mitigated. A community’s approach could be specific to flood damage or encompass related objectives, such as water quality protection, groundwater recharge, or the management of stormwater, wetlands, and riparian zones. As a local initiative, an NAI-based plan removes the impression that floodplain management is something imposed by the Federal government. Instead, it promotes local accountability for developing and implementing a comprehensive strategy and implementation plan.
At the community level, the NAI floodplain management approach and implementation plan should be comprehensive and address the following:

- Natural hazard risk mapping
- Mitigation
- Infrastructure
- Planning
- Development standards and regulations
- Emergency services
- Education and outreach with a focus on communicating risk.

NAI floodplain management makes sense, and is the just, equitable, and legally appropriate thing to do. Too often, discussions on development approaches turn into arguments over the scope of application and the effect these approaches may have on those who choose to encroach upon the floodplain. To reduce future costs and inequities, this perspective must be changed. A holistic management stance that prevents any development activity from imposing additional negative flood impacts on other properties and, also, frees communities to manage flood hazards and development through comprehensive local plans will more effectively protect the property rights and natural environment of the “whole community.”

**NAI vs. Minimum Standards**

The minimum standards in the United States for floodplain management and for addressing all community actions that will impact flood risk are wholly inadequate to stop and reverse the long-term trend towards increasing flood damages. For example: The minimum provisions found within the NFIP generally dictate the setting of minimum construction standards, within local communities, that often do not provide sufficient protection from all local flood hazards, nor do they account for the effects of urbanization, or the effects of a changing climate, on future flood levels. They will 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 in the floodplain and watershed. There are no widespread existing 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, the continued problem of changing hazards downstream necessitating a dam to be retrofitted to higher levels.

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1 As a concept, Whole Community, as defined by FEMA, is a means by which residents, emergency management practitioners, organizational and community leaders, and government officials can collectively understand and assess the needs of their respective communities and determine the best ways to organize and strengthen their assets, capacities, and interests. See [http://www.fema.gov/whole-community](http://www.fema.gov/whole-community).
standards is problematic. There are no commonly applied flood-loss reduction standards for critical facilities, such as wastewater treatment plants, emergency operations centers, and especially critical infrastructure. There are no consistent flood standards for local road systems, nor are there any effective standards for subdivisions and large-scale developments.

“Sedimentation, erosion, channel migration and ice jams in rivers, and coastal erosion, often cause flood hazards that are not adequately reflected” in Special Flood Hazard Area (SFHA) maps. Ground subsidence, or uplift in areas of isostatic rebound, are other examples of what may create different flood problems in the future, even if the maps are accurate when they are drawn. “The NFIP regulatory standards may not work adjacent to lakes where the water levels may remain high for months or years.” (NAI Toolkit, ASFPM, pg. 6)

Community Rating System

Why not get rewarded for going beyond minimum standards and implementing NAI measures in your community? The Federal Emergency Management Agency (FEMA) has placed an emphasis on encouraging communities to go beyond the “minimum” standards by developing the NFIP Community Rating System (CRS). Similar to NAI, the CRS Program is voluntary and provides a strong incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. As a result, flood insurance premium rates are discounted to reflect reduced flood-risk resulting from community actions that meet CRS’s primary goals:

1. Reduce flood damage to insurable property;
2. Strengthen and support the insurance aspects of the NFIP; and
3. Encourage a comprehensive approach to floodplain management.

The FEMA CRS Program foundation is strikingly consistent with a NAI approach and communities choosing tools in the NAI Toolkit can often get CRS credits. For more information on CRS go to: http://www.fema.gov/national-flood-insurance-program/national-flood-insurance-program-community-rating-system.

NAI Advantages

There are many advantages to the community, its businesses, and citizens for embracing the NAI approach. Below are some of the advantages:

1. **Reduced liability.** NAI doesn’t take away property rights – it protects them. NAI prevents one person from harming another’s property. One of the most important options a government typically has for reducing liability for flood losses, while maintaining responsibility for their own actions in the use of (development of) land, is the prevention of increasing flood levels and erosion hazards due to government actions (either direct actions such as approvals and, in some cases, inaction). To do this, governments can adopt NAI hazard management standards for new
public and private activities and implement this goal through regulatory and non-regulatory approaches.

2. **Lower long-term costs in financially strapped communities.** Whether the assault on local infrastructure comes from nature, or from diminishing availability of local, State, and Federal funds for maintenance and upgrades, there is always a need for communities to protect what works, while at the same time avoiding continued investment in flood-damage repairs. Change will not often-times be immediate, but if applied for long-term, flood-damage reduction, and applied throughout the watershed, the NAI approach will have positive results. For example: an acquisition or relocation project in a severely flood prone area not only can result in a community amenity (green or open space), but result in less maintenance of community infrastructure (roads, storm drains, public utilities) and less risk to first responders who must conduct search and rescue operations.

3. **Improved partnerships.** Informed local government officials that are aware of community flood hazards can make the right critical decision in protecting the community. Economic development organizations, transportation and public works departments, and local utilities need to be working with planners and floodplain managers to implement an NAI-based approach. Local officials must assume responsibility for their flood problems and floodplain management programs (*NAI Toolkit, ASFPM, pg. 6*) and must be proactive when assigning and distributing money, time, and manpower into reducing future losses.

4. **Meeting unique community needs.** The NAI concept offers communities a framework to design programs and standards that meet their true needs, not just the requirements of a Federal or State governmental agency. The NAI floodplain management initiative empowers communities (and their citizens) to work with stakeholders to build a program that effectively reduces and prevents current and future flooding issues. It should be recognized that NAI floodplain management is about communities being proactive toward understanding potential impacts and implementing preventive measures and mitigation activities prior to any occurrence; thus avoiding unnecessary property loss and human misery associated with devastating flood events.

NAI has many benefits. By developing activities that directly address situations that are unique to the local community, and that do not harm others, communities can:

- Prevent flooding from increasing or damaging others;
- See a reduction in flood losses over time;
- Avoid challenges and lawsuits over causing or aggravating a flood problem; and
- Receive recognition for efforts through the Community Rating System (*CRS*). (*NAI Toolkit, ASFPM, pg. 8*)

Adopting a NAI approach helps a community develop and/or follow planning principles, and building and infrastructure design guidelines, which ensure that future development provides a community with better protection against storms and floods.
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 is not keeping pace with demand and is 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 that many green infrastructure techniques are compatible with the NAI approach.
Section Three: Infrastructure at the NAI Level

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, extremely susceptible to flood damage, and expensive to repair or replace.

One way to better manage and protect infrastructure is to ensure that 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.

Some communities, such as Charlotte-Mecklenburg, have incorporated future conditions mapping based on projections of fully built-out watersheds that encompass Mecklenburg County (Figure 4). 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.

Figure 3: 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 for 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 both public and private infrastructure must, for practical reasons, be located in flood hazard areas. When this situation arises, it is imperative that 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 \textit{watertight manhole covers} be used in any condition where the manhole may be affected by street runoff, rising water, or floodwater velocities. \textit{Watertight connections} are also imperative. This 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 (see the Infrastructure section). 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 both 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 backup 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” (http://training.fema.gov/EMIWeb/IS/is860a/CIRC/CIKRintro.htm). 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 Mitigation NAI How-To Guide (ASFPM 2013).

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 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, at a minimum. 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.

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 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 of dollars 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 to withstand extreme flood events and ensure that 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.

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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.
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 United States 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 that 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 largely 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 (American Lifelines Alliance 2005). 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. The nature of damage to roads and drainage elements can include any or all of the following (American Lifelines Alliance 2005):

- 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 flooding-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 (NOAA 2013). 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 steps below 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 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 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 Both 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 2009). 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. U.S. Environmental Protection Agency (EPA) has produced Green Streets: A Conceptual Guide to Effective Green Streets Design Solutions (EPA 2009), 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.

Such activities are usually assisted by having a robust road data collection system in place. After a 1997 flood event on the Ohio River, a community was unprepared for the impact of the flood and had to call for a hasty evacuation in the 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.

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 decisionmaking. 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 (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.
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. They 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.

- **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.

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 (Figure 6).
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.

- Types of planting methods:
  o 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 Web site: [http://www.soundnativeplants.com/calculator](http://www.soundnativeplants.com/calculator).

- **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: [http://vegbank.org](http://vegbank.org).

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 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 the 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.
Tool 5: Riparian Buffers

Widely recognized as an effective tool to efficiently 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 make-up 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 the 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.

Table 1: Elements Needed for NAI-Based Riparian Buffers to Mitigate Flood

<table>
<thead>
<tr>
<th>NAI-Based Riparian Buffers</th>
<th>Elements Needed</th>
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<tbody>
<tr>
<td>Space for floodwater storage and conveyance</td>
<td>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.</td>
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<tr>
<td>Achieve erosion/sedimentation equilibrium</td>
<td>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.</td>
</tr>
<tr>
<td>Vegetative maintenance</td>
<td>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.</td>
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## NAI-Based Riparian Buffers

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<tr>
<th>NAI-Based Riparian Buffers</th>
<th>Elements Needed</th>
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</thead>
<tbody>
<tr>
<td>Soil makeup and compaction</td>
<td>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.</td>
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<tr>
<td>Unobstructed flow</td>
<td>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.</td>
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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: War Stories

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

According to the Kenai River Center’s Web site, the River Center in Soldotna, Alaska 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 additional 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 that people find help with at the Kenai River Center.

River Center Bank Restoration and Access Project

The Kenai River 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 at the Kenai River Center in the spring and early summer of 2003.

The Issue

The bank behind the Kenai River 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 (www.kenairivercenter.org).

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 use of 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, NE - In January 2000, the Nebraska Emergency Management Agency approved HMGP funds for the City of Lincoln’s Waste Water Treatment Plant (WWTP), 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 the time of 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 over 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 had a total cost of 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

Sometimes you have to see it to believe it. A report titled “Resilience of NJ Transit Assets to Climate Impacts” was New Jersey Transit’s first review into climate change effects in the New Jersey area (First Environment, Inc. 2012). 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 and tropical storm 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.

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, and 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’s 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 from 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

References Cited

Some material within this document was developed with information from other sources. Also, some material references outside documents containing more information. Below is a compiled list of these sources and references broken down by section.

Introduction:

Section One:

Section Two:

Section Three:
- ASFPM, 2013. Mitigation NAI How-To Guide
- Ecological Society of America’s Panel on Vegetation and Classification. VegBank database: http://vegbank.org

• Licking County, 2009. Subdivision, Land Division, Development and Congestion Prevention Regulations for Licking County, Ohio.


**Section Four:**


**Additional Resources**


Fact Sheet

The fact sheet is designed to be a break-away reference that can be distributed to highlight the importance and application of NAI in hazard mitigation.
The Concept

Hazard mitigation is an excellent concept and practice on its own; however, without applying the principles of No Adverse Impact (NAI) Floodplain Management, it can be insufficient to truly protect the community. NAI requires a long-term perspective on the everyday challenges faced in protecting a community. Though many local programs address immediate issues, they rarely are sufficient to provide long-term solutions that will not have negative impacts either in the future or to the surrounding area. Some benefits of utilizing an NAI approach in hazard mitigation programs include:

- Locating New Infrastructure
- Retrofitting Critical Existing Infrastructure
- Effective Management of Local Road Systems
- Bio-Engineered Embankments
- Riparian Buffers

Improve Mitigation Strategy Effectiveness

When considering or reviewing local hazard mitigation strategies, the NAI approach can encourage planners to address the anticipated long-term effects of those strategies. This may cause them to revisit the benefits, costs, and overall effectiveness of the strategy, and replace or remove the strategy altogether. It may also help to fine-tune or broaden the strategy to encapsulate the issue as a whole.

Efficient Mitigation Project Selection

Both political will and funding tend to drive the prioritization of mitigation projects. By emphasizing an NAI approach in the criteria applied during the selection of many projects vying for support, multiple factors can be considered that go beyond simply loss reduction, including social, economic, and environmental benefits to the community, and therefore prioritized more accurately and efficiently. Funding will not only go into the most pressing issue, but rather into the most beneficial to the community over the life of the project.

“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 (NAI) 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://www.floods.org/PDF/NAI_Case_Studies.pdf
Reduce Community Liability

Legally, NAI Floodplain Management can reduce community liability for flood losses. A court may hold that a “standard” approach is not reasonable in certain circumstances as data and technologies improve and the standard of care in floodplain management increases. By going a step further and applying an NAI approach to hazard mitigation, a community can demonstrate that full effort was given to reduce risk.

In Summary

Utilizing NAI in the mitigation process has benefits beyond what is highlighted in this fact sheet. Improving mitigation strategy effectiveness, more efficient mitigation projects, and reducing community liability are just a few of the benefits gained by taking the NAI approach in the community. To learn more, the sites listed below are a good place to start.

Resources

For more information refer to:

- ASFP: [www.floods.org](http://www.floods.org)

To speak to an expert in No Adverse Impact, contact ASFP via:

E-mail: ASFPM@Floods.org
Phone: 608-828-3000