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Inland Port Community Resilience Roadmap

January 2018

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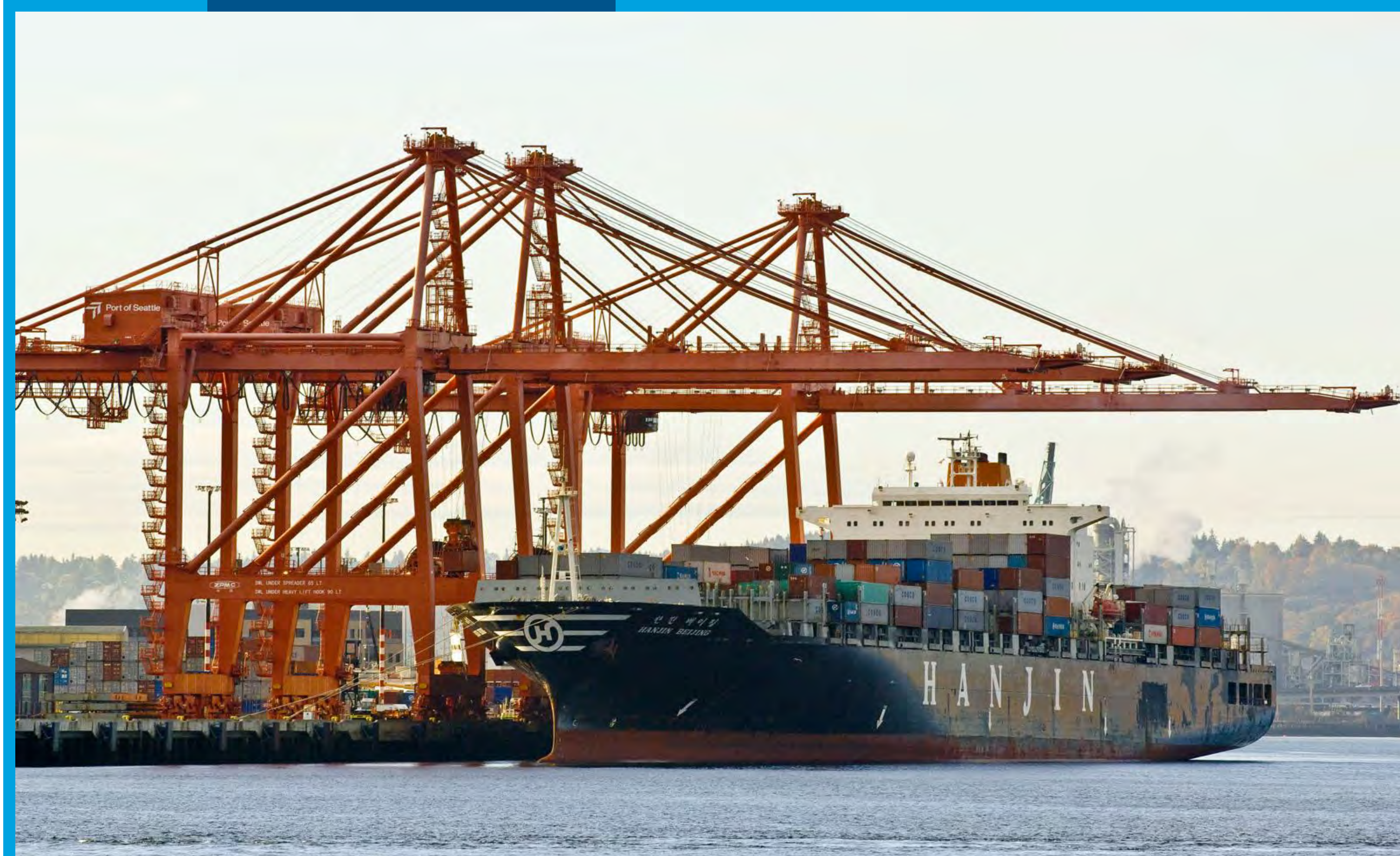

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Acknowledgements, Authors, Reviewers

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I. Executive Summary

Inland ports are vulnerable to damage or disruptions from extreme high and low water levels. Extreme water levels can cause periods of flooding or drought and may restrict or alter port operations and freight movement. Those vulnerabilities affect not only the port itself, but also the surrounding port community. Improving the resilience of inland ports and the communities that depend on them will become increasingly important in the future as water levels become more variable and extreme.

This roadmap provides actionable information and steps for local governments and port and community stakeholders to increase their resilience to the variability of river water levels. The major steps include:

- **Step 1 – Conduct outreach and identify resilience objectives.** Step 1 centers on improving communication between all port community resilience stakeholders and working with stakeholders to identify resilience goals and objectives. In many cases, there may be stakeholders who do not currently coordinate closely with the port, but who may have an important role to play in increasing resilience. Improving coordination can improve the development of effective port resilience strategies.
- **Step 2 – Identify and analyze resilience challenges.** Step 2 focuses on analyzing baseline commodity flow, historical and projected trends in extreme events, mode shifts, and transportation scenarios. Potential impacts include those to public and private infrastructure, transportation operations and equipment, local and regional economies, environment, and health. Assessing the impacts of different extreme weather and alternative freight movement scenarios on the port and port community will help to determine resilience challenges to be addressed.
- **Step 3 – Identify strategies to improve resilience.** Step 3 outlines potential strategies to increase resilience by sector, including public and private infrastructure, transportation operations and equipment, long-term economics, environment and human health, and emergency management. The majority of these strategies can be implemented at the local or state government level. Implementation of any resilience strategies, however, will require coordination across a range of port and community stakeholders.
- **Step 4 – Develop institutions and performance measures to support resilience objectives.** Step 4 focuses on supporting resilience objectives through funding sources and a process for incorporating resilience considerations into freight transportation planning and port infrastructure projects. This step also introduces resilience indicators to measure performance and a process for revisiting progress made on the resilience goals and objectives over time.
- **Step 5 – Implement strategies and evaluate progress.** Step 5 focuses on implementing the resilience strategies and evaluating progress. Implementation will likely involve managing and coordinating projects across multiple private and public sector agencies. Based on the performance of existing strategies, and experience with implementation, adjustments and improvements to the resilience program may be necessary.

To help implement the roadmap, the Table of Contents doubles as a step-by-step guide to increasing the resilience of ports and near-port communities to extreme water levels.

There is a large array of possible strategies and processes to address resilience. This roadmap is intended to help users identify and pursue the most appropriate and high value strategies for the particular operating environment of a port and the specific characteristics of the larger port community.

Further, port communities face many challenges including high probability, weather-related risks associated with flood and drought, and low-probability but extreme risks resulting from infrequent storms or other hazards. This roadmap is focused on inland ports, which because of their inland locations, are less likely to experience risks associated with catastrophic events such as hurricanes. The roadmap is not intended to address all forms of risk or to guide emergency planning, but rather to offer a process and tools for increasing community resilience to dynamic conditions that routinely upset normal port operations resulting in environmental, economic, and even human health impacts that, with careful planning, can be avoided.

II. Introduction

Inland ports are vulnerable to damage or disruptions from extreme high and low water levels. Those vulnerabilities affect not only the port itself, but also the surrounding port community. Many ports are located in areas with a high percentage of low-income and minority populations,[1] and these populations may be particularly vulnerable due to limited resources to address these impacts in their communities.

This roadmap provides actionable information and steps local governments and port stakeholders can take to increase their resilience to variability in river water levels—including extreme high water levels and periods of flooding, as well as extreme low water levels that may restrict freight movement. The roadmap includes action items for a variety of stakeholders, including port and local government employees and other community members. The text box on page 17 lists example stakeholders.

The ultimate goal of resilience in the context of this roadmap is to ensure that ports and surrounding port communities grow stronger and more economically vibrant in the face of future changes and that adverse health and environmental impacts of these changes are minimized.

The roadmap builds on an assessment conducted for the Port of Memphis and its surrounding community in Memphis, Tennessee (see Appendix A). The assessment involved desk research and focus groups with several groups of stakeholders (port authority staff, private terminal operators, shipping companies, elected officials, local government staff, nonprofit groups, and community leaders) to identify existing challenges during times of drought and flooding. The assessment also identified potential opportunities to help businesses and communities evaluate how to adapt to future changes more efficiently and minimize threats to public health and the environment.

Key Definitions

This roadmap uses these key terms as follows:

- **Port** – a geo-economic entity, referring to the collective port-related activities of a particular place that may be operated by many different entities, which may be public or private, or some combination of the two*
- **Port authority** – a government entity that may own facilities in one or more ports, and may include both seaports and airports*
- **Port community** – towns, cities, or neighborhoods where a port is located
- **Near-port community** – community (e.g., neighborhoods, residences, businesses) in the immediate vicinity of the port and disproportionately affected by port operations and related transportation systems; note that near-port communities can include Native American tribal groups and tribes are sovereign nations, which may have associated treaty rights that influence port-community relations*

*U.S. Environmental Protection Agency, "Ports Primer: 3.1 Port Operations," EPA.gov, accessed July 24, 2017, https://www.epa.gov/ports-initiative/ports-primer-31-port-operations#authority.

Several resources provided in this roadmap are from EPA's Ports Initiative, which brings together port stakeholders to develop recommendations for a voluntary ports program, the goal

[1] U.S. Environmental Protection Agency, "Final Rule, Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder," *Federal Register* 73, no. 88 (May 6, 2008): 25098, https://www.gpo.gov/fdsys/pkg/FR-2008-05-06/pdf/E8-7999.pdf.

of which is to encourage strategies that reduce emissions and improve air quality. As reference materials continue to become available for ports to use to improve their sustainability and reduce emissions, these documents will be posted on the Ports Initiative website.[2]

1. Definition and importance of resilience

The inland waterway system of the United States is used to transport a large portion of the nation's coal, petroleum, and agricultural products. Localized disruptions to it can result in difficulties in moving freight through ports, lost wages and economic activity in the community, and social uncertainty. Because much of the cargo shipped by barge is used as raw materials for other industries, disruptions in barge transportation at a local scale may also result in production disruptions and economic losses throughout the country.

The impacts of inland waterway system disruptions were evident during the 2011–2013 flooding and drought cycles on the Mississippi River, which severely curtailed barge traffic. These disruptions had significant economic impacts on the barge services, other marine shipping, and agricultural industries. While barge cargo can often be re-routed to other modes, it can potentially overwhelm highway and rail systems and can cause localized increases in air pollution and other negative effects on noise levels, road safety, and emergency access. Low water levels can restrict freight throughput and have ripple effects throughout the supply chain. River variability has increased in recent years, and extreme high and low water levels are becoming more frequent.

Looking ahead, communities with major inland ports are likely to face more challenges related to extreme weather events, freight movement, and community and economic impacts. The volume of cargo transported via inland waterways may grow with the Panama Canal expansion.[3] Congestion on existing highways and rail lines is also expected to increase.[4] Inland port communities can respond by becoming more resilient to inland water disruptions.

Key Definition

- **Community resilience** – the sustained ability of a community to withstand and recover from adversity (e.g., economic stress, public health pandemics, man-made or natural disasters)

Community resilience refers to the sustained ability of a community to withstand and recover from adversity (e.g., economic stress, public health pandemics, man-made or natural disasters). Community resilience entails the capacity of the community to account for its vulnerabilities and develop capabilities that aid the community in (1) preventing, withstanding, and mitigating a stress or stressors; (2) recovering in a way that restores the community to a state of self-sufficiency and at least the same level of economic, environmental, public health, and social functioning; and (3) using knowledge from a past response to

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[2] U.S. Environmental Protection Agency, "Ports Initiative," *EPA.gov*, accessed July 2017, http://www.epa.gov/ports-initiative.

[3] Sarah Baker, "The Panama Effect: Canal Expansion Should Spark More Cargo, CRE Demand in Memphis," *Memphis Daily*, March 18, 2013, https://www.memphisdailynews.com/news/2013/mar/18/the-panama-effect/print.

[4] C. James Kruse, Annie Protopapas, and Leslie Olson, "A Modal Comparison of Domestic Freight Transportation Effects on the General Public: 2001-2009," *Texas Transportation Institute*, February 2012, http://www.nationalwaterwaysfoundation.org/study/FinalReportTTI.pdf.

strengthen the community's ability to withstand future incidents. The text box below provides additional background for this definition.

Defining Resilience

Resilience is a multifaceted concept that can be defined in different ways. A variety of organizations have promulgated slightly different definitions in a variety of contexts, such as:

- **National Academies of Sciences, Engineering, and Medicine** – "The ability to prepare and plan for, absorb, respond, recover from, and more successfully adapt to adverse events."*
- **Federal Transit Administration** – "The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions such as significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment."†
- **National Institute of Standards and Technology Community Resilience Panel** – "The ability to prepare for anticipated hazards, adapt to changing conditions, and withstand and recover rapidly from disruptions."‡
- **Rockefeller 100 Resilient Cities program** – Urban resilience is "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience."§
- **Community and Regional Resilience Institute** – The ability to "withstand the potential initial impacts of these events, respond quickly to the events, and recover in a way that sustains or improves the community's overall well-being."‖
- **Executive Order 13653** – "The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions." ¶

All touch on the same core principle of the ability to prepare for, withstand, and recover from adversity.

*National Academies of Sciences, Engineering, and Medicine, "Resilience @ The Academies," *NationalAcademies.org*, accessed July 2017, http://www.nationalacademies.org/topics/resilience/.

†Federal Transit Administration, "49 CFR § 602.5 Definitions," Cornell Law School, 2013, https://www.law.cornell.edu/cfr/text/49/602.5.

‡National Institute of Standards and Technology, "Community Resilience Planning Guide for Buildings and Infrastructure Systems," NIST Special Publication 1190-1, Washington, D.C., 2016, https://www.nist.gov/sites/default/files/community-resilience-planning-guide-volume-1_0.pdf.

§The Rockefeller Foundation, "100 Resilient Cities," 100 Resilient Cities, 2017, http://www.100resilientcities.org/.

‖Community and Regional Resilience Institute and Meridian Institute, "Community Resilience System Phase I Report: Community Experiences, Observations and Implications for FEMA," Community and Regional Resilience Institute and Meridian Institute, 2012, https://recoverydiva.files.wordpress.com/2012/10/crs-phase-1-report-general-release.pdf.

¶Executive Order No. 13653, (November 1, 2013), https://obamawhitehouse.archives.gov/the-press-office/2013/11/01/executive-order-preparing-united-states-impacts-climate-change.

2. Impacts of extreme water levels on ports and need for resilience planning

2.1 Extreme high water levels

Extreme high water levels have a wide range of effects on ports, port communities, and the broader economies that depend on them. Potential impacts include:

Key Definition

- **Port facility** – port infrastructure such as buildings, wharves, warehouses, yards, and docks

Extreme high water levels can lead to flooding at ports, which in turn can disrupt port operations and damage cargo, electronic equipment, and port facilities. Erosion caused by high waters can cause significant damage to port lands and nearby industrial complexes. For instance, a 1-in-250-year flood in Memphis with an annual exceedance probability of 0.4 percent in May 2011 (see Figure 1) caused $9 million of damage to President's Island, where the Port of Memphis is located, in erosion and structural damage to the island itself.[5,6] Several port facilities and some cargo were damaged.

Flooding can also deposit extensive debris and silt that reduces the depths of navigation channels and requires dredging and cleanup. There are significant costs associated with dredging as well as uncertainties for how to plan for these costs. The U.S. Army Corps of Engineers (USACE) estimates the annual need for maintenance dredging alone ranges from $1.3 to $1.6 billion, and there are already existing maintenance backlogs.[7]

High water can also reduce access to the port or associated industrial parks. In response to reduced port access following the 2011 floods in Memphis, the city added material to elevate the port access road base to ensure employees can get to work under high water conditions. In

[5] Daniel G. Driscoll, Rodney E. Southard, Todd A. Koenig, David A. Bender, and Robert R. Holmes, Jr., "Annual exceedance probabilities and trends for peak streamflows and annual runoff volumes for the Central United States during the 2011 floods," *U.S. Geological Survey Professional Paper 1798–D*, Reston, VA, 2014, http://dx.doi.org/10.3133/pp1798D.

[6] Wayne Risher, "Port of Memphis needs $9 million for flood fix," *Commercial Appeal*, December 2, 2011, https://www.pressreader.com/usa/the-commercial-appeal/20111202/281913064931512.

[7] American Association of State Highway and Transportation Officials, "Waterborne Freight Transportation: Bottom Line Report", *American Association of State Highway and Transportation Officials*, June 2013, https://www.yumpu.com/en/document/view/27971418/waterborne-freight-transportation-bottom-line-report-cambridge-.

Figure 1: Aerial image of flood extent over Memphis on May 10, 2011, with water levels at 47.87 feet; box shows President's Island. Image source: NASA Earth Observatory; image created by Jesse Allen and Robert Simmon, using Landsat data provided by the United States Geological Survey

some cases, ports may have little redundancy in terms of access roads, so flooding on those access roads can cause significant disruptions.

High water levels also pose a threat to the health and safety of employees working at docks and on barges. At high water, the river flows more quickly, which can create dangerous conditions and fleet breakaways.

Damage to terminal facilities and fast-moving water can also shut down port operations and disrupt commerce on the river. For example, in 2011, the U.S. Coast Guard closed a 15-mile stretch of the river to reduce pressure on the levees, which caused an estimated $300 million in economic losses per day.[8] As in low water situations, river closures or terminal disruptions can cause goods to shift to alternate transportation modes, though the precise outcomes are variable.

High water conditions can cause a temporary spike in employment needs at ports, as loading and unloading may become more difficult and port operations can increase. Higher staffing needs raises the cost of moving cargo at the port. In particular, the need for trained personnel on barges increases and because the demand is high and the supply of trained and certified pilots is relatively fixed, costs rise.

Finally, **locks and dams, which are critical to the inland waterway system, are also sensitive to damage from extreme high water levels.** There are 242 locks in the U.S. inland waterway system including along the Mississippi River and the Ohio River, two critical shipping channels particularly for the agriculture sector.[9,10] Currently, 60 percent of U.S. locks and dams are over 50 years old.[11] It is estimated that by 2020, 78 percent of locks and dams will exceed

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[8] Daily Mail Reporter, "$300 million a day: Cost of Mississippi floods revealed as 15 miles of river is closed to shipping," *The Daily Mail*, May 17, 2011, http://www.dailymail.co.uk/news/article-1387910/Fifteen-miles-Mississippi-closed-shipping-fears-grow-flooding-cost-economy-300million-day.html.

[9] Pamela Glass, "Lockdown: Inside America's decaying waterways infrastructure," *WorkBoat,* January 19, 2017, https://www.workboat.com/news/coastal-inland-waterways/lockdown-decaying-inland-waterways-infrastructure/.

[10] U.S. Department of Agriculture, "A Reliable Waterway System is Important to Agriculture," *U.S. Department of Agriculture*, October 2015, https://www.ams.usda.gov/sites/default/files/media/Importance%20of%20Waterways%2010-2015.pdf.

[11] Sarah Scully, "Aging river infrastructure means challenges for barges," *Houston Chronicle,* March 30, 2015, http://www.houstonchronicle.com/business/article/Higher-tax-will-improve-aging-waterways-6161707.php.

their design life.[12] Locks and dams are critical to moving freight through shipping channels of varying water levels. If a lock or dam is damaged or closed for repairs, cargo must often wait until the lock or dam reopens to continue moving up or down the shipping channel causing delays.[13] Scheduled and unscheduled delays in 2010 imposed $33 billion in costs on U.S. products.[14] In 2013, there were 142,000 hours of unplanned lock closures to make repairs.[15] To keep up with the needs of maritime shipping, the inland marine sector has made improving and updating locks and trans-modal facilities a top-priority in recent years.[16]

2.2 Extreme low water levels

History also provides numerous examples of the impacts of low water on barge freight movements. These impacts include:

Low water events can require the reduction of barge drafts in navigation channels or close the river all together. Most recently, in August 2012, low water required the closure of the river at Greenville, Mississippi, for over a week, which prevented access to Memphis and other ports from the south. Approximately 100 barges were delayed. This section of the river was also closed during a low water event in 1988.

At the Port of Memphis, among other impacts, the 2012 low water event caused:

- Reduced tow sizes, from about 30–45 barges to no more than 25 barges southbound and 36 (no more than 20 loaded) northbound
- Reduced draft levels from 12 feet to 9 feet for over a month on the Lower Mississippi[17]
- Reduced barge loads, ranging from 10 to 25 percent less than normal[18,19]
- Slowed terminal operations (smaller tonnage per barge means more barges need to be loaded, plus barges have difficulty getting close enough to docks so it is more difficult to load or unload material)

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[12] Pamela Glass, "Lockdown: Inside America's decaying waterways infrastructure," *WorkBoat,* January 19, 2017, https://www.workboat.com/news/coastal-inland-waterways/lockdown-decaying-inland-waterways-infrastructure/.

[13] Sarah Scully, "Aging river infrastructure means challenges for barges," *Houston Chronicle,* March 30, 2015, http://www.houstonchronicle.com/business/article/Higher-tax-will-improve-aging-waterways-6161707.php.

[14] American Association of State Highway and Transportation Officials, "Waterborne Freight Transportation: Bottom Line Report", *American Association of State Highway and Transportation Officials*, June 2013, https://www.yumpu.com/en/document/view/27971418/waterborne-freight-transportation-bottom-line-report-cambridge-.

[15] Sarah Scully, "Aging river infrastructure means challenges for barges," *Houston Chronicle,* March 30, 2015, http://www.houstonchronicle.com/business/article/Higher-tax-will-improve-aging-waterways-6161707.php.

[16] Texas A&M Transportation Institute, "Our Inland Waterways: A Maintenance and Funding Challenge," *Texas A&M University,* July 16, 2015, https://tti.tamu.edu/2015/07/16/our-inland-waterways-a-maintenance-and-funding-challenge/.

[17] Karl Plume, "Coast Guard Eases Barge Draft Restrictions on Lower Mississippi River," *Chicago Tribune*, September 4, 2012, http://articles.chicagotribune.com/2012-09-04/news/sns-rt-us-usa-grain-bargesbre8830wt-20120904_1_barge-northbound-tows-mississippi-river.

[18] John Yang, "Drought Sends Mississippi into 'Uncharted Territory'," *NBC News*, August 15, 2012, http://usnews.nbcnews.com/_news/2012/08/15/13295072-drought-sends-mississippi-into-uncharted-territory?lite.

[19] David Bennett, "Low Mississippi River Forces Light-loading of Barges," *Delta FarmPress,* August 24, 2012, http://deltafarmpress.com/management/low-mississippi-river-forces-light-loading-barges.

- Slowed river operations, as a narrower river channel means the Mississippi can become one-way only, and barges must wait for traffic coming from the other direction to pass
- Increased likelihood of barge groundings (20 reported cases in 2012)

The American Waterways Operators Association estimated the following impacts from extreme low water levels:

- It costs towing companies at least $10,000 a day when a towboat sits idle.
- With every 1-inch loss of water, each barge is unable to move 17 tons of cargo.[20]
- The typical tow on the lower Mississippi is 30–45 barges, resulting in decreased capacity of up to 765 tons for 1-inch loss of water.[21]

Reduced drafts could also increase the need for dredging to maintain ideal shipping channel depths. While there are costs for lost channel depths, there are also significant costs associated with dredging as well as uncertainties for how to plan for these costs. As noted above, the USACE estimates the annual need for maintenance dredging alone ranges from $1.3 to $1.6 billion, and there are already existing maintenance backlogs.[22]

Low water situations, often linked to droughts, can also affect the amount of hydropower utilities can produce. The Tennessee Valley Authority, for example, has 29 hydroelectric dams in Tennessee, which provide about 12 percent of the electricity produced in the state.[23] Reductions in hydropower can affect power availability or the cost of electricity, affecting community members and port stakeholders alike.

Challenges on the inland port system can lead to challenges in other transportation modes as well. While 6 to 7 percent of all ton-miles are moved on the inland waterway system,[24] the share of inter-city freight moved on the U.S. waterway system is approximately twice as high at 14 percent. The inland waterway system is very important for specific commodities, carrying 20 percent of coal consumed for electric power generation, 22 percent of all domestic petroleum shipments, and 60 percent of farm exports.[25] Texas Transportation

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[20] American Waterways Operators, "Nation's Waterways Operators Concerned about Impact of Drought Conditions, Low Water Levels," *American Waterways Operators*, July 20, 2012, http://www.americanwaterways.com/media/press/2012/nation%E2%80%99s-waterways-operators-concerned-about-impact-drought-conditions-low-water-0.

[21] Ibid.

[22] American Association of State Highway and Transportation Officials, "Waterborne Freight Transportation: Bottom Line Report", *American Association of State Highway and Transportation Officials*, June 2013, https://www.yumpu.com/en/document/view/27971418/waterborne-freight-transportation-bottom-line-report-cambridge-.

[23] Average for 2013 through 2016, annual net electricity generation for conventional hydroelectric as a portion of all fuels – U.S. Energy Information Administration, "Electricity Data Browser," *U.S. Department of Energy*, July 2017, https://www.eia.gov/electricity/data/browser/.

[24] National Academies of Sciences, Engineering, and Medicine, "Funding and Managing the U.S. Inland Waterways System: What Policy Makers Need to Know What Policy Makers Need to Know, Chapter 2: Role of the Inland Waterways System in National Freight Transportation," *The National Academies Press*, Washington, D.C., 2015, https://www.nap.edu/read/21763/chapter/4#18.

[25] U.S. Army Corps of Engineers, "Inland Waterway Navigation, Value to the Nation," *U.S. Army Engineer Institute for Water Resources,* 2009, http://www.mvk.usace.army.mil/Portals/58/docs/PP/ValueToTheNation/VTNInlandNav.pdf.

Institute estimated that should cargo need to shift from waterways transport to other modes, it is very likely that congestion would rise on the nation's highways. The hypothetical diversion of current waterway freight traffic to the nation's highways would add 742 combination trucks (to the current 887) per day per lane on a typical rural interstate. Cost to ship goods via rail would also likely increase.[26]

2.3 Impacts on port community

High and low water levels alike can have numerous effects on inland waterway navigation and surrounding port communities. Waterway navigation impacts include delays, reductions in the volume freight that can be moved by barge, reductions in the number of barges that can be transported, increased cost of barge transportation and increases in truck traffic from mode shifts. In turn, these impacts can affect environmental and health conditions in nearby port communities and disrupt the local and regional economies by increasing road and rail congestion, road and rail infrastructure degradation, and local air emissions from the increased traffic. Other potential community impacts during a flood or storm surge event could include oil and hazardous material spills or shipping containers swept into neighborhoods. The Memphis assessment identified port terminal operators and individual shippers as the stakeholders most likely to bear the costs of extreme water levels—particularly in the short term—as they absorb any delays or product losses, but long-term costs will be distributed more broadly. Figure 2 summarizes illustrative port impacts and the cascading effects on port communities, local and regional economies, and the national economy.

[26] C. James Kruse, Annie Protopapas, and Leslie Olson, "A Modal Comparison of Domestic Freight Transportation Effects on the General Public: 2001-2009," *Texas Transportation Institute*, February 2012, http://www.nationalwaterwaysfoundation.org/study/FinalReportTTI.pdf.

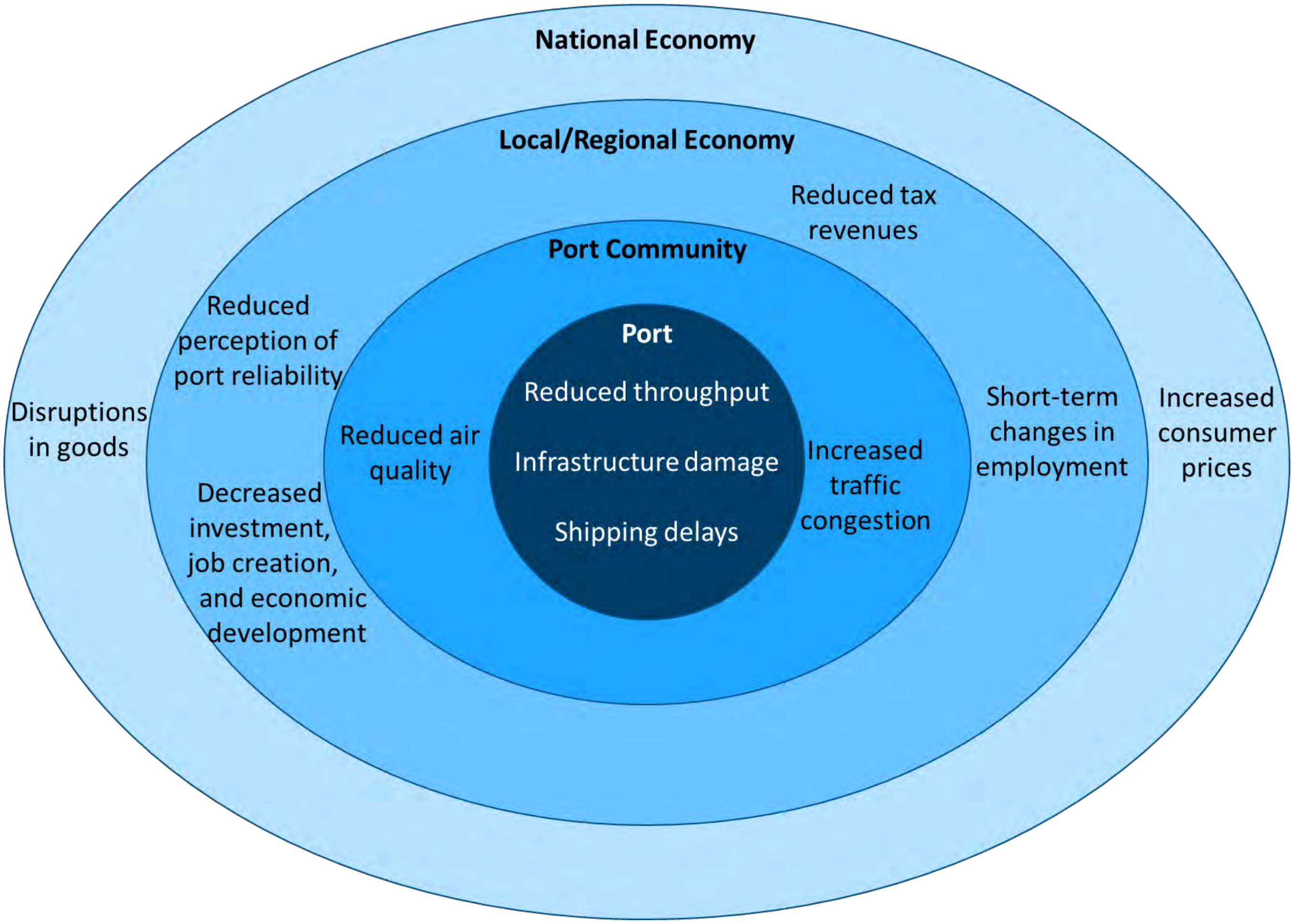

Figure 2: Illustrative summary of impacts of high and low water levels on inland ports, communities, and economies

Understanding systemic risks associated with severe weather to the inland waterway system is essential to proper resilience planning. Severe weather can affect port operations and impact businesses and communities along the river. The economic, social, and environmental impacts of disruptions in barge freight movements can be significant. By understanding these risks, inland ports can make plans to reduce their exposure to disruptions that may occur. Developing an outreach process with port stakeholders and the larger community to understand the magnitude of the potential impacts and developing strategies to address these risks can significantly reduce the negative impacts of high and low water levels when they occur.

3. Overview of roadmap for resilience

The ultimate goal of the roadmap is to increase inland *port community* resilience by increasing resilience of the inland *port* itself.

Port communities face many challenges including high probability, weather-related risks associated with flood and drought, and low-probability but extreme risks resulting from infrequent storms, or other hazards. This roadmap is focused on inland ports, which because of their inland locations, are less likely to experience risks associated with catastrophic events such as hurricanes. The roadmap is not intended to address all forms of risk or to guide emergency planning, but rather to offer a process and tools for increasing community resilience to dynamic conditions that routinely upset normal port operations resulting in environmental, economic, and even human health impacts that, with careful planning, can be avoided.

Port community resilience requires coordination and action from a variety of actors, including port stakeholders, local governments, and community stakeholders. While one entity—likely a port authority or local government office—may lead the effort, all stakeholders have a role to play.

This roadmap presents a series of steps to increase port resilience and, by association, port community resilience:

- Step 1 – Conduct Outreach and Identify Resilience Objectives
- Step 2 – Identify and Analyze Resilience Challenges
- Step 3 – Identify Strategies to Improve Resilience
- Step 4 – Develop Institutions and Performance Measures to Support Resilience Objectives
- Step 5 – Implement Strategies and Evaluate Progress

Each chapter provides background information, resources, and a checklist to facilitate building a project plan and taking action. The Table of Contents therefore can also double as a step-by-step guide for the actions that can be taken to increase the resilience of ports and port communities to changes in water levels.

Icons throughout the roadmap indicate which categories of stakeholders will play a key role in each step:

Lead organization (likely port authority or local government)

Port stakeholders

Local government stakeholders

Community stakeholders

III. Step 1 – Conduct Outreach and Identify Resilience Objectives

1. Improve routine communication among port community resilience stakeholders

In some ports and port communities, individuals from the port, local government, and community may not know each other or communicate regularly, particularly if they work in different organizations. Improving communication within port stakeholder networks and between port stakeholders, local government stakeholders, and community stakeholders is important for resilience.

In addition, stakeholder and expert relationships that may be important for resilience issues include academic or research organizations, USACE officials, or organizations involved in providing real-time water level monitoring. Private sector supply chain professionals may also have significant insight and data relevant to the resilience of freight operations. Resilience experts who can address planning and engineering challenges and community stakeholders who may be able to provide citizen science insights and data are also important to engage. Experts could include residents from near-port communities as well as representative vulnerable populations. EPA's Environmental Justice Screening and Mapping tool (EJSCREEN) can be used to ensure a representative sample of community stakeholders are

Notes

Example Port Community Resilience Stakeholders

Port Stakeholders

- Port authority or equivalent
- Private-sector port tenants
- Public-sector port tenants
- Port users (e.g., companies that rely on the port)
- Nearby industrial facilities
- Shippers
- Carriers
- Port workers
- Tug operators
- Riverboat pilots
- Coast Guard
- U.S. Army Corps of Engineers

Local Government Stakeholders

- Local government staff (planning, environmental, air quality, transportation)
- Regional planning staff (e.g., metropolitan planning organization)
- State agency representatives (e.g., environmental, transportation)

Community Stakeholders*

- Residents and homeowners in neighborhoods surrounding the port
- Faith-based organizations serving neighborhoods surrounding the port
- Community-based organizations serving neighborhoods surrounding the port
- National non-governmental organizations (NGOs) or affiliated chapters that represent the interests of the port community
- Academic and research organizations

Other Resilience Stakeholders

- Federal and state transportation departments
- Civil engineers
- Transportation planners
- Risk analysis experts

*U.S. Environmental Protection Agency, "Draft Environmental Justice Primer for Ports," *EPA-420-P-16-002*, Washington, D.C., 2016, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OYGB.pdf.

included in the conversations by identifying potentially affected minority and/or low-income populations.[27]

It can be useful to have key stakeholders on resilience issues communicate more regularly. If an emergency occurs, individuals who have pre-existing relationships will work together more effectively. In addition, by communicating more effectively, stakeholders can become more aware of what their partners are doing, and how their own activities may support them.

Communication and information sharing can be facilitated by in-person meetings, informal gatherings, a regular email newsletter, briefings, a LinkedIn group, or other electronic communication. Information dissemination could also be incorporated as a component of an existing communication from a port (e.g., a newsletter). This could be incorporated with the outreach process described above, or complement it by providing an additional avenue for communication.

The EPA Ports Initiative, which works in collaboration with the port industry, communities, and all levels of government to improve environmental performance and increase economic prosperity, is another resource for increasing communication and collaboration.[28] The EPA Ports Initiative resources include:

- Pilot Projects: Port and Near-Port Community Collaboration[29] – three pilot projects underway in Savannah, Georgia, New Orleans, Louisiana, and Seattle, Washington, for the EPA's Near-Port Community Capacity Building Project to test and build on the community engagement tools and resources
- Ports Primer for Communities[30] – interactive tool and reference document to help community leaders participate effectively in the decision-making process by increasing understanding of the role of ports and how ports can impact local land use, economic trends, and the environment, and by providing tools and resources that have been successful in other communities
- Community Action Roadmap: Empowering Near-Port Communities[31] – step-by-step guide to help port communities effectively engage in port decisions that may impact local land use, environmental health, and quality of life
- Environmental Justice Primer for Ports[32] – interactive tool and reference document with case studies to help port decision-makers understand the needs of near-port communities and

[27] U.S. Environmental Protection Agency, "EJSCREEN: Environmental Justice Screening and Mapping Tool," *EPA.gov,* accessed July 2017, www.epa.gov/ejscreen.

[28] U.S. Environmental Protection Agency, "Port Initiative," *EPA.gov*, accessed July 2017, https://www.epa.gov/ports-initiative.

[29] U.S. Environmental Protection Agency, "Pilot Projects – Port and Near-Port Community Collaboration," *EPA.gov*, accessed July 2017, https://www.epa.gov/ports-initiative/pilot-projects-port-and-near-port-community-collaboration.

[30] U.S. Environmental Protection Agency, "Draft A Ports Primer for Communities," *EPA-420-P-16-001*, Washington, D.C., 2016, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100P1UQ.pdf.

[31] U.S. Environmental Protection Agency, "Draft Community Action Roadmap," *EPA.gov*, accessed July 2017, https://www.epa.gov/ports-initiative/draft-community-action-roadmap.

[32] U.S. Environmental Protection Agency, "Draft Environmental Justice Primer for Ports," *EPA-420-P-16-002*, Washington, D.C., 2016, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OYGB.pdf.

how they can help address these needs and build productive community relationships during planning activities and operations

Checklist

- ✓ Compile a list of key stakeholders that could be affected by disruptions to the port. See Example Port Community Resilience Stakeholders text box.
- ✓ Reach out to experts who have knowledge and data that can provide advanced warning of high, low, or variable water levels on the river or local academics who may be studying port resilience.
- ✓ Establish a working group or committee to address resilience that consists of key stakeholders and experts, including community stakeholder representatives, as appropriate.
- ✓ Schedule regular meetings with key stakeholders.
- ✓ Share contact information between all parties. Consider other avenues for communication and information sharing and ensure there are both informal and formal avenues for communication among port stakeholders.
- ✓ Reassess key stakeholders and outreach candidates and determine if any others are needed. Establish communication and outreach with these additional stakeholders.
- ✓ Consult the EPA Ports Initiative website for a suite of collaboration resources.

2. Conduct research and communicate with stakeholders

One important component of outreach is to share information with stakeholders on why it is essential to address resilience. This step involves pulling together available information on extreme water levels, expected trends for those events, and the potential impacts on the port and port community. More details on analyzing this information are provided in Step 2.

This step also involves evaluating current land use plans, planning processes, and strategic planning documents to identify existing resilience planning efforts, barriers to implementing resilience measures, and opportunities for improvement. Determining whether resilience is being considered in the current planning process is an important output of this effort.

In gathering this information, the port authority or local government lead should meet with relevant stakeholders (e.g., shipping companies, government agencies, elected officials, nonprofit groups, community leaders, and academics) as done in the Port of Memphis assessment to identify challenges stakeholders face from extreme water levels as well as opportunities for increasing business and community resilience.

Resources for evaluating available information on past extreme water levels and their impacts to the port and port community include:

- Interviews or surveys of stakeholders about past events (see example questions in text box)

- Local news articles about past extreme water level events
- Disaster declaration records
- National Weather Service (NWS) Advanced Hydrologic Prediction Service data on river levels[33]
- Resources for identifying expected trends in extreme weather include: The National Climate Assessment
- The USACE climate change and hydrology literature assessments and analysis tool of river basins across the United States.

After assembling this information, the lead entity can communicate higher-level findings to other stakeholders that will build a "big picture" understanding of why planning for port resilience is an important issue for stakeholders. For example, it may be helpful to communicate potential impacts of extreme water level events on the local economy, air quality, health, and employment. Much of this information may already exist, but needs to be pulled together, packaged, and communicated to key stakeholders. A best practice is to use simple messages, repeated often from trusted sources.[34] Obtaining buy-in on the foundational concepts and principles behind resilience planning can help increase support for more concrete and specific goals and actions.

Checklist

✓ Begin the research process by evaluating available information on past extreme water levels and their impacts to the port and the port community.

Example Questions for Stakeholders about Past Extreme Events

Port Stakeholders

- What were the impacts of a previous extreme water level event on port facility infrastructure? Facility operations? Movement of goods? Staff ability to access the facility?
- What are your most pressing challenges related to facility maintenance and operations?
- Are there any key water level thresholds (low or high) that you watch for and at which point you change your operations?
- What data or information do you maintain on damages or maintenance costs associated with past events?

Other Stakeholders

- How much does the city coordinate with the port and local communities in times of extreme water levels and routinely?
- What were the impacts of a previous extreme water level event on air pollution? Noise pollution? Land-based transportation?
- Was there a plan in place for dealing with the impacts? If so, what were the successes and challenges of implementing the plan?
- What data or information do you maintain on pollution or transportation impacts associated with past events?

All

- How did you cope with the impacts?
- How long did it take to return to "business as usual"?
- Were problem areas fixed or upgraded after the last event? Do you think you would be more or less impacted by a future event?

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[33] National Weather Service, "Advanced Hydrological Prediction Service," *National Oceanic and Atmospheric Administration*, accessed 2017, https://water.weather.gov/ahps/.

[34] U.S. Environmental Protection Agency, "Reach Out & Communicate about Climate & Energy," *Climate and Energy Resources for State, Local and Tribal Governments*, accessed May 2017, https://19january2017snapshot.epa.gov/statelocalclimate/reach-out-communicate-about-climate-energy_.html.

✓ Identify, at a high level, expected trends in extreme water levels, such as those due to climate change. A more detailed assessment can occur later and is described in Step 2.

✓ Review and evaluate existing land use plans, current planning processes that are already in place, and any strategic planning documents that could be updated.

✓ Prepare a document to communicate a "big picture" understanding of why resilience is important in port communities and how impacts on the port can have larger implications for the local economy and community. See text box for tips for effective communication.

✓ Share information with stakeholders on why port resilience is an important issue.

Tips for Effective Communication*

- Define Objectives – Stay focused on the "**why.**" Consider the overarching goals of your project and communication strategy.
- Define and Understand Audiences – Get to know **who** you are trying to reach so that you can identify the most effective messages, channels, and methods to engage them. Determine what motivates those you want to reach, what they value, and who they trust.
- Develop and Test Key Messages and Frames – Messages will help you use **what** motivates stakeholders to accomplish your objectives. Research what has been done before; ask audiences what they want; test the effectiveness of messaging; and pick a simple message that can be repeated often by trusted sources.
- Develop a Timeline – Maximize impact by engaging stakeholders early and often, considering **when** there are critical project milestones and when people will be receptive to your message.
- Identify Channels – Determine **where** you will reach your audiences by considering how target audiences receive information and repeat messages over multiple channels.
- Select Methods and Trusted Messengers – Choose **how** your audience will receive the message (methods and messengers). Identify trusted sources to deliver your message and the most effective communication method for your message.

*U.S. Environmental Protection Agency, "Reach Out & Communicate about Climate & Energy," *Climate and Energy Resources for State, Local and Tribal Governments*, accessed May 2017, https://19january2017snapshot.epa.gov/statelocalclimate/reach-out-communicate-about-climate-energy_.html.

3. Identify resilience goals and objectives

In order to improve the resilience of the port, community, and economy, it is necessary to first identify the desired performance level of the port, community, and economy during and following an extreme water level event. This will facilitate identifying goals and objectives for achieving and maintaining that desired level of performance. By defining specific and actionable goals, private and public sector partners can be encouraged to focus their efforts on initiatives that support these goals. One way to measure resilience, for example, would be to measure whether the port community would be the same (or otherwise acceptable) levels of operational, social, environmental, and economic functioning at extreme water levels as at normal water levels.

In addition, port stakeholders can gain awareness of how their own ongoing activities may be prioritized to support their own resilience, particularly when identifying vulnerabilities and implementing resilience strategies. To be resilient, port communities should effectively balance economic, environmental, and societal benefits and costs associated with marine transportation system operations. Insert

Specific goals can be identified for multiple areas, including improving the resilience of port infrastructure operations, the port community, environmental and human health, and the local economy, as detailed below.

Each set of stakeholders should articulate their resilience goals and objectives to inform a coordinated resilience effort.

3.1 Port infrastructure and operations goals

Port stakeholders developing resilience goals for infrastructure and operations might consider the following "functioning" measures:

- Port operational functioning:
  - Number of barges loaded/unloaded per day
  - Volume of freight movements through the port
  - Employees unable to access port facilities
  - Portion of operations that could function on backup power sources
  - Backup power capacity
  - Operation of power lines
  - Product inventory damaged in flooding
- Infrastructure functioning:
  - Integrity of road infrastructure under various water level scenarios and operational scenarios (i.e., volume of freight movement via truck)
  - Integrity of rail infrastructure under various operational scenarios (i.e., volume of freight movement via rail)
  - Integrity of drinking water and sewage infrastructure under various scenarios

Therefore, actionable goals might include target levels of functioning, such as:

- Move X amount of freight per day regardless of water levels
- Minimize disruptions from extreme events to fewer than X hours per event
- Maintain the integrity of road infrastructure under a high operational scenario of X volume of freight movement via truck

There are many cases where improving port resilience will also improve the efficiency and value of port infrastructure. Having targeted resilience goals will help make clear how improving resilience is consistent with existing business, operational, environmental, and community goals that may exist. Measurable and actionable goals will also help with identifying appropriate resilience strategies and tracking resilience progress.

Checklist

- ✓ Evaluate existing data on barge activity such as number of barges loaded/unloaded per day and whether or not barge activity levels may be affected by extreme water levels.
- ✓ Identify actionable resilience goals to maintain port operations and infrastructure.

Notes

3.2 Port community goals

Port communities can also experience impacts from port operational disruptions and should increase their resilience as well. Near-port community infrastructure (e.g., roads, bridges), networks (e.g., neighborhoods, churches, businesses, schools), and individuals are all impacted by port operational disruptions, although the impacts may not always be immediately perceived. In addition, other community infrastructure could be affected by the same events that disrupt the port—especially in the case of flooding.

Local effects may include environmental risks, such as flooding or drought conditions, water quality and pollution concerns; noise pollution from port, truck, and marine vessels; health risks such as higher concentrations of air pollutants; changes in port employment needs; roadway congestion; and safety concerns from truck traffic passing through neighborhoods near the port. Further, the residential neighborhoods near inland ports—those most likely to be affected by port disruptions—may often be home to overburdened communities with lower incomes or other disadvantaged demographic groups. These communities often face a cumulative burden of local impacts due to their proximity to polluting industries and lack the resources to respond or recover from the impacts (e.g., transportation to evacuate during a flood disaster, healthcare to cover the consequences of higher air pollutant exposure, access to information).[35]

One way for local governments to reduce near-port community impacts is to set environmental justice goals to reduce disparate impacts of the port and the freight transportation system on local citizens. Guidance from the National Environmental Justice Advisory Council to the EPA recommends goals focused on zoning and land use decisions, emergency planning and preparedness, climate adaptation planning including green infrastructure and built

Key Definitions

This roadmap uses these key terms as follows:

- **Environmental justice** – The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.*
- **Overburdened communities** – Overburdened describes ethnic, minority, low-income, tribal, and indigenous populations or communities in the United States that potentially experience disproportionate environmental harms and risks due to exposures or cumulative impacts or greater vulnerability to environmental hazards. This increased vulnerability may be attributable to an accumulation of both negative and lack of positive environmental, health, economic, or social conditions within these populations or communities, including the inability to participate meaningfully in the decision-making process.†

*U.S. Environmental Protection Agency, "Environmental Justice," *EPA.gov*, accessed July 24, 2017, https://www.epa.gov/environmentaljustice.

†U.S. Environmental Protection Agency, "Plan EJ 2014," Washington, D.C., 2011, https://nepis.epa.gov/Exe/ZyPDF.cgi/P100DFCQ.PDF?Dockey=P100DFCQ.PDF.

[35] Community Resiliency in Environmental Justice Industrial Waterfront Communities Work Group, "Proposed Recommendations for Promoting Community Resilience in Environmental Justice Industrial Waterfront Areas," *National Environmental Justice Advisory Council*, May 2015, https://www.epa.gov/sites/production/files/2016-08/documents/communityresilienceinejindustrialwaterfrontcommunities.pdf.

environment measures, upgrading and retrofitting utilities and infrastructure, and pollution prevention strategies.[36]

Improving planning and flood adaptation and mitigation efforts can help local communities increase their resilience to extreme weather events and the subsequent port operational disruptions. Other resources for developing community resilience goals include:

- The Rockefeller 100 Resilient Cities Framework[37]
- The National Institute of Standards and Technology (NIST) Community Resilience Planning Guide [38]

[36] Community Resiliency in Environmental Justice Industrial Waterfront Communities Work Group, "Proposed Recommendations for Promoting Community Resilience in Environmental Justice Industrial Waterfront Areas," *National Environmental Justice Advisory Council*, May 2015, https://www.epa.gov/sites/production/files/2016-08/documents/communityresilienceinejindustrialwaterfrontcommunities.pdf.

[37] The Rockefeller Foundation, "The City Resilience Framework," *100 Resilient Cities*, accessed 2017, http://www.100resilientcities.org/resilience#/-_/.

[38] National Institute of Standards and Technology, "Community Resilience Planning Guide for Buildings and Infrastructure Systems," *NIST Special Publication 1190-1*, Washington, D.C., 2016, https://www.nist.gov/sites/default/files/community-resilience-planning-guide-volume-1_0.pdf.

- The U.S. Climate Resilience Toolkit[39]

Measures of social "functioning" that may help to create targeted community resilience goals for these topics may include:

- Roadway congestion (e.g., volume/capacity ratios)
- Homes, businesses, and schools flooded
- Homes, businesses, and schools with flood insurance
- Number of hospital visits
- Respiratory illness rates
- Life expectancy
- Unemployment levels
- Emergency power generation emissions

Therefore, targeted community resilience goals may include:

- Reduce roadway congestion from X volume/capacity ratio to Y volume/capacity ratio
- X percent unemployment rate
- Increase flood resilience efforts such as implementing Community Rating System[40] floodplain management activities, green spaces with water retention ponds, bioswales, permeable pavement, and other green infrastructure options
- Decrease disproportionate impacts on minority and low-income populations in near-port communities from port-related activities such as diesel emissions from truck traffic congestion or oil and hazardous material spills during flood events
- Update local planning documents and emergency procedures
- Update zoning laws to create a buffer between port activities and residential areas

Checklist

✓ Identify a representative group of stakeholders across the near-port community to work together to create actionable goals for near-port community resilience to port disruptions.

✓ Consult the EPA Ports Initiative's near-port community capacity building and engagement tools (described under Step 1.1).[41]

[39] National Oceanic and Atmospheric Administration, "U.S. Climate Resilience Toolkit," *Toolkit.Climate.gov,* accessed May 2017, https://toolkit.climate.gov/.

[40] Federal Emergency Management Agency, "Community Rating System," *Department of Homeland Security*, accessed 2017, https://www.fema.gov/national-flood-insurance-program-community-rating-system.

[41] U.S. Environmental Protection Agency, "Near-Port Communities," *EPA.gov*, accessed 2017, https://www.epa.gov/ports-initiative/near-port-communities.

✓ Develop actionable community resilience goals to increase the resilience of the local community to extreme weather events and port disruptions. Goals could address impacts such as environmental justice issues, flooding, or road congestion.

3.3 Environmental and human health goals

Ports produce a spectrum of environmental and health effects, including noise pollution, air pollution, water pollution, and solid waste. EPA's EJSCREEN[42] and Community-Focused Exposure and Risk Screening Tool (C-FERST)[43] can help port and community stakeholders develop environmental and human health goals. EJSCREEN allows users to assess environmental and demographic indicators and C-FERST allows users to explore exposure and risk reduction options. The C-FERST Issue Profiles contain links and information about specific environmental issues that may be of concern. Profiles are also provided on other topics that may be beneficial to communities including brownfields, smart growth, and healthy housing.

Air emissions are one of the most prominent impacts. In order to develop appropriate air emissions reduction goals and objectives, ports should conduct a baseline emissions inventory of all equipment associated with the port. This includes the barge emissions, truck emissions, cargo handling equipment, and other associated sources.

Mode shifts that may occur if barge transportation operations are disrupted could increase air pollutant emissions in port communities. During an extreme water level event, air emissions will increase from the number of trucks needed to replace barges, and potentially from emergency power generation sources. Reducing air emissions from the existing freight transportation system is one way to minimize the air emissions impacts of mode shifts on human health.

[42] U.S. Environmental Protection Agency, "EJSCREEN: Environmental Justice Screening and Mapping Tool," *EPA.gov,* accessed July 2017, www.epa.gov/ejscreen.

[43] U.S. Environmental Protection Agency, "Community-Focused Exposure and Risk Screening Tool (C-FERST)," *EPA.gov*, accessed 2017, https://www.epa.gov/c-ferst.

Other measures of environmental and health “functioning” may include:

- Particulate matter, ozone, and other pollutant levels estimated through inventory or air monitoring
- Asthma-related hospitalizations
- Water pollution levels
- Noise decibel measures in the community
- Solid waste production

Therefore, actionable environmental and health goals can involve targeted reductions in air emissions and other pollutants, such as:

- Reduce X pollutant emissions/levels by Y percent
- Maintain X air quality during extreme events
- Decrease asthma-related hospitalizations by X percent
- Reduce the air emissions of truck activity by X percent

Checklist

✓ Conduct a baseline emissions inventory of all equipment associated with the port.

✓ Identify and learn more about potential environmental and human health issues using EJSCREEN[44] and EPA’s Community-Focused Exposure and Risk Screening Tool (C-FERST).[45]

✓ Identify actionable resilience goals to reduce air emissions from mode shifts and emergency power generation during extreme water level events.

✓ Identify actionable resilience goals to reduce emissions from trucks serving the port.

✓ Identify actionable resilience goals to reduce other pollutants such as noise, water, and solid waste.

3.4 Economic goals

Economic resilience goals could include providing the capacity to transport freight by alternative modes. Barge transportation is often the least costly way to transport bulk commodities for industries located near an inland waterway. If flooding or low water disrupts barge operations, having access to rail transportation can allow businesses to continue to operate with minimal

[44] U.S. Environmental Protection Agency, “EJSCREEN: Environmental Justice Screening and Mapping Tool,” *EPA.gov,* accessed July 2017, www.epa.gov/ejscreen.

[45] U.S. Environmental Protection Agency, “Community-Focused Exposure and Risk Screening Tool (C-FERST),” *EPA.gov*, accessed 2017, https://www.epa.gov/c-ferst.

economic disruption. Providing bulk freight transportation alternatives is one way to reduce the cost impacts of flooding and low water on barge freight movements and local industries.

Other economic resilience goals could focus on diversifying the port community's economy. If the economy is reliant on only a few barge-dependent industries, the impacts of flooding and drought on economic activity will be more pronounced. Economic diversification of the local economy is a broader and longer-term strategy that can be pursued to make a port community more economically resilient. Obtaining an understanding of how reliant a local economy is on inland waterway transportation can be a first step in defining an economic resilience goal.

Resilience goals should also focus on maintaining economic growth. Measures of economic "functioning" to consider under extreme water level conditions might include:

- Feasibility (capacity and competitiveness) of alternate modes to transport river freight
- Unemployment levels
- Wage levels

Therefore, actionable economic resilience goals might include establishing target levels of functioning, such as:

- Expanding industry access to roads, rail, or other alternative freight modes
- Hiring X temporary employees during extreme water level events to maintain operations
- Expanding or improving road or rail infrastructure to attract industries that are not as heavily dependent on port transportation

Checklist

✓ Identify actionable resilience goals for improving the access of barge-dependent industries to alternative low-cost transportation options during flooding or low water events.

✓ Identify actionable resilience goals to diversify economic activity in the port community.

IV. Step 2 – Identify and Analyze Resilience Challenges

1. Define baseline commodity flow and transportation scenario

The first step to identify and analyze resilience challenges is to understand what freight is moving in a region and what freight flows are forecast based on existing trends. This can serve as a baseline to measure how changes in the reliability and cost of inland waterway freight transportation may affect the business-as-usual freight movement scenario. Port stakeholders will be central to this effort.

Sources of data include:

- Waterborne commerce statistics – provides data on waterborne freight movements by port, waterway, origin, and destination, as well as whether freight is moving up- or down-river
- USACE – may have more detailed data on freight tonnage moving to individual docks, but this is often considered confidential business information that can only be used with special permission
- Freight Analysis Framework (FAF) – FAF public data provides data on freight tonnage moved by all modes (air, truck, rail, marine) for "port regions"
- Local metropolitan planning organizations (MPOs) or state departments of transportation (DOTs)
- Individual port stakeholders

Baseline freight flows are typically developed by commodity, origin, and destination. The time of year freight flows occur could be important to estimating the impact of seasonal flooding, although this type of data is not typically available in existing databases. Developing an understanding of freight flows to and from the port is the first step in understanding the vulnerabilities of the port and local economy to disruptions in barge transportation and the potential for mode shifts. Port stakeholders should therefore be aware of port operations information such as whether any specialized equipment is used to move specific freight commodities or if the port is vulnerable to freight traffic disruptions at particular times of year or between particular origins and destinations.

Port stakeholders should also consider how freight flows may change in response to major projects and economic drivers such as the Panama Canal expansion completed in June 2016, which may change the quantity or type of freight moving through a given port. Although port-specific projections remain uncertain, the Panama Canal expansion is expected to significantly alter freight flows across the United States. Ships are now able to carry up to 13,200 containers instead of 4,400 containers through the Canal between the Pacific and the Atlantic Ocean.[46] This means, for example, that many shipments from Asia that previously went to West Coast ports to be transported by rail or truck throughout the United States, may instead come through the Canal to Gulf Coast or East Coast ports.[47] Higher quantities of freight can be moved through the Canal faster and more cost efficiently. The Port of Memphis is one of the U.S. ports that may see higher freight flows as a result of the expansion and because of the port's prime proximity to rail and truck routes.

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[46] Sarah Baker, "The Panama Effect: Canal Expansion Should Spark More Cargo, CRE Demand in Memphis," *Memphis Daily*, March 18, 2013, https://www.memphisdailynews.com/news/2013/mar/18/the-panama-effect/print.

[47] William Fierman, "The New Panama Canal is Opening Soon and will cause an 'Evolution' in a Vital US Industry," *Business Insider*, May 8, 2016, http://www.businessinsider.com/panama-canal-rail-2016-4.

Checklist

- ✓ Review data on freight moving through the port, including freight flows by commodity and freight flows by origin, destination, and time of year, if possible.
- ✓ Define a baseline freight flow and transportation scenario given the data available.
- ✓ Consider how the Panama Canal expansion and other drivers may affect the baseline commodity flow or transportation scenario.
- ✓ Share information on port operations with port stakeholders.

2. Identify recent and expected trends in extreme events

Next, identify recent and expected trends in extreme events to better understand if and how extreme water levels are changing over time. This can inform a range of plausible scenarios and assessment of potential impacts under those scenarios.

Changes in the frequency, intensity, and duration of extreme weather events such as drought and floods appear likely to increase in the future. Extreme temperatures are expected to increase in the lower Mississippi River basin, for example, which could cause synergistic impacts with changes in seasonal rainfall and contribute to more frequent and severe droughts. While average rainfall is difficult to predict, more rain will likely fall as heavy downpours leading to higher flooding potential.[48]

The following resources provide information on recent and expected trends:

- **U.S. Geological Survey (USGS) National Water Information System (NWIS)** (recent trends) – NWIS provides real-time and historical data at stream and river gauges across the country, including high and low water records.[49]
- **USACE Nonstationarity Detection Tool** (recent trends) – This web tool allows the user to apply a series of statistical tests to assess the stationarity of annual peak streamflow data series at any USGS annual instantaneous peak streamflow gage site with sufficient data. For example, the tool shows that for the St. John River at Nine mile Bridge, Maine, there has been a statistically significant increase in peak flows (see Figure 3).[50]

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[48] Jerry M. Melillo, Terese (T.C.) Richmond, and Gary W. Yohe, "Climate Change Impacts in the United States: The Third National Climate Assessment," U.*S. Global Change Research Program*, U.S. Government Printing Office, Washington, D.C., 2014, doi:10.7930/J0Z31WJ2.

[49] U.S. Geological Survey, "National Water Information System," *USGS.gov*, accessed May 2017, https://waterdata.usgs.gov/nwis.

[50] U.S. Army Corps of Engineers, "Nonstationarity Detection Tool (NSD) – PROD," *US Army Corps of Engineers,* accessed 2017, http://corpsmapu.usace.army.mil/cm_apex/f?p=257:2:0::NO::::.

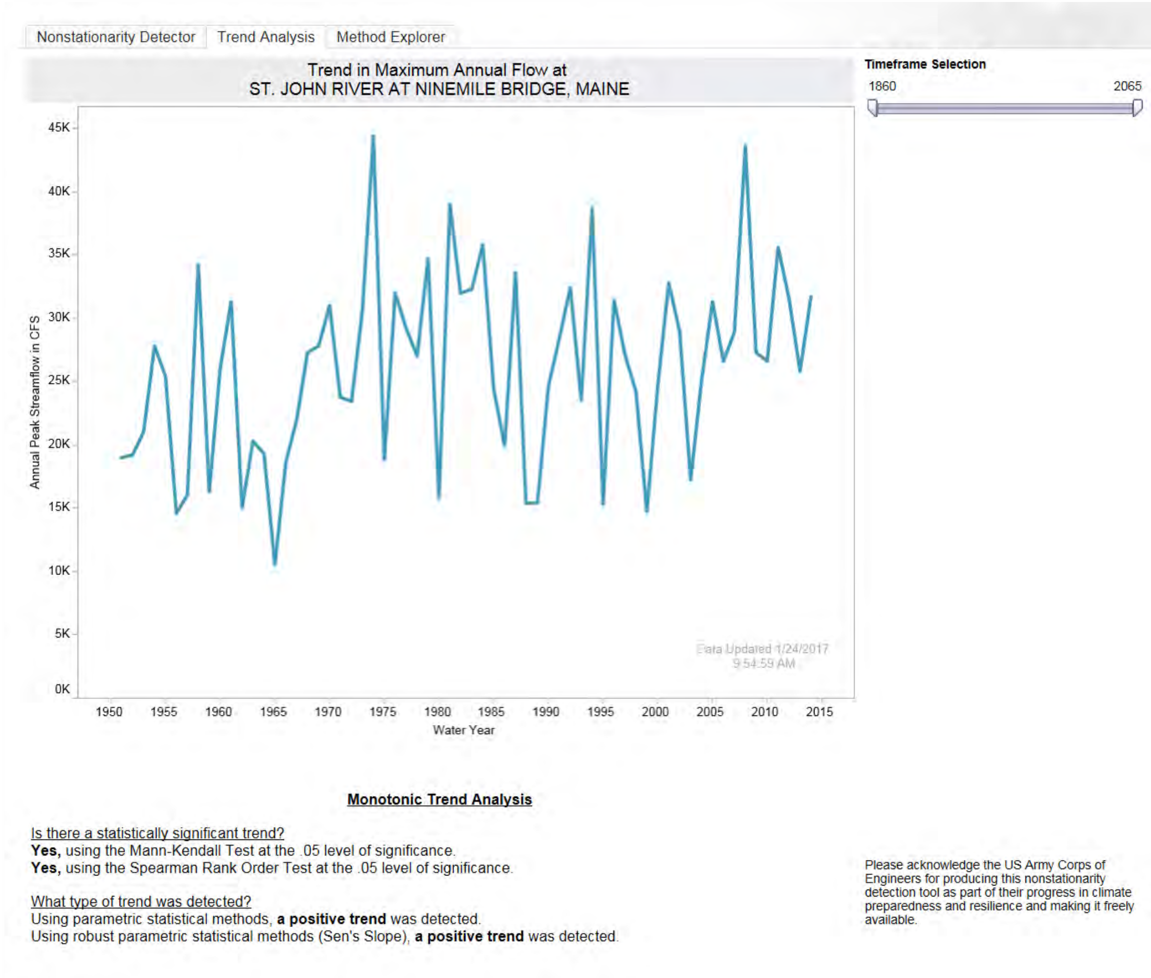

Figure 3: USACE Nonstationarity Detection Tool trend analysis screenshot

- **USACE Climate Hydrology Assessment Tool** (recent and expected trends) – This web tool accompanies USACE's Engineering and Construction Bulletin 2016-25, Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects.[51] The tool walks the user through the process of detecting trends in observed annual peak instantaneous streamflow, climate-modeled projected annual maximum monthly flow range, and trend detection in annual maximum monthly flow models. For example, Figure 4 shows results for the Lower Mississippi-Hatchie watershed [Hydrologic Unit Code (HUC) 0801]. The blue line shows the projected annual maximum monthly streamflow, and the yellow bars show the range.[52]

[51] U.S. Army Corps of Engineers, "Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects," *Engineering and Construction Bulletin 2016-25*, Washington, D.C., 2016, http://www.iwr.usace.army.mil/Portals/70/docs/Climate%20Change/ecb_2016_25.pdf.

[52] U.S. Army Corps of Engineers, "Climate Hydrology Assessment Tool – PROD," *U.S. Army Corps of Engineers,* accessed 2017, http://corpsmapu.usace.army.mil/cm_apex/f?p=313:2:0::NO.

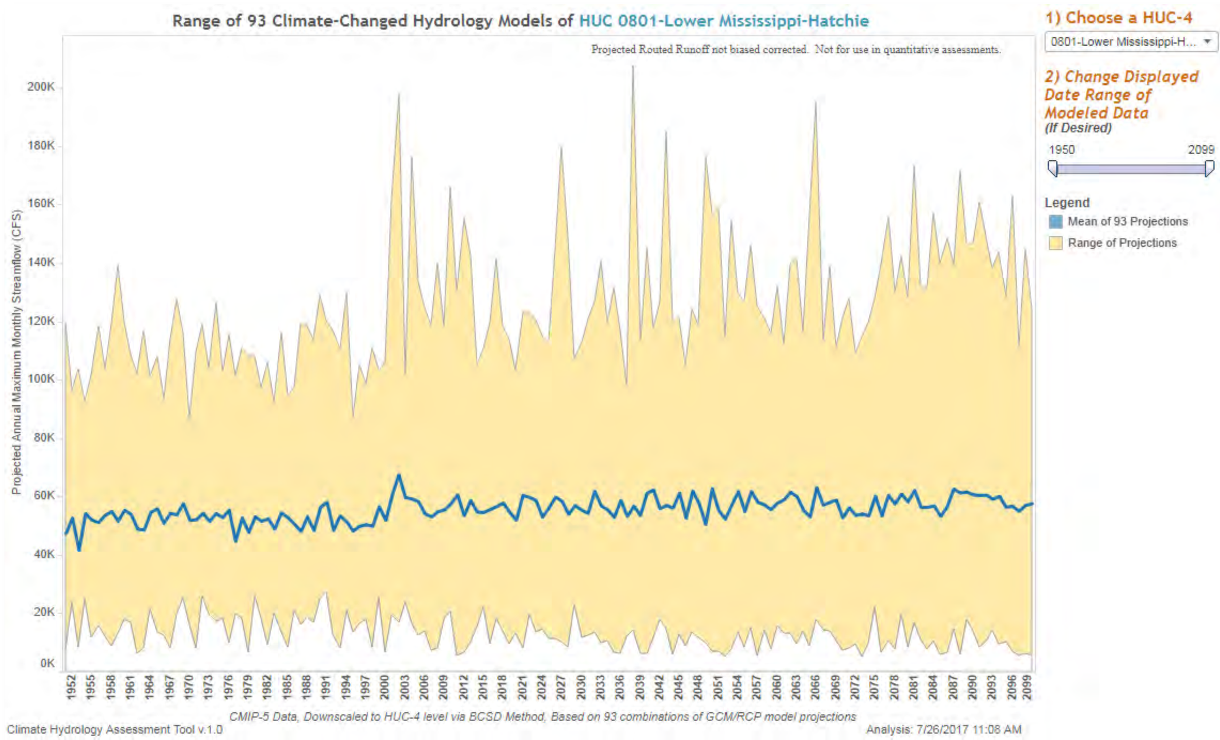

Figure 4: USACE Climate Hydrology Assessment Tool hydrology projections screenshot

- **USACE climate change and hydrology literature reviews** (expected trends) – In 2015, USACE commissioned a series of literature reviews on climate change potentially affecting operations in various USACE Regions. Each of the 21 regional reports "summarizes observed and projected climate and hydrological patterns cited in reputable peer-reviewed literature and authoritative national and regional reports, and characterizes climate threats to USACE business lines."[53] These reviews provide higher-level information than the two previously mentioned tools.

For example, recent and expected trends for the Port of Memphis include:

- Expected increases in the frequency and areal extent of droughts (of at least 12-month duration) in the lower Mississippi River basin.[54]
- Expected increases, albeit relatively small, in the number of high (>10 mm) precipitation days for the region, the number of storm events greater than the 95th percentile

[53] U.S. Army Corps of Engineers, "Responses to Climate Change Program: Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions," *U.S. Army Corps of Engineers*, revised September 30, 2015, http://www.corpsclimate.us/rccciareport.cfm.

[54] E. Joetzjer, H. Douville, C. Delire, P. Ciais, B. Decharme, and S. Tyteca, "Hydrologic benchmarking of meteorological drought indices at interannual to climate change timescales: A case study over the Amazon and Mississippi river basins," *Hydrology and Earth System Sciences* 17, (2013): 4885-4895, doi.org/10.5194/hess-17-4885-2013.

of the historical record, and the daily precipitation intensity index (annual total precipitation divided by number of wet days).[55]

While the Mississippi River is highly managed, changes in heavy precipitation events leading to flooding, along with the potential for increased droughts could exacerbate challenges to existing inland port operations. These events could also create further disruptions in the social and economic conditions within the surrounding community. Ports should collect data and review severe weather trends to understand better their vulnerabilities to severe weather, and the need for strategies to enhance resilience.

Checklist

- ✓ Collect and summarize information on extreme weather trends.
- ✓ Provide stakeholders with information pertaining to the impacts of drought and flooding on the river to understand the magnitude of the potential risks.
- ✓ Communicate with the USACE to understand how extreme weather and river water levels affect river management.

3. Identify extreme water level scenarios with specific impacts on navigation and costs

Next, identify potential high and low water level scenarios to determine potential impacts of events and facilitate resilience planning.

3.1 High water events (floods)

Port operations are highly sensitive to variable and extreme water levels on the river. High water levels can flood ports, damage port infrastructure, damage cargo, create safety risks for port workers, and shut down operations for days at a time. Floods that affect the port may also affect nearby communities (including residences) and other infrastructure, such as access roads, rail lines, and utilities, on which the port and community depend.

Defining a high water scenario involves using recent and expected trends to develop one or more scenarios for how many additional high water events may occur and how large those events might be. Based on these scenarios, the impacts and costs of these floods can then be estimated, and the vulnerability of port operations can be assessed.

For example, the Mississippi River at Memphis has experienced two of its highest all-time crests since 2011.[56] River gauge records indicate that river levels on the lower Mississippi have become increasingly variable over time. In addition to year-to-year variability (Figure 5), in

[55] U.S. Army Corps of Engineers, "Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions: Lower Mississippi Region 08," *U.S. Army Corps of Engineers*, September 1, 2015, http://www.corpsclimate.us/docs/rccvarreports/USACE_REGION_08_Climate_Change_Report_CWTS-2015-01_Lo.pdf.

[56] National Weather Service, "Advanced Hydrologic Prediction Service," *National Oceanic and Atmospheric Administration*, accessed 2017, http://water.weather.gov/ahps.

recent years river levels have fluctuated up to 3 feet within a single day, and 7–8 feet over two days (Figure 6).

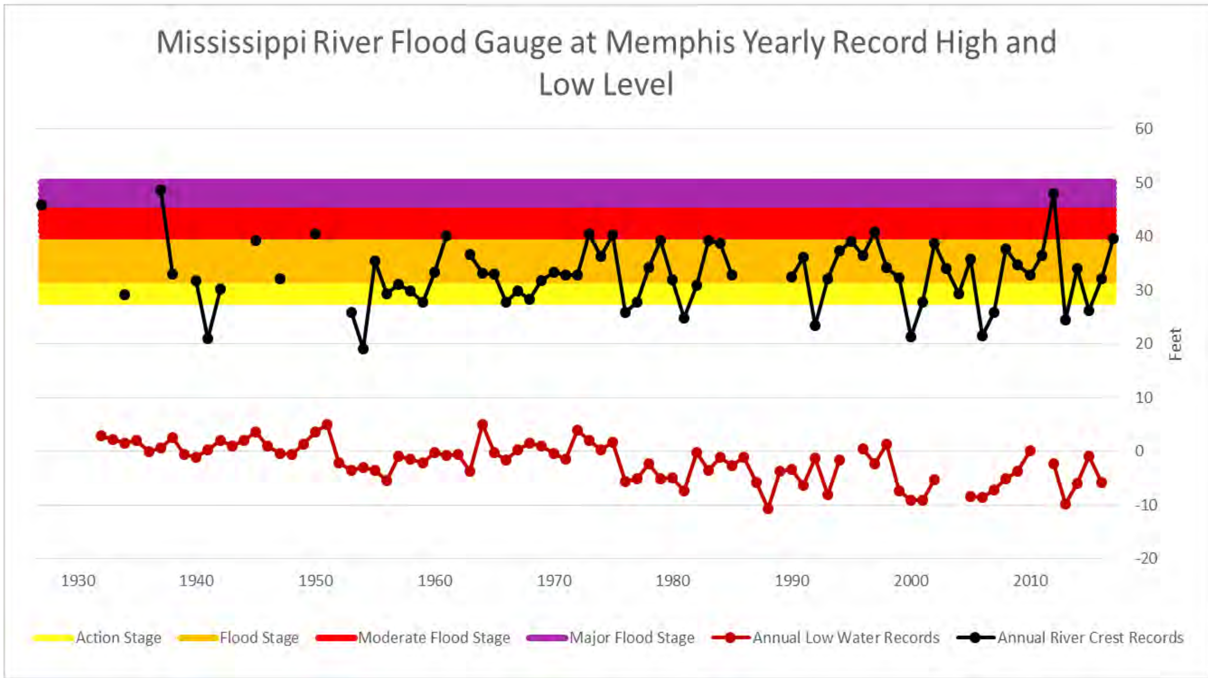

Figure 5: Annual high and low river levels, Mississippi River at Memphis, 1927–2016 (chart developed by ICF using data from National Weather Service Advanced Hydrologic Prediction Service, Mississippi River at Memphis (MEMT1)

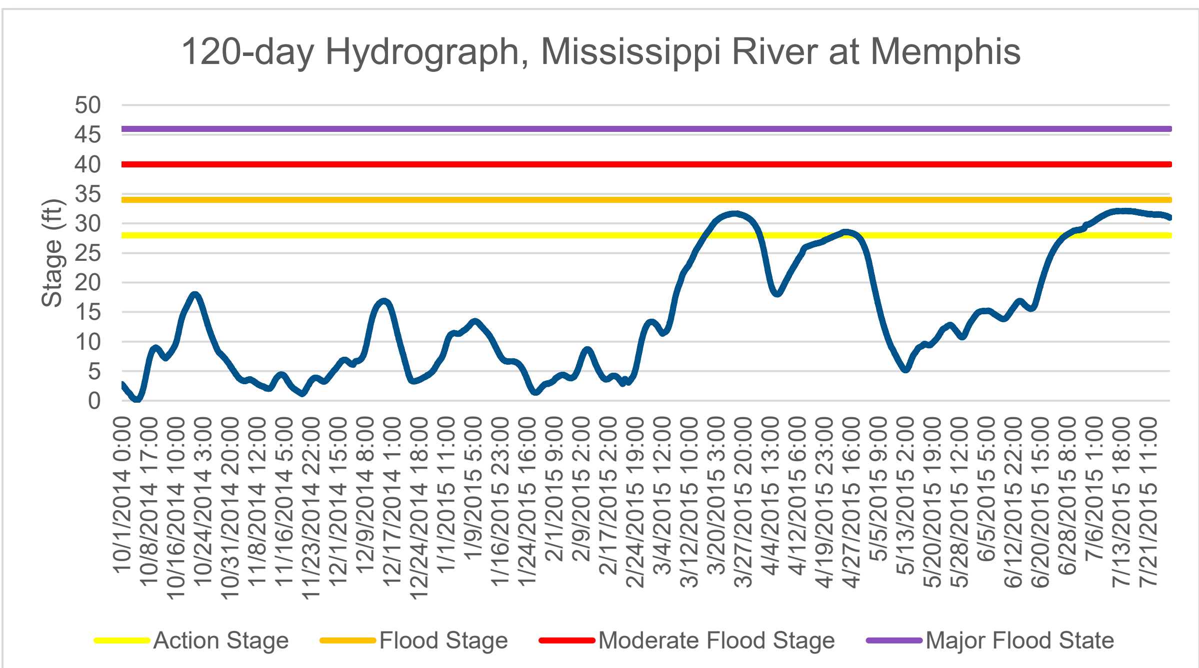

Figure 6: Example hourly river levels (shown for the 120-day period, 10/1/2014–7/21/2015) (chart developed by ICF using data from USGS National Water Information System, Mississippi River at Memphis)

Variability in river levels disrupts port operations. For instance, high water situations can flood port facilities, damage cargo, and create safety risks for port workers. Low or high water levels can also impede the loading and unloading of barges.

Extreme weather event scenarios, such as events like Superstorm Sandy, should also be considered. Many ports along the East Coast faced damages and/or closures due to Superstorm Sandy. National Cooperative Freight Research Program (NCFRP) Report 30 completed a Superstorm Sandy case study profiling six port terminals under the control of the Port Authority of New York and New Jersey. In addition to the extensive damage to the ports and storage facilities, all other alternative modes of freight transport were also affected. Roadways, railways, and airports also experienced damage and limited operations during and immediately following the storm. An extreme event similar to Superstorm Sandy that goes beyond just flooding impacts could temporarily paralyze shipping operations and therefore should also be considered as a “worst-case” scenario.

Resources for collecting data on the prevalence and likelihood of flooding include:

- NWS Advanced Hydrologic Prediction Service[57]
- The USGS National Water Information System[58]
- USACE Climate Hydrology Assessment Tool[59]

Checklist

- ✓ Collect data on the prevalence and likelihood of flooding.
- ✓ Explore event histories and future outlooks for weather-related changes in water levels from flooding. Examine related impacts of erosion on riverbanks and navigation channels.
- ✓ Develop high water event scenarios based on historical data and projected changes in the future.
- ✓ Identify critical threats to the port community as illustrated by the historical level of severity and frequency of events.
- ✓ Establish an understanding of how management of the river by the USACE or others affects river variability.

[57] National Weather Service, “Advanced Hydrologic Prediction Service,” *National Oceanic and Atmospheric Administration*, accessed 2017, http://water.weather.gov/ahps.

[58] U.S. Geological Survey, “National Water Information System,” *USGS.gov,* accessed May 2017, https://waterdata.usgs.gov/nwis.

[59] U.S. Army Corps of Engineers, “Climate Hydrology Assessment Tool – PROD,” *U.S. Army Corps of Engineers,* accessed 2017, http://corpsmapu.usace.army.mil/cm_apex/f?p=313:2:0::NO.

3.2 Low water events (droughts)

Port operations are highly sensitive to extreme low water levels on the river, as well as to extreme high levels. For instance, high or low water events could affect the vulnerability of navigation channel depths and allowable drafts to erosion or other changes in the river bed. In low water situations, inland waterways have less capacity to handle freight. For instance, on the Mississippi River, barges must reduce their loads and the number of barges that can pass through the river at a given time can be restricted. A 2012 drought event on the Mississippi River, for example, affected the Port of Memphis by disrupting shipping operations, closing the Kinder Morgan terminal for nine months until barges could reach the docks, stranding hundreds of barges, and causing Ingram Barge to cut its shipping volume by 40 percent.[60]

Implications of Low Water Levels for Freight Movement

- For every 1 inch of lost water, each barge is unable to move 17 tons of cargo.*
- Typical tow on the Lower Mississippi is 30–45 barges,* meaning decreased capacity of up to 765 tons for 1 inch of lost water.
- Cargo capacity (dry tons):
  - Barge: 1,750 tons
  - Rail car: 110 tons
  - Truck: 25 tons

*American Waterways Operators, "Nation's Waterways Operators Concerned about Impact of Drought Conditions, Low Water Levels," *American Waterways Operators*, July 20, 2012, http://www.americanwaterways.com/media/press/2012/nation%E2%80%99s-waterways-operators-concerned-about-impact-drought-conditions-low-water-0.

†C. James Kruse, Annie Protopapas, and Leslie Olson, "A Modal Comparison of Domestic Freight Transportation Effects on the General Public: 2001-2009," *Texas Transportation Institute*, February 2012, http://www.nationalwaterwaysfoundation.org/study/FinalReportTTI.pdf.

When freight cannot pass on the river, shippers have several options, including: wait until water levels rise, dredge to maintain port operations (at significant additional cost), divert freight to an alternate port or river, divert freight to rail, or divert freight to truck. Decisions about how to move individual units of cargo during an event rests with the product owners and is dependent on factors such as time sensitivity of delivery, global prices for the product, capacity of alternate modes, prices on alternate modes, and the availability of infrastructure to support transfer. Some industries, like oil refining, can only move product by barge (because it is too large or requires specialized containers to transport by any other means), so refineries are forced to limit production until the product can be moved. When river levels are too low, barges may need to reduce their tonnage in order to navigate the river. This can increase the cost per ton.

As discussed previously (recall Figure 2, for example), when low water events impair waterway throughput, this can lead to several cascading effects throughout the port community, local economy, and national economy. For example, freight diversions to truck could increase local air pollution near the port, increase prices for consumer goods, and lead to reduced perceived reliability of the port for potential investors.

Defining a low water scenario involves identifying one or more scenarios for however many days river traffic may be restricted due to lower water. In addition, estimates of the level of

[60] Wayne Risher, "Ripple effect – Low water cuts into shipping volumes, raises costs," *Commercial Appeal*, July 17, 2012, https://www.pressreader.com/usa/the-commercial-appeal/20120717/281956014900580.

restriction are also needed. How many days would inland waterways be closed? How many barges would be delayed and for how long? How many days would there be draft restrictions for barges and what level of restrictions would there be? One or more scenarios could be developed based on historical impacts of low water events and trends in extreme weather.

Checklist

- ✓ Develop low water event scenarios based on historical data and projected changes in the future.
- ✓ Identify critical threats to the port community as illustrated by the historical level of severity and frequency of events.
- ✓ Establish an understanding of how management of the river by the USACE affects river variability.
- ✓ Explore event histories and future outlooks for weather-related changes in water levels from drought. Examine related impacts on navigation channels.

4. Conduct research to understand how mode shifts occur

If extreme water levels—particularly low water levels— increase the cost or transit time of barge transportation, freight may be shifted to truck or rail transportation modes. The types of mode shifts that are likely can be difficult to predict, and will be determined in real-time by the length of haul, type of commodity, availability of alternative modes, cost of alternatives, service requirements, infrastructure, and competitiveness of industries. Table 1 shows some key factors that affect mode shifts.

Notes

Table 1: Key Factors Affecting Mode Shifts

Factors affecting mode shifts	Potential impact
Length of haul	Long hauls would tend to be shifted to rail, while shorter hauls would tend to be shifted to truck. Route circuitry may vary depending on origins and destinations.
Availability of competing transportation modes	Rail facilities are fixed in place, so may only be available to some shippers or receivers.
Commodity value	Lower value commodities will be more sensitive to the cost of transportation since transportation may represent a larger percentage of the price paid by the consumer. Increases in transportation costs will increase the price of these commodities more, and could reduce demand.
Service requirements	Some commodities may be less sensitive to transportation disruptions since they can be stockpiled at low cost. For example, utilities may maintain large inventories of coal.
Infrastructure	Specialized equipment may be required to load or unload commodities to rail lines or onto trucks.
Cost of competing transportation options	The cost of transportation alternatives may vary significantly depending on market conditions. Captive shippers may pay more for rail transport.
Competitiveness of industry	Some business operations may only be marginally profitable. Transportation cost increases that are too large could render some business activities uneconomic, resulting in reduction of freight shipments.

During the Port of Memphis assessment, port stakeholders identified mode shifts as an area that would benefit from more research. Understanding mode shifts require a detailed understanding of logistics in a port's region. This requires an understanding of the transportation options available in a region and the ability of local businesses to use these alternatives.

Ports may also benefit from documenting and tracking basic data on truck traffic during low and high water events. Some of this data may be already available from continuous traffic monitoring devices currently in place. There was little data available in Memphis on whether truck traffic increases due to mode shifts during instance of high and low water levels.

<u>Checklist</u>

- ✓ Exchange information with local carriers and shippers concerning the impacts of low and high water events on their use of barge transportation and their use of alternative modes of transportation during these events.
- ✓ Understand the magnitude of freight diversions, if they are necessary, to truck and rail during extreme water level events. Consider the social and economic impacts of diversions as well.
- ✓ Understand important localized congestion and emissions impacts at potentially sensitive locations, if freight diversions are necessary.

5. Develop alternative freight movement scenarios

Building on the understanding of baseline freight movement and how mode shifts occur, analyze the potential impacts on freight movement under the high and low water scenarios (from Step 3).

As discussed, high and low water events can alter the movement of freight. Impacts could include a reduction in the total quantity of freight moved by barge, changes in the timing of freight movement, shifts of barge freight to other modes, and changes in freight origins and destinations.

The full extent of disruption, however, is dependent on the temporal and geographic scale of disruption as well as on the type of commodity affected. Short-term events will be less disruptive than long-term events that may require permanent re-routing of freight. On a geographic scale, if the disruption is limited to a certain port in an area with easy access to rail or roadways, alternative modes of transportation can be used with little impact. However, if another mode is not available, too costly, or lacks the capacity to transport the freight such as not having the necessary equipment, then delays and disruptions will be more widespread.

For instance, in some cases alternative modes may lack the equipment to accommodate different types of dry bulk or liquid bulk freight, or lack container loading equipment. In addition, it may be necessary to transport new types of freight during flooding to repair infrastructure or provide emergency supplies. All of these factors should be considered when developing alternative freight movement scenarios in the context of climate resilience.[61]

Alternative freight scenarios are based on changes in cost, transit time, reliability, and other factors that affect barge transport. High and low water events in particular could increase delays, increase cost per ton-mile, and result in mode shifts.

Based on increases in barge transport costs, one can forecast how freight would likely be shifted from barge to truck or rail under the different high and low water scenarios. Mode shifts can be estimated with economic models that account for commodity, length of haul, value, transit time or other characteristics. Mode shares by commodity can be estimated and mode shifts could be calculated based on changes in tonnage from baseline commodity flows. One model that integrates the mode shift analysis with an emissions model is the Geospatial Intermodal Freight Transportation (GIFT) model.[62] A variety of resources for estimating mode shifts in freight flow are summarized in Table 2.

[61] National Cooperative Highway Research Program, "NCHRP Report 732: Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System," *Transportation Research Board*, Washington, D.C., 2012, https://transops.s3.amazonaws.com/uploaded_files/nchrp_rpt_732.pdf.

[62] The Laboratory for Environmental Computing and Decision Making, "Geospatial Intermodal Freight Transportation (GIFT)," *Rochester Institute of Technology*, accessed May 2017, http://www.rit.edu/gccis/lecdm/gift2.php.

Table 2: Summary of Models Related to Multi-Model Shifts in Freight Flows

Model or framework	Accessibility (complexity, data requirements, cost)	Relevance (geographic, modal, sustainability)	Strengths	Weaknesses
Supporting Secure and Resilient Inland Waterways (SSRIW)	Some data are available for free from the USACE, but original data collection is required for different regions	Covers barge, truck, and rail, but was developed for a specific segment of the Upper Mississippi	Focuses specifically on barge freight movements and on the availability of infrastructure to transfer freight between modes making the model results more accurate than generic mode shift models	Limited geographic coverage and requires significant data inputs
National Oceanic and Atmospheric Administration (NOAA) Port Resilience Tool	Free tool with no inputs or outputs and easy to navigate checklists and datasets	Port profiles are available for all ports in the U.S. and cover marine and truck (landslide access to ports) modes	Provides an overview of all major port resilience issues to consider and easy to use checklists	Information is general and therefore should only be used as a starting point
Geospatial Intermodal Freight Transportation (GIFT) Model	Free, web-based, technically complex tool that allows user to develop customized scenarios including different types of equipment, cost, and freight flow patterns	Covers road, rail, and marine modes of transportation across the U.S., considers all commodity flows, and can estimate mode shifts based on changes in cost	Estimates the environmental impacts of mode shifts and the geographical distribution of emissions	Requires significant resources to acquire and run the model
Community-LINE Source Model (C-LINE) and Community-Scale Near-Source Air Quality System to Assess Port-Related Air Quality Impacts (C-PORT)	Free tool with readily available data and a user-friendly format	C-LINE can be used nationwide to measure roadway impacts C-PORT provides air quality impact data based on port activity at a community scale; C-PORT has been parameterized for 24 ports (primarily in the southeast U.S.) and additional parameterizations are continually being	Simple and user-friendly tools with initial parameterization provided for both emissions (based on available inventory data) and meteorology, plus C-PORT allows for uploading of local data where available. Both tools estimate	Both C-PORT and CLINE only address dispersion of emissions but do not estimate secondary pollutants such as ozone directly. C-PORT is currently parameterized for 24 ports primarily in the southeast,

Model or framework	Accessibility (complexity, data requirements, cost)	Relevance (geographic, modal, sustainability)	Strengths	Weaknesses
		added. C-PORT can be applied anywhere in the U.S. even if initial parameterizations specific to port activities may not be available, because C-PORT allows local emissions data uploads.	dispersion of criteria pollutants (or surrogates) and air toxics.	with additional ports added continually.
MIT Port Mapper	Free tool with readily available data and mapping feature	Covers marine vessels across the entire U.S. and considers all barge freight including commodities such as chemicals, coal, and manufactured goods	Wide geographic coverage and includes all major shipping commodities	Only covers port-to-port commodity shifts

In order to support resilience planning, port stakeholders should develop and review one or more alternative freight movement scenarios. One approach would be to develop a worst-case scenario and an alternative scenario. By developing projections of the impacts of severe weather on barge transportation and mode shifts, ports can obtain a better picture of the likely impacts on local communities from increased truck traffic and its associated effects. Generally, the more alternative modes of transportation available to the port, the more resilient the port will be to extreme water level disruption. The Port of Memphis, for example, is often affected by river lows and highs, but benefits from easy access to five Class I railroad carriers, two barge fleeting services, Interstates 40 and 55, Memphis International Airport, and a multitude of other barge and truck transportation services.

NCHRP Report 732 presents a five-step process for evaluating a range of freight network disruption events and the potential economic impacts that ports can follow to better understand their vulnerabilities.[63] Ports should consider commodity characteristics, such as value, time sensitivity, and volumes and disruption characteristics, such as duration, geographic scale, number of transport alternatives available, and significant disruptions within a specific industry sector. These characteristics will inform the transport costs, inventory costs, lost industry productivity, and output variables to assess the economic impact. The steps to this framework include:

[63] National Cooperative Highway Research Program, "NCHRP Report 732: Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System," *Transportation Research Board*, Washington, D.C., 2012, https://transops.s3.amazonaws.com/uploaded_files/nchrp_rpt_732.pdf.

1. Identify the direct and immediate physical impacts of a network disruption – such as specific transportation facilities affected and modes of transport within, into, and out of the affected region.

2. Identify current and future affected network flows by facility – such as mode re-routing or long-term disruption implications.

3. Identify freight supply chain characteristics and parameters.

4. Model the response of the supply chain to disruptions – such as short-term mode re-routing.

5. Model the economic impacts of network disruptions by examining social and public sector costs and direct supply chain costs.

Port stakeholders can increase their resilience by understanding potential extreme weather risks, preparing a response to extreme weather events, and expanding access to alternative modes of transportation as well as necessary equipment or resources to swiftly facilitate mode shifts.[64]

NCHRP Report 732 also offers network-based models and industry supply chain models for estimating the economic impacts of disruption. Network-based models assume freight is diverted and estimate the transport costs and inventory value of impacts. These models include simple cargo diversion models in which freight is assumed to be diverted to the least-cost alternative and freight network simulation models in which a complex network of single-mode and multiple-mode freight flow diversions are evaluated. Industry supply chain models, including business supply chain optimization and dynamic supply chain simulation models, alternatively optimize business operations and address industry decisions regarding sourcing, inventory levels, and route choice.

NCHRP Report 732 additionally presents two types of economic impact models: static/input-output-based models and dynamic economic simulation models. Static/input-output-based models assume declines in industry final demand and calculate the associated direct, indirect, and induced impacts across all industries. Dynamic economic simulation models provide a more complex analysis assuming changes in supply, demand output, prices, or other direct economic impacts, and using dynamic modeling to simulate the overall economic impact.

Checklist

- ✓ Use data on the impacts of severe weather on barge movements to estimate mode shifts.
- ✓ Produce one or more alternative freight movement scenarios by commodity, origin, and destination.

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[64] National Cooperative Highway Research Program, "NCHRP Report 732: Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System," *Transportation Research Board*, Washington, D.C., 2012, https://transops.s3.amazonaws.com/uploaded_files/nchrp_rpt_732.pdf.

6. Estimate impacts at the port and on navigation

Estimate the potential direct impacts at the port of the extreme water levels under the chosen scenarios. The introduction details the potential effects of extreme high and low water levels, beginning on page 10.

In Memphis, for example, the high water event of 2011 caused $9 million of damage to President's Island (where the Port of Memphis is located) in erosion and structural damage to the island itself.[65,66] It also precipitated a $20 million investment by the USACE to reconstruct the river bank.[67]

The low water event of 2012, on the other hand, reduced draft by about 3 feet, reduced tow sizes, reduced barge loads, and increased incidence of groundings.[68]

One method to estimate impacts at port and on navigation is to conduct a vulnerability analysis. A vulnerability analysis includes:

- Identifying any potential navigation limitations under the scenario. For example, consider key issues and constraints about infrastructure capacity, such as channel depths and widths, under-bridge clearances, navigation obstacles and the flexibility of docks in high and low water. Also, consider the feasibility of actions to maintain port operations under changing water levels such as dredging.
- Identifying the location, condition, and potential vulnerabilities of port infrastructure used for water freight transportation. Consider whether some freight can be unloaded at different docks. Some freight may require specialized equipment to unload or require an industrial facility for unloading without a reasonable alternative bulk transportation option.
- Evaluating the vulnerability of landside infrastructure connections, industrial complexes, and land. Assess the vulnerability of critical access points to the port such as rail lines, bridges, and roadways.

Checklist

- ✓ Conduct a vulnerability analysis to examine the impact of flooding and low water on port assets and operations. Also, assess the vulnerability of rail and road access points.
- ✓ Collect information on the cost impacts to barge transportation from changes in water levels on the river.

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[65] Daniel G. Driscoll, Rodney E. Southard, Todd A. Koenig, David A. Bender, and Robert R. Holmes, Jr., "Annual exceedance probabilities and trends for peak streamflows and annual runoff volumes for the Central United States during the 2011 floods," *U.S. Geological Survey Professional Paper 1798–D*, Reston, VA, 2014, http://dx.doi.org/10.3133/pp1798D.

[66] Wayne Risher, "Port of Memphis needs $9 million for flood fix," *Commercial Appeal*, December 2, 2011, https://www.pressreader.com/usa/the-commercial-appeal/20111202/281913064931512.

[67] Ibid

[68] Wayne Risher, "Low water causes unusual traffic jam, blocking commerce along Mississippi River," *Knoxville News Sentinel*, August 22, 2012, http://archive.knoxnews.com/business/low-water-causes-unusual-traffic-jam-blocking-commerce-along-mississippi-river-ep-360201258-356738301.html/?bppw=absolutely&suppressAds=youbet.

✓ Collect information on the additional potential costs for maintaining port operations under high and low water level events such as dredging the shipping channel.

7. Estimate impacts to the port community

Freight diversions to alternate land-based modes of transportation such as trucks and trains can increase road and rail congestion, road and rail degradation, and local air pollution which may negatively affect the larger port community and, in particular, the near-port community. The impacts of additional freight movements and emissions on near-port communities could be estimated by examining data on the population exposed to emissions. Analysis of data on population characteristics could be used to determine if there are disparate impacts by race, economic class, or other socio-economic characteristics that are relevant to environmental justice. Disadvantaged groups may be less able to adapt to stress on their local community. Local impacts may also include noise and other environmental impacts, congestion, safety, and employment impacts.

The EPA has developed a number of tools and resources that can assist community stakeholders and local governments with assessing freight movement impacts on the port community. These include:

- EPA's EJSCREEN tool to help identify overburdened communities and provide an initial screen on air emissions impacting a community. This tool allows a community to view a combination of environmental and demographic indicators, and generate other reports, including the Centers for Disease Control and Prevention (CDC) Environmental Public Health Tracking (EPHT) Network which provides environmental health issues for a community's county. [69]
- EPA's C-FERST tool to create maps to visualize a community's environmental concerns. The Community Data Table provides a summary of environmental conditions for a community, including estimated concentrations, exposures and risks for select pollutants, as well as demographic information. C-FERST also allows users to add local data, observations and photographs to the maps for ground-truthing. [70]
- EPA's Environmental Justice Primer for Ports for more information on how to identify environmental justice populations and impacts.[71]
- EPA Ports Primer, Section 5.0 for more information on goods movement and transportation planning, land use, potential community impacts, and case study examples.[72]

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[69] U.S. Environmental Protection Agency, "EJSCREEN: Environmental Justice Screening and Mapping Tool," *EPA.gov,* accessed July 2017, www.epa.gov/ejscreen.

[70] U.S. Environmental Protection Agency, "Community-Focused Exposure and Risk Screening Tool (C-FERST)," *EPA.gov*, accessed 2017, https://www.epa.gov/c-ferst.

[71] U.S. Environmental Protection Agency, "Draft Environmental Justice Primer for Ports," *EPA-420-P-16-002*, Washington, D.C., 2016, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OYGB.pdf.

[72] U.S. Environmental Protection Agency, "Ports Primer: 5.0 Land Use and Transportation," *EPA.gov*, accessed 2017, https://www.epa.gov/ports-initiative/ports-primer-50-land-use-and-transportation.

In Memphis, for example, high volumes of truck traffic—even in "normal" times—disproportionately affect neighborhoods in South Memphis, bordered by both Interstate 240 and Interstate 55. South Memphis is a low-income, majority African American neighborhood with a high prevalence of childhood asthma. Changes in traffic congestion or truck traffic due to port disruptions from high or low water events could thus disproportionately affect this neighborhood.

Flooding that affects the port can also directly affect the port community if it is not protected by levees. High waters can back up other rivers and streams that feed into them resulting in flood damage to homes and businesses. This is true, for example, for the Port of Memphis community in Frasier, Millington, and other portions of North Memphis. Flood control measures can also be rendered less effective by damage from previous floods and debris.

Stakeholders should also engage in conducting a vulnerability assessment to examine the impact of flooding and other extreme weather events on residential communities in close proximity to the port. A holistic approach should be taken to the assessment, focusing on the overall community health and well-being. A community's physical, social, and economic vulnerabilities must be inventoried and mapped to guide the development of resilience strategies. Active participation of local stakeholders is essential to the data gathering process.

- Physical vulnerabilities – Estimate and map the number of people and property at risk, including critical facilities (e.g., hospitals, fire and police stations, daycares, schools, sewage and water treatment facilities, other utilities).
- Societal vulnerabilities – Identify and map the most socially vulnerable populations. This group includes the elderly, low-income households, women and children, and those with special needs and disabilities. It also includes linguistically isolated populations, or those with other cultural barriers.
- Economic vulnerabilities – Identify and map employers in the community at risk of closure or restricted access. Estimate the number of employees at each location.

For guidance on identifying and evaluating, community risk and vulnerabilities, see NOAA's Community Vulnerability Assessment Tool (CVAT) Methodology. Although piloted in New Hanover County, NC, a coastal community, the methodology is transferrable to any hazard in any location.

Notes

Checklist

- ✓ Identify the vulnerability of communities and potential impacts on communities from the ports. See EPA's EJSCREEN and C-FERST tools.[73,74]
- ✓ Identify whether there are environmental justice implications associated with air emissions and other impacts. See EPA's EJSCREEN tool and the Environmental Justice Primer for Ports.[75,76]
- ✓ Assess other types of local impacts including noise, congestion, safety, and employment. See the EPA Ports Primer, Section 5.0.[77]
- ✓ Identify additional physical, societal, and economic vulnerabilities from extreme water levels.

8. Estimate environmental and human health impacts

Once changes in freight transportation activity have been estimated, including mode shifts, the emissions and human health effects can then be estimated—likely by the local air quality department. In addition to air emissions, which are described in more detail below, ports that contain Resource Conservation and Recovery Act (RCRA) facilities and Superfund sites can leech harmful chemicals or contaminants into the water supply or larger port community during flood events.

There are three components to a community health risk assessment for air emissions, including:

- Estimating emissions or pollutants,
- Assessment of the ambient concentration of those pollutants, and
- Assessment of exposure concentrations and pollutant exposure health risk assessment.

The specific steps necessary to implement each of these analyses are discussed below in more detail.

Identify pollutants to measure. Emissions are typically estimated for criteria air pollutants (CAPs) and may also be estimated for mobile source air toxics (MSATs). The Clean Air Act requires EPA to set National Ambient Air Quality Standards (NAAQS) for six common air

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[73] U.S. Environmental Protection Agency, "EJSCREEN: Environmental Justice Screening and Mapping Tool," *EPA.gov,* accessed July 2017, www.epa.gov/ejscreen.
[74] U.S. Environmental Protection Agency, "Community-Focused Exposure and Risk Screening Tool (C-FERST)," *EPA.gov*, accessed 2017, https://www.epa.gov/c-ferst.
[75] U.S. Environmental Protection Agency, "EJSCREEN: Environmental Justice Screening and Mapping Tool," *EPA.gov,* accessed July 2017, www.epa.gov/ejscreen.
[76] U.S. Environmental Protection Agency, "Draft Environmental Justice Primer for Ports," *EPA-420-P-16-002*, Washington, D.C., 2016, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OYGB.pdf.
[77] U.S. Environmental Protection Agency, "Ports Primer: 5.0 Land Use and Transportation," *EPA.gov*, accessed 2017, https://www.epa.gov/ports-initiative/ports-primer-50-land-use-and-transportation.

pollutants. These criteria pollutants are particulate matter (PM), ground-level ozone (O_3),[78] carbon monoxide (CO), sulfur dioxides (SO_2), nitrogen oxides (NO_X), and lead. CAPs are those that EPA regulates by developing human health–based (primary) and/or environmentally based (secondary) criteria for permissible levels. Each has one or more temporal averaging periods associated with the threshold level. For example, EPA regulates $PM_{2.5}$ (the fraction of particulate matter with diameter less than 2.5 micrometers) based on concentrations averaged over 24-hour and annual average periods.

Hazardous air pollutants, also known as "air toxics," are those pollutants known or suspected to cause cancer or other serious health impacts.[79] Seven pollutants with significant contributions from mobile sources have been identified as among the national- and regional-scale cancer risk drivers. These priority MSATs include: acrolein, benzene, 1,3-butadiene, diesel particulate matter (DPM) plus diesel exhaust organic gases, formaldehyde, naphthalene, and polycyclic organic matter.

In general, heavy-duty trucks and other diesel powered equipment will have the greatest impacts on NO_x, $PM_{2.5}$, and DPM. Some studies focus on changes in these pollutants. Which pollutants to consider depends on the goals and context of the analyses. For instance, some areas are nonattainment areas for specific pollutants.

Select air emissions model(s) and measure emissions. The choice of which model to use to estimate air emissions will depend on the desired emission sources and complexity of the analysis. EPA created the Motor Vehicle Emissions Simulator (MOVES) model to estimate emissions produced from on-road and off-road mobile sources for both CAPs and air toxics. The MOVES model does not include marine vessels or locomotives, and thus other approaches would be needed to estimate these emissions. The GIFT model integrates an emissions model with a mode shift model and could also be used for this type of analysis.

The accessibility, relevance, strengths, and weaknesses of emissions analysis tools are summarized in Table 3.

Table 3: Summary of Tools to Estimate Air Emissions

Tool or report	Accessibility (complexity, data requirements, cost)	Relevance (geographic, modal, pollutants)	Strengths	Weaknesses
Motor Vehicle Emissions Simulator (MOVES2014a)	Low – technically complex, high data requirements	Medium – any geography and pollutant; includes on-road and most non-road sources (locomotives and	Widely accepted model and considered accurate	Requires training and experience to run the model

[78] Note that O_3 is not directly emitted, but rather a product of chemical reactions involving NOx and Volatile Organic Carbon (VOC) species with sunlight in the atmosphere.

[79] U.S. Environmental Protection Agency, "Hazardous Air Pollutants," *EPA.gov*, accessed 2017, https://www.epa.gov/haps.

Tool or report	Accessibility (complexity, data requirements, cost)	Relevance (geographic, modal, pollutants)	Strengths	Weaknesses
		marine engines are not included)		
SmartWay Tools	Medium – technically accessible, but requires detailed fleet data	Medium – any geography; pollutants include CO_2, NO_x, PM_{10}, and $PM_{2.5}$; includes individual tools for shippers, logistics companies, and truck, barge, rail, air, and multimodal carriers	User-friendly and EPA-approved model	Designed for use by individual company fleets and operations
EPA Guidance Manual on Emission Inventories for Ports	Low – technically complex and significant data requirements	High – applies to any geography, relevant modes (including marine vessels and rail), and pollutants	Provides flexible approaches to capturing port modes	Requires significant data collection and calculations, different for each mode
EPA Investigation of Fugitive Emissions from Petrochemical Transport Barges Using Optical Remote Sensing	High – simple if applying emission rates of study	Low – only applies to fugitive emissions from barges transporting petrochemicals	Simple description of results	Results have limited application
Texas Transportation Institute Modal Comparison of Domestic Freight Transportation	High – report presents results of study	Low – present national level mode shift analysis	Provides accessible overview of modal shift impacts	Not applicable to smaller geographic scope and does not provide novel emissions model
Geospatial Intermodal Freight Transportation (GIFT) Model	Low – technically complex	High – estimates local level emissions for all relevant modes	Widely accepted and accurate model applicable to freight mode shifts	Requires significant resources to run model
Community-LINE Source Model (C-LINE) and Community-Scale Near-Source Air Quality System to Assess Port-Related Air Quality Impacts (C-PORT)	Free tool with readily available data and a user-friendly format	C-LINE can be used nationwide to measure roadway impacts; C-PORT provides air quality impact data based on port activity at a community scale; C-PORT has been parameterized for 24 ports (primarily in the southeast U.S.) and	Simple and user-friendly tools with very accurate data; both estimates emissions and conducts the dispersion analysis	Both C-PORT and C-LINE only addresses air toxic concentrations, but C-PORT is not parameterized for all ports nationwide

Tool or report	Accessibility (complexity, data requirements, cost)	Relevance (geographic, modal, pollutants)	Strengths	Weaknesses
		additional parameterizations are continuously being added. C-PORT can be applied anywhere in the U.S. even if initial parameterizations specific to port activities may not be available, because C-PORT allows local emissions data uploads.		

Select air dispersion model and assess ambient concentration of these pollutants. Once emissions estimates are produced, an air dispersion model is required to estimate ambient air concentrations of the pollutants. American Meteorological Society and the EPA Regulatory Model (AERMOD) model is capable of such assessments at the regional level and is EPA's currently recommended model for such assessments. There are a number of other tools to choose from, each with different strengths and weaknesses. These are described in Table 4 below.

Table 4: Summary of Dispersion and Air Quality Analysis Tools

Tool or report	Accessibility (complexity, data requirements, cost)	Relevance (geographic, modal, pollutants)	Strengths	Weaknesses
AERMOD (American Meteorological Society/Environmental Protection Agency Regulatory MODel) Modeling System	High – technically accessible and commonly applied, with moderate data requirements	High – may be applied to any conveyance source type, but expected to perform better when limited to inert pollutants in simpler or near-field dispersion situations	Capable of modeling any conveyance method and most pollutants of interest relatively easily	Somewhat complicated to implement and accuracy reduced for far-field applications
CALPUFF Modeling System	Medium – more technically complex in execution and data requirements than AERMOD but less than PGMs	High – may be applied to any conveyance source type and expected to perform better than AERMOD in	Enhanced set of pollutants and capabilities over other dispersion models; applicable to any transportation	More complicated to use than other dispersion models and without universally recognized accuracy

Tool or report	Accessibility (complexity, data requirements, cost)	Relevance (geographic, modal, pollutants)	Strengths	Weaknesses
		far-field, complex terrain, or urban scale applications	source; could be used to determine regional impacts of mode shifts	improvements; intended for regional rather than local applications
Photochemical Transport Models	Low – very complex to implement with high data requirements	Medium – applicable for urban- to regional-scale analysis for a complete set of pollutants	Comprehensive analysis method; could be used to determine regional impacts of mode shifts	Results are slow and difficult to obtain and generally limited to episodic analysis; resource intensive to operate; intended for regional rather than local applications
Community-LINE Source Model (C-LINE) and Community-Scale Near-Source Air Quality System to Assess Port-Related Air Quality Impacts (C-PORT)	Free tool with readily available data and a user-friendly format	C-LINE can be used nationwide to measure roadway impacts. C-PORT provides air quality impact data based on port activity at a community scale, but is currently only available for Charleston, SC	Simple and user-friendly tools with very accurate data; both estimates emissions and conducts the dispersion analysis	Both C-PORT and C-LINE only addresses air toxic concentrations; but C-PORT is not applicable nationwide

Assess exposure concentrations and conduct pollutant exposure health risk assessment. Once ambient concentrations of pollutants have been assessed, the population pollutant exposure and resulting incremental changes in health risk from the action may then be estimated based on the ambient concentrations from the dispersion model through an exposure and risk analysis. This could be done by using the EPA Air Pollutants Exposure (APEX) model throughout the region with post-processing for incremental health risk impacts, or by implementing a direct, screening-type assessment. The tools and resources that ports can use to evaluate exposure and health risks are summarized in Table 5.

Table 5: Summary of Exposure and Health Risk Assessment Tools

Tool or method	Accessibility (complexity, data requirements, cost)	Relevance (geographic, modal, pollutants)	Strengths	Weaknesses
Direct Calculation (using any of the data analyses from Table 3 & Table 4 to apply risk factors to the predicted concentrations to assess risk)	High – relies on publicly available information and methodology crafted entirely by the user	High – can be tailored directly to the problem at hand and estimate exposure and risk	No special software required to assess risk; very flexible and customizable; all required inputs available	Requires complete characterization by the user, including complex calculations; unlikely to be able to allow stochastic or time-series exposure estimates
Air Pollutants Exposure Model (APEX)	Medium – software is easily accessible and commonly applied, but with high data requirements	High – may be applied to concentrations from any conveyance source type and includes in-vehicle exposure	Capable of assessing population exposure through multiple scenarios	Does not calculate risk directly; complex to use
Hazardous Air Pollutant Exposure Model (HAPEM)	Medium – software is easily accessible and commonly applied, but with high data requirements	High – may be applied to concentrations from any conveyance source type and includes in-vehicle exposure, but with lower resolution than APEX	Capable of assessing population exposure through multiple scenarios	Does not calculate risk directly; complex to use; more typically applied to national screening level assessments

Although there is no standard set of models specifically for estimating port air emissions and health effects, one possible set could include MOVES, AERMOD, APEX, coupled with a postprocessor to assess health risk. These models are EPA's recommended models for emissions and dispersion, and assess exposure in a method similar to that done by EPA in other applications.

In the Memphis port community, a series of maps by pollution type in Shelby County, Tennessee, were created from EPA stationary facility data.[80] All emissions pollutants analyzed (CO, Lead, Mercury, NH_3, NO_X, $PM_{2.5}$, SO_2, VOC), except CO, are highest near the port. Figure 7, for example, shows the concentration of mercury emissions for Shelby County. These concentrated emissions have implications for the larger community, especially if there is an

[80] Angela Antipova, "Maps of air borne emissions ($PM_{2.5}$. PM_{10}, NH_3, NO_X, SO_2, VOC and Lead) in Shelby County, TN. (2008)" (personal communication, 2015).

increase in emissions from rail and truck freight movement. High air pollutant concentrations are associated with a variety of negative health effects such as heart attacks, asthma attacks, bronchitis, respiratory symptoms, and premature death.[81] Children and elderly residents are most at risk.

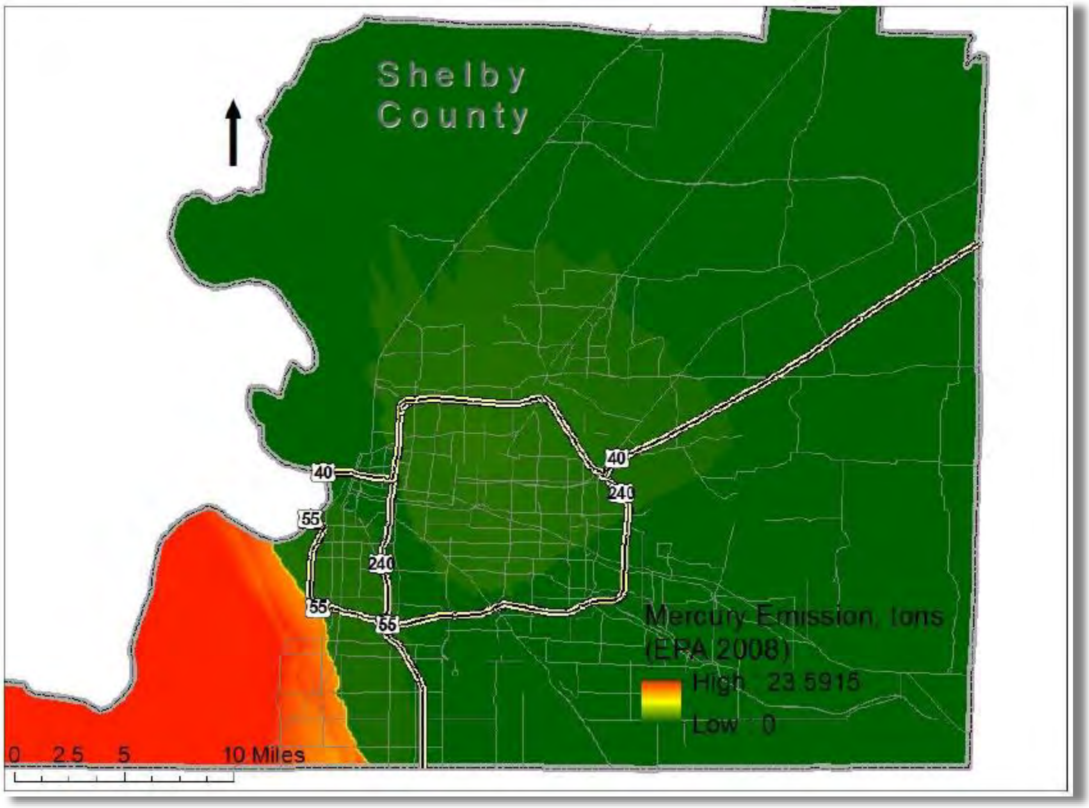

Figure 7: Mercury emissions in Shelby County, Tennessee[82]

By estimating emissions, dispersion, and exposure and human health risk, regions can obtain a better understanding of the incremental health impacts associated with changes in operations throughout it, due to extreme water levels.

In addition, consider potential risks to ecosystems, ecosystem services, and related health outcomes. EnviroAtlas is a web-based decision support tool that combines a geospatial mapping application with downloadable information related to ecosystem services (nature's benefits). The tool allows users to view and analyze maps and interpretive information on ecosystem services using seven broad benefit categories to organize its information and data:

- Clean Air
- Clean and Plentiful Water

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[81] U.S. Environmental Protection Agency, "EPA's Report on the Environment: Outdoor Air Quality," *EPA.gov*, accessed May 2017, https://cfpub.epa.gov/roe/chapter/air/outdoorair.cfm.

[82] Angela Antipova, "Maps of air borne emissions ($PM_{2.5}$. PM_{10}, NH_3, NO_X, SO_2, VOC and Lead) in Shelby County, TN. (2008)" (personal communication, 2015).

- Natural Hazard Mitigation
- Climate Stabilization
- Recreation, Culture, and Aesthetics
- Food, Fuel, and Materials
- Biodiversity Conservation

For example, the Memphis Community Summary Factsheet from EnviroAtlas provides an overview of the local community including land cover, demographics, and ecosystem services data.

The Eco-Health Relationship Browser, a complementary tool to EnviroAtlas, interactively displays the linkages between selected ecosystems, ecosystem services, and health outcomes. The information in the Browser is meant to interactively display nature's benefits to human health and well-being, and is based on a systematic literature review of peer-reviewed journal articles published through 2014. An update to 2015 is currently underway.

Checklist

- ✓ Identify environmental linkages between the port and the local community. Consider key sources of point and mobile emissions, for example.
- ✓ Collect information on barge activity, much of which is readily available. However, detailed information on truck movements may not be available at some ports. If resources permit, additional data on truck trips may be collected through truck origin destination surveys. Truck trip tables may also be estimated to characterize regional origins and destinations for trucks.
- ✓ Engage with and receive input from affected communities. Refer to EPA's Ports Primer on how communities should effectively engage with ports over environmental concerns.[83]

[83] U.S. Environmental Protection Agency, "Draft A Ports Primer for Communities," *EPA-420-P-16-001*, Washington, D.C., 2016, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100P1UQ.pdf.

- ✓ Consider the full spectrum of environmental impacts including air, noise, water, and solid waste from port activities. Consider, for example, stormwater runoff and waste management of the industries at ports.
- ✓ Determine whether ports have contaminated or potentially contaminated industrial land on their premises, which could leech contaminants under higher or more frequent flood water levels.
- ✓ Use the tools and resources provided in Table 3 of the roadmap to estimate air emissions.
- ✓ Use the tools and resources provided in Table 4 of the roadmap to estimate emissions dispersion and air quality.
- ✓ Use the tools and resources provided in Table 5 of the roadmap to estimate exposure and human health risk.
- ✓ Identify additional potential risks to ecosystems, ecosystem services, and related health outcomes.

9. Estimate economic impacts

Disruptions of port activities have broader economic impacts in the port community. Stakeholders from the Tennessee Department of Economic and Community Development, City of Memphis, Shelby County, and the Port of Memphis emphasized that port vulnerability to extreme water levels may damage Memphis' reputation as a reliable transportation hub and harm Memphis' ability to recruit and retain company operations in the Memphis area, which has significant implications for economic development and jobs in the community. The Port of Memphis contributes an estimated $8.46 billion per year and more than 20,000 jobs to the Shelby County economy.[84]

Port activity disruption effects on reputation and industry recruitment and retention are a concern for any port. Furthermore, disruptions may raise costs of shipping freight, negatively affecting freight shippers and receivers. Ports may also be required to employ additional personnel to clean up debris from floods or repair damaged equipment. In the short run, this might appear as an economic stimulus to a region, but in the long run this raises the cost of shipping freight. These costs will be passed on to the customers of the port, increasing their costs, reducing their productivity, and subtracting from economic growth. Port disruptions or failures can also affect port communities economically through loss of access to jobs and damage to infrastructure, roads, and buildings.

Economic impacts from disruptions will therefore vary by industry as shown below:

- Goods owners – increased cost to ship goods, which is passed on to the consumer

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[84] Memphis and Shelby County Port Commission, "The Economic Impact of the Port of Memphis on the Memphis and Shelby County Economy," prepared by Younger Associates for the Memphis and Shelby County Port Commission, August 2014.

- Port tenants and users – increased labor costs and overtime costs from the cleanup and recovery process
- Terminals – decreased revenues due to reduced freight movement
- Towing companies – increased operating costs
- Marine services – increased activities (providing refueling and moving barges) and revenues
- Local government – short-term tax revenues and long-term ability to recruit and retain employers

There are different approaches to measuring the broader economic impacts of port operations. In standard economic impact analysis, there are three different types of impacts: direct, indirect, and induced impacts:

- ***Direct impacts*** are created by money from a defined activity entering or being removed from the economy. For instance, if a port spends money to build a levee to make the port more resilient, the money spent to build the levee would be considered a direct impact.
- ***Indirect impacts*** are determined by the amount of the direct effect spent within the study region on supplies, services, labor, and taxes. It also includes business purchases from other businesses. For instance, if a construction company purchased sand and gravel and hired workers, this would be an indirect impact.
- ***Induced impacts*** are the economic activity and jobs created due to consumers' consumption expenditures in all local industries. Expenditures arise from the household incomes generated by the direct and indirect effects of demand changes. For example, workers who were employed building the levee would spend their income in the local economy, creating additional impact through their purchase of goods and services.

Economic impact analyses can also be used to assess negative direct effects, which subtract economic activity from the economy. For instance, if extreme water levels reduce the ability of local businesses to transport and sell their products, there would be negative direct, indirect, and induced impacts as well. These would include lost sales to suppliers, job losses, and lost sales from unemployed workers who no longer have money to spend in the local economy. Models such as IMPLAN and Regional Input-Output Modeling System (RIMS II) can be used to assess these types of economic impacts.

One challenge with traditional economic impact analysis models is that they do not account for changes in input prices. For instance, if the cost of transportation rises, businesses might use less of the transportation mode. The IMPLAN and RIMS II models discussed above cannot account for this. It is important to take account of these dynamic effects because they are an important source of productivity improvements for businesses. Dynamic models such as the Regional Economic Models, Inc. (REMI) TranSight tool or Transportation Economic Development Impact System (TREDIS) are needed to capture the productivity impacts of transportation improvements on the economy.

In general, extreme water level events that disrupt port operations and increase the cost of barge transport will make the economy less productive and reduce economic output. Likewise, investments that make a port more resilient will lower transport costs and improve productivity in the long run.

While the models mentioned above may be appropriate for more complex analyses, some regions may want to conduct more simplified analyses of the potential economic impacts. One approach to this is to examine the regional dependence of industries on barge freight. What percentage of output, value added, and regional employment are in industries that depend on barge freight? How diversified is the local economy? Are there only a few dominant industries? Would these be significantly impaired by disruption of barge freight movements? What percentage of commodities is being moved by barge? Could these commodities be easily diverted to rail or truck? Answering these questions can provide a rough estimate of the scale of likely employment and economic output impacts that are possible from port disruptions. More complex analyses could be conducted if the economic impacts were deemed likely to be significant.

Checklist

- ✓ Identify the economic linkages between the port and the local economy. Examine the broader economic impacts of port disruptions on local industries, employment, output, and the broader supply chain.
- ✓ If a comprehensive economic impact analysis is deemed necessary, use economic models to estimate the direct, indirect, and induced impacts of the extreme water level scenarios.
- ✓ If needed, use dynamic economic models if a comprehensive analysis of industry productivity impacts is needed.
- ✓ If economic modeling is not feasible, conduct simplified analysis of potential economic impacts.

V. Step 3 – Identify Strategies to Improve Resilience

With an understanding of potential impacts, port communities can identify a path to increased resilience. There are numerous strategies that can improve the resilience of inland port communities. Comprehensive resilience will likely require a variety of strategies implemented by a range of stakeholders. This section outlines potential strategies by sector, including public and private infrastructure, transportation operations and equipment, emergency management, environment and human health, and long-term economics.

The majority of these strategies are those that can be implemented at the local or state government level. Implementation of any resilience strategies, however, will require coordination across a range of port and community stakeholders.

In many cases, there may be stakeholders who do not currently coordinate closely with the port, but who may have an important role to play in increasing resilience. One overarching strategy for all stakeholders and sectors is to closely coordinate resilience efforts between internal and external stakeholders. This includes expertise, data collection, and shared resources. Coordinating with other stakeholders and utilizing the resources provided throughout this roadmap will make a significant difference in the development of effective port resilience strategies.

1. Public and private infrastructure

Strategies to improve the resilience of inland port infrastructure can include protecting critical assets through hardening, more resilient design and materials. For example, see the Port Authority of New York and New Jersey Climate Resilience Design Guidelines.[85] Other means include managing extreme weather events and associated extreme water levels through operational changes and maintenance improvements or relocating to less vulnerable locations. Specifically, public and private infrastructure resilience strategies can include increasing redundancy in roadway access, adopting floodplain management best practices, using flexible infrastructure, and increasing rail capacity. Each of these strategies is discussed below.

- **Increasing port access redundancy** may be important when the port is only served by a single roadway that is vulnerable to flooding. Protection of existing access routes (through flood barriers or elevation) or the creation of redundant access routes could increase a port's resilience to flooding events and allow port staff and emergency responders to access the area. It may be necessary to first conduct additional research to identify where redundant access is needed.
- **Adopting floodplain management best practices**—such as building above the base flood elevation or raising the elevation of the port, stream abatement, elevating and securing backup generators, drainage maintenance, retrofitting infrastructure assets, and others—can reduce flooding vulnerabilities across the community, including and beyond the port. For example, Port of Memphis stakeholders identified clearing debris from storm drains as an effective best practice example. At the Port of Cates Landing in northwest Tennessee, stakeholders decided to purposely build the port above the 100-year floodplain and an adjacent industrial park above the 500-year floodplain.[86]
- Although retrofits may not always be necessary, **installing flexible infrastructure** that can function regardless of water levels—or at least in a wider range of water levels—can be a cost-effective way to increase resilience. In some areas, individual port stakeholders have begun to make opportunistic capital investments in flexible infrastructure to increase their resilience to variable water levels. Flexible infrastructure includes floating docks and flexible conveyors that are more resilient to extreme river fluctuations. Retractable docks may also enable smoother port operations under a wider range of water level conditions.
- **Increasing rail capacity** can allow shippers alternative transportation options when barge transportation becomes disrupted. Extreme water levels have far-reaching economic

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[85] Port Authority of New York and New Jersey, "Design Guidelines: Climate Resilience," *Port Authority of New York and New Jersey*, last updated January 1, 2015, https://www.panynj.gov/business-opportunities/pdf/discipline-guidelines/climate-resilience.pdf.

[86] Northwest Tennessee, "Port of Cates Landing is America's Newest Multimodal Inland Port," *Northwest Tennessee*, accessed May 2017, http://northwesttn.com/news-archive/67-port-of-cates-landing.

consequences when freight cannot be cheaply or easily transported by other means. One possible way to mitigate these impacts is to incentivize excess or redundant rail capacity that can absorb barge cargo when necessary.

- **Prioritizing maintenance for locks and dams** to decrease the frequency or severity of damage and subsequent delays. As previously noted, the inland marine sector has made improving and updating locks and trans-modal facilities a top priority in recent years.[87] This priority has a co-benefit of increasing resilience to high and low water levels. Pursuit of this priority will involve broad stakeholder coordination including the freight industry, the EPA SmartWay program, the U.S. Department of Transportation (DOT), and others.
- **Other engineering enhancements** for port facilities to deal with extreme heat or flooding may include isolating electrical connections to reduce incidents of lost power, increasing covered areas for handling goods, and coastal defenses such as installing physical measures to reduce wave reflection around piers, and increasing breakwater dimensions.

<u>Checklist</u>

✓ Conduct a comprehensive port infrastructure assessment to determine vulnerabilities and appropriate strategies to address them. Account for extreme water level scenarios when evaluating equipment and infrastructure.

✓ Consider the vulnerability of access roads to flooding.

✓ Assess the utility and feasibility of flexible infrastructure and improved rail access.

✓ Consider adjusting port construction standards to account for an updated understanding of future extreme water level frequency (e.g., accounting for expected climate change).

✓ Identify potential resilience measures and best practices appropriate for the port context.

✓ For local governments, consider using the EPA Smart Growth Flood Resilience Checklist to increase the community's overall flood preparedness.[88]

✓ Consult the NIST Community Resilience Economic Decision Guide for an economic methodology for evaluating investment decisions to improve the ability of communities to adapt to, withstand, and recover from disruptive events.[89]

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[87] Texas A&M Transportation Institute, "Our Inland Waterways: A Maintenance and Funding Challenge," *Texas A&M University,* July 16, 2015, https://tti.tamu.edu/2015/07/16/our-inland-waterways-a-maintenance-and-funding-challenge/.

[88] U.S. Environmental Protection Agency, "Flood Resilience Checklist," *EPA.gov*, last updated November 1, 2016, https://www.epa.gov/smartgrowth/flood-resilience-checklist.

[89] Stanley W. Gilbert, David T. Butry, Jennifer F. Helgeson, and Robert E. Chapman, "The Community Resilience Economic Decision Guide," *U.S. Department of Commerce National Institute of Standards and Technology*, last updated April 5, 2017, https://www.nist.gov/community-resilience-economic-decision-guide.

2. Transportation operations and equipment

Reducing emissions from the existing truck fleet that operates at the port is one way to reduce the risk of future environmental and human health impacts from mode shifts to trucks. This strategy has two different components: equipment-based strategies and operational strategies. Equipment-based strategies can reduce emissions from the vehicles themselves. Operational strategies can reduce emissions by making truck operations more efficient. Both of these strategies will have value to port stakeholders now, in addition to making the port more resilient in the future.

2.1 Equipment-based emissions reduction strategies

The equipment strategies discussed below are focused on reducing air emissions from trucks, with the goal of making port communities less vulnerable to air quality issues related to future mode shifts to truck carriers. Port authorities would be primarily responsible for implementing these strategies with some assistance from local or federal agencies. Example strategies include:

- **Voluntary clean truck programs** – to reduce emissions from trucks with retrofits, rebuilds, or vehicle/engine replacements. Because heavy-duty truck fleets serving most ports are owned by private companies, clean truck programs are typically voluntary and often have accompanying **monetary incentives**. EPA has helped to support clean truck programs at a number of different ports.[90] For instance, some ports have clean truck programs that provide rebates, low-cost financing, or grants to trucking companies serving ports to take emissions reduction strategies, including:
  - Retrofitting existing trucks with updated emissions control systems, such as oxidation catalysts and diesel particulate filters that reduce NO_X and $PM_{2.5}$ emissions
  - Purchasing new vehicles that are 2010 or later also ensures that vehicles will have the latest emissions control equipment
  - Electrification of truck stops
  - Providing clean fuels for trucks in the port community

Notes

[90] Port Authority of New York and New Jersey, "Port Authority launches program to replace older, more polluting trucks serving the Port of NY/NJ," *The Port Authority of New York and New Jersey*, March 10, 2010, http://www.panynj.gov/press-room/press-item.cfm?headLine_id=1267.

- The **SmartWay Partnership**[91] – a different type of voluntary program that addresses modal shifts, carrier selection, and more efficient operational practices in addition to fuel-saving technologies. SmartWay convenes experts in the freight movement field and facilitates sharing innovative strategies and best practices that leading-edge organizations use to improve freight efficiencies—and their bottom line. The companies that sign up for this EPA partnership make a commitment to measure their air emissions and energy usage and as a result, many make improvements in their operations. The program allows partners to benchmark their performance against similar transportation companies. SmartWay promotes a variety of equipment strategies to reduce emissions and energy use, including wide based tires, automatic engine shut down and improved truck aerodynamics. Businesses adopting strategies such as mode diversification also have the added benefit of improving the resilience of their supply chains.

SmartWay Partnership

The EPA SmartWay Partnership provides information on best practices for saving fuel and reducing emissions for truck carriers, rail carriers, and shippers. The partnership publishes information on best practices and certifies the effectiveness of some vehicle technologies. The partnership provides information on a wide range of technological and operational strategies. For example, some of the strategies promoted by the partnership for truck carriers include:

- Wide-based tires
- Weight reduction
- Low viscosity lubricants
- Speed reduction
- Driver training
- Idle reduction
- Automatic tire inflation systems
- Improved freight logistics
- Improved aerodynamics
- Hybrid power trains
- Longer combination vehicles

Checklist

✓ Identify approaches to incentivize carriers to reduce emissions from trucks serving the port.

✓ Consider employing equipment strategies based around retrofitting, rebuilding, or replacing engines and vehicles.

✓ Consider replacing vehicles that operate within the port with cleaner alternatives such as electric or hybrid vehicles to reduce emissions.

✓ Consider electrification of stationary cranes to reduce emissions.

✓ Encourage carriers to join voluntary programs such as SmartWay.

2.2 Operational emissions reduction strategies

Another way to reduce air emissions from trucks is to implement operational strategies. These can include:

[91] U.S. Environmental Protection Agency, "SmartWay," *EPA.gov*, accessed 2017, https://www.epa.gov/smartway.

- **Idle reduction policies** – such as reducing truck wait times in the port or restrictions on truck idling. Reduced wait times may be achieved by more effectively coordinating and scheduling pick-up and delivery at the port. In some cases, improved terminal gate operations can reduce truck queueing and idling at the gate.
- **Congestion reduction strategies** – including improving roadway operations and timing lights near the port. Reducing empty miles or improved routing of port trucks are strategies that can reduce truck miles traveled and their associated impacts on the community.
- **Traffic management measures** – such as roadway operations and light timing, are also important during or in advance of extreme water level events to minimize bottlenecks. Increasing the size of the port is another way to minimize the bottleneck effect on goods.
- **Enhanced coordination and information sharing** – may allow businesses to more effectively utilize trucks serving the port, reducing emissions. Improving the operations and access to intermodal terminals may also provide access to rail capacity that can be used if barge transportation is disrupted.
- **Reducing the exposure of sensitive populations to air emissions** – another strategy that can improve human health. In urban areas, changes in truck routes (that are established by regulation) could reduce exposure of residential populations and improve human health, even if they do not reduce total emissions.

Ports should consider how operational strategies may need to change under an extreme water level scenario and develop a plan for implementing such changes.

Ports should identify the strategies that are most appropriate for their environment. While some of these strategies can be directly implemented by the port, others will require coordination between the port, the private sector, and/or local government.

Checklist

- ✓ Identify alternative routes for truck traffic to limit congestion and noise pollution in near-port communities.
- ✓ Identify operational strategies that are appropriate for the port such as idle reduction policies, congestion reduction strategies, and traffic management measures.
- ✓ Identify strategies to improve coordination and information sharing among businesses that utilize trucks at the port.
- ✓ Consider if alternative operational strategies are needed under extreme water level scenarios.

3. Environment and human health

In addition to air emissions, there are a number of other environmental, human health, and economic impacts that could occur due to low and high water events at ports. Mitigating these potential impacts can improve the resilience of the port. Example strategies include:

- **Implementing an Environmental Management System (EMS)** could help ports identify and mitigate the full spectrum of environmental risks. Through an EMS, ports can engage in a systematic process of assessing and documenting their environmental risks, reporting this information to stakeholders, and engaging in a process of continuous improvement. An EMS would cover noise, water, air, and solid waste environmental impacts.
- **Updating processes for disposing of silt after floods** could reduce the environmental impacts of flooding. When a river floods, it deposits large amounts of silt, which may be contaminated with hazardous chemicals. Environmental regulations prevent the silt from being deposited back in the river, and cleanup is expensive. Streamlining the process of post-flood cleanup could be helpful to reduce costs and speed recovery. Alternatively, more funds could be allocated toward dredging and beach nourishment programs to help speed recovery. Changes in environmental regulations and available government funding would be primarily driven by government agencies, however ports could still take action to streamline their cleanup process and re-allocate available funds.
- **Reviewing and ensuring the reliability of flood pumps** (where applicable) is another strategy that can improve resilience. For some ports, such as the Port of Memphis, backwater pumps are 50 or more years old, and replacement parts may not be easily available if they were to malfunction. Port authorities should also ensure that pumping stations have adequate backup power sources. Port communities would be better protected against flooding if they have replacement parts and backup power ready to respond during an event.
- **Increasing coordination with the USACE and the Coast Guard** may also serve to make ports more resilient. The USACE and the Coast Guard manage water levels and traffic on the Mississippi River and other rivers. Improved coordination—such as regular communication, open communication lines, or periodic meetings—could improve ports' ability to cope with fluctuating river levels. For example, river level variability could be driven as much by river management as by weather events. Enhancing communication would allow ports to provide their input to river management decisions.
- Similarly, **increasing communication and coordination with community stakeholders** would also serve to make ports more resilient. Community-level actions, such as community waste management activities to reduce debris build-up, help to increase both the port and the community's resilience to flooding. Therefore, it is important for ports to connect with community stakeholders. Other actions include holding a forum or distributing materials to educate community members about potential impacts during an extreme water level event and increasing access to health facilities and services to help reduce air quality impacts on residents.
- **Improving river management** is another resilience strategy, but may require additional research on the relative contributions of river management and weather events to river level

variability. Port stakeholders involved with the Port of Memphis study identified this as an issue on the Mississippi. For example, river levels in Memphis are influenced by what happens upstream, including weather events (snow, rainfall, drought, etc.), but also river management decisions such as whether to store or release water in reservoirs. River management decisions can also help smooth out the impacts of weather changes and maintain river levels at a predictable stage. Port stakeholders identified a research need to determine how river management and weather events have each contributed to the recent increase in river level variability in Memphis. This knowledge could help inform decisions about whether and how river management may need to adapt to a changing climate.

- **Implementing ecosystem enhancements** is another way to mitigate extreme water level impacts on the port while simultaneously strengthening the resilience of the local ecosystem. Port or community stakeholders could implement ecosystem adaptation strategies such as wetland restoration, which can help increase port and community resilience to flooding. Ports can strengthen wetland protection by implementing wetland management programs to ensure the distribution, diversity, and health of wetland ecosystems. Sustainable land use and development is another strategy for increasing flood protection while minimizing ecosystem impacts. Sustainable land use and development projects, for example, could actively consider and avoid drainage overflow or slope destabilization. Coastal ports could implement additional ecosystem-based adaptation strategies, including beach nourishment, coral reef protection, mangrove protection, and other ecosystem restoration efforts.[92]
- **Increasing the availability of river pilots** could help to ensure the economic resilience of ports. Demand for experienced river pilots exceeds supply, particularly in times of extreme high or low water levels. The training time required to become a river pilot has increased and many river pilots have left because of medical issues, resulting in a decline of pilots working in the industry. There may be a need for ports to increase the supply of river pilots, whether through outreach to encourage more people to enter the profession, or changing training requirements. This would help ensure that labor shortage would not disrupt barge operations during low and high-water events.
- **Ensuring emergency power generators meet the most stringent emissions standards** to minimize potential decrease in port community air quality during grid power failure.
- **Joining the EPA Ports Initiative**, which brings together port stakeholders to develop recommendations for a voluntary ports program, the goal of which is to encourage strategies that produce emissions reductions and improve air quality in a meaningful way. The Ports Initiative offers technical resources, collaboration resources, and best practices for port operations.[93]

In general, port stakeholders should work together to proactively document risks to the port. How susceptible are local businesses to disruptions in the port? Are there changes that can be made to supply chain management to mitigate these risks? By understanding risk, stakeholders

[92] United Nations Environment Programme, "Linking Ecosystems Risk and Vulnerability Reduction: The Case of Jamaica," *Risk and Vulnerability Assessment Methodology Development Project (RiVAMP), United Nations Environment Programme,* Geneva, 2010, http://postconflict.unep.ch/publications/RiVAMP.pdf.

[93] U.S. Environmental Protection Agency, "Ports Initiative," *EPA.gov*, accessed July 2017, http://www.epa.gov/ports-initiative.

can improve the management of port operations, private sector businesses, and public organizations to enhance the resilience of the port.

Checklist

- ✓ Consider implementing an EMS to comprehensively document all environmental risks.
- ✓ Identify vulnerabilities in the systems, procedures, and equipment needed to respond to floods.
- ✓ Work proactively to implement strategies such as ensuring that adequate backup power and spare parts are available for pumps.
- ✓ Research relative contributions of river management and weather events to river level variability and improve communication about river management.
- ✓ Increase communication and work proactively with stakeholders, businesses, and community members to implement strategies to improve resilience.

4. Economy

Strategies to create a more resilient economy can be based on diversification of the freight transportation system and economic activity. Port regions whose economies are dominated by relatively few industries dependent on barge transportation are likely to be less resilient than those that have economic activity diversified across many economic sectors. In addition, diverse freight transportation options, including intermodal and rail transportation options, can help to reduce the impacts of barge transport disruptions. A resource to help communities assess their economic vulnerability to climate change and improve their economic resilience is the Planning Framework for a Climate-Resilient Economy, which includes a pilot study conducted in Kingstown, Rhode Island.[94]

Knowledge of supply chains and how industry uses transportation should form the basis of a long-term economic strategy. Port regions may find that they need to conduct research to obtain a better understanding of the economic impacts of extreme weather events. For example, flooding on industrial land or access roads can cause significant damage, impose large economic cost to existing land and property, and disrupt business activity. While some research has been done in this area, more research is needed on how supply chains respond to disruptions caused by extreme water levels. This effort could include research on mode shifts and the extent to which they occur under extreme water level scenarios. It may be possible to use existing data from continuous traffic counters to get a better sense of how much freight is being diverted to trucks during extreme water level events. If diversions are common or important in magnitude, then research into social and environmental impacts could follow.

[94] U.S. Environmental Protection Agency, "Planning Framework for a Climate-Resilient Economy," *EPA.gov*, last updated May 5, 2016, https://www.epa.gov/smartgrowth/planning-framework-climate-resilient-economy.

In many cases ports may be separated from the local community and “out of sight, out of mind,” for most residents. An educational program about the value of the port to the community and the vulnerabilities it faces due to extreme water levels could increase the political will to implement strategies to improve port resilience.

Checklist

- ✓ Conduct research to better understand the linkage between barge freight transportation and the economy.
- ✓ Consider diversifying trading partners and business lines to lower risk and manage future uncertainty.
- ✓ Consider improving alternative bulk freight transportation options as well as the access of barge-dependent industries to alternative low-cost transportation options during flooding or low water events.
- ✓ Consider an economic development strategy to diversify the economy. Consult the Planning Framework for a Climate-Resilient Economy.[95]
- ✓ Consider establishing an educational program for community members that covers the value of the port, extreme water level vulnerabilities, and strategies to improve resilience.

5. Emergency management

In addition to the aforementioned strategies, port communities will also need to ensure emergency management plans and procedures account for trends in extreme water levels. Emergency management can be broken down into three phases, described below: planning, response, and recovery.

5.1 Planning

Ports need to plan to prepare to handle an emergency such as flooding. Emergency management planning can occur at different levels including strategic, operational, and tactical. The definitions below are based on those used by the Federal Emergency Management Agency (FEMA) and are relevant to resilience planning.[96] Planning for likely or possible future extreme weather scenarios can make ports and the surrounding community more resilient.

- **Strategic plans** describe how a jurisdiction wants to meet its resilience responsibilities over the long term. These plans are driven by policy from senior leadership and establish planning priorities.

[95] U.S. Environmental Protection Agency, “Planning Framework for a Climate-Resilient Economy,” *EPA.gov*, last updated May 5, 2016, https://www.epa.gov/smartgrowth/planning-framework-climate-resilient-economy.

[96] Federal Emergency Management Agency, “Developing and Maintaining Emergency Operations Plans,” *Comprehensive Preparedness Guide (CPG) 101, Version 2.0*, Washington, D.C., 2012, https://www.fema.gov/media-library-data/20130726-1828-25045-0014/cpg_101_comprehensive_preparedness_guide_developing_and_maintaining_emergency_operations_plans_2010.pdf.

- **Operational plans** provide a description of roles and responsibilities, tasks, integration, and actions required of a jurisdiction or its departments and agencies during emergencies. Jurisdictions use plans to provide the goals, roles, and responsibilities that a jurisdiction's departments and agencies are assigned, and to focus on coordinating and integrating the activities of the many response and support organizations within a jurisdiction. They also consider private sector planning efforts as an integral part of community based planning, and to ensure efficient allocation of resources.
- **Tactical plans** focus on managing personnel, equipment, and resources that play a direct role in an incident response. Pre-incident tactical planning, based on existing operational plans, provides the opportunity to pre-identify personnel, equipment, exercise, and training requirements. These gaps can then be filled through various means (e.g., mutual aid, technical assistance, updates to policy, procurement, contingency leasing).

Planning for high and low water events can make a port and the surrounding community more resilient. For instance, clearing debris from storm drains before extreme weather ensures the drainage system has maximum capacity to reduce the impacts of these events. Having the proper plans in place will also make the response and recovery to events more effective.

Emergency management planning should be informed by assessing port community vulnerabilities. This process includes a direct analysis of the potential changes in temperature and weather affecting the waterway and the subsequent economic, environmental, and health impacts on port operations and the surrounding port community. FEMA 100-year or 500-year floodplain maps can be used as a starting point to identify potentially impacted areas from major flood events. This would provide a greater understanding of the port's resilience to climate change. It is also important to update plans as needed following extreme water level events. Points of access to the port are of special concern; their consideration could provide insights into investments and changes to operations and maintenance that may be needed to enhance resilience. This analysis would also raise awareness on the importance of climate change impacts to port representatives.

A Superstorm Sandy case study also identified establishing strong communication and coordination with government entities, public agencies, public and private organizations, and stakeholders in advance of an emergency as extremely beneficial during response to and recovery from an event.[97] These connections can help facilitate a faster recovery by providing resources, information, and assistance.

Checklist

- ✓ Define emergency management needs with respect to extreme weather events.
- ✓ Develop strategic, operational, and tactical plans.

[97] National Academies of Sciences, Engineering, and Medicine, "Making U.S. Ports Resilient as Part of Extended Intermodal Supply Chains," *The National Academies Press*, Washington, D.C., 2014, https://doi.org/10.17226/23428.

- ✓ Evaluate and update plans and maintenance programs as needed in preparation for or in response to an extreme water level event.
- ✓ Consider points of access to the port under climate conditions to provide insights into investments, operations and maintenance, and resilience.
- ✓ Establish strong partnerships between the port, government entities, public agencies, public and private organizations, and stakeholders in advance of an emergency event.

5.2 Response

Response activities take place during an emergency and include actions taken to save lives and prevent further property damage both at the port and across the surrounding port community.

Port operations are one component of community emergency response activities. Closing the port or shutting down some operations prior to equipment operation thresholds being met could help prevent damage from extreme weather events and decrease worker and community safety concerns during the extreme event. For example, tying down cranes can help prevent damage to port equipment, and securing facilities can protect against environmental contamination during the event.

Response also includes ensuring critical systems like flood pumps continue to operate throughout the duration of an extreme weather event to protect critical assets and facilities from flood waters. Ports and port community members at risk of flooding should consider installing backup generators above flood levels to maintain critical facilities both at the port and in the community during an event. Interviews with stakeholders at six New York and New Jersey ports following Superstorm Sandy identified protecting electrical power as a crucial priority during an emergency extreme weather event.[98] Other ways to prevent power failures during extreme events are proactive engagement with power providers and looking into micro-grid technologies.

Evacuating or rescuing residents or workers is another critical component of response during an extreme weather event such as flooding. Given the projected increase in the frequency and severity of extreme weather events, ports may want to enhance their emergency evacuation plans in anticipation. Early flood warning systems and extreme temperature warnings are another way to help save lives and prevent further property damage.

[98] National Academies of Sciences, Engineering, and Medicine, "Making U.S. Ports Resilient as Part of Extended Intermodal Supply Chains," *The National Academies Press*, Washington, D.C., 2014, https://doi.org/10.17226/23428.

Advance flood warnings can give the port and larger community time to prepare and evacuate, if necessary, in advance of a flood. Additionally, extreme temperature warnings can alert workers and port community members to heat stress risks so that precautionary measures can be taken to reduce heat stress such as adjusting construction windows or opening public cooling spaces.

Checklist

- ✓ Evaluate port operations during or in advance of an emergency. Ensure critical systems remain operational and shut down any non-essential equipment, if necessary.
- ✓ Reassess emergency evacuation plans in advance of the next extreme weather event to ensure the port and surrounding community are prepared.
- ✓ Consider establishing warning systems at the port and in the community to reduce risk such as early flood or extreme temperature warning systems.

5.3 Recovery

The recovery phase of emergency management includes actions taken to return to a normal or an even safer situation following an emergency. Recovery includes cleanup and getting financial assistance to help pay for the repairs. Port communities can consider identifying ways to maintain economic resilience in the face of extreme events such as utilizing displaced personnel in debris cleanup and other recovery efforts (e.g., port workers whose jobs are not available until recovery has occurred). Recovery efforts may include cleaning up debris after floods, repairing or replacing equipment used to operate the port, rebuilding levees, or repairing roadways and bridges.

Checklist

- ✓ Target recovery investments toward ensuring the resilience of ports, including investing in such projects as raising access roads or constructing new facilities in locations that are less vulnerable.
- ✓ Utilize new public awareness of the vulnerabilities of the port to build consensus for more investment in resilience, as part of recovery process.
- ✓ Reassess and update all emergency management plans given the planning, response, and recovery experiences of the last emergency event.

VI. Step 4 – Develop Institutions and Performance Measures to Support Resilience Objectives

1. Identify and delineate the sources of funding to invest in resilience

The predominant source of funding for port resilience is likely to come from port authorities and the private sector. Ports regularly employ user fees and charges to tenants to fund infrastructure improvements. Private sector shippers and dock owners also have significant resources invested in their facilities. If the business case is made for investments in resilience, these entities may have access to the financial resources to implement them.

Public agencies also have a role to play and public sector sources of funding for inland port resilience projects are diverse. A wide range of issues can be included under this area, including transportation infrastructure, environmental issues, economic development, community impacts, and others. Because resilience encompasses many different issues, the potential sources of funding for resilience projects are spread across many federal, state, and local agencies. For example:

- The National Oceanic and Atmospheric Administration (NOAA) might get involved in funding a program related to disseminating real-time information on weather and water levels, which could be relevant to effectively managing port operations.
- USACE provides funding for dredging projects, maintenance of inland waterway infrastructure, and management of water levels along important inland waterway routes.
- FEMA helps ports plan, respond, and recover from natural disasters such as floods and hurricanes.
- The Federal Highway Administration (FHWA) has a funding program for intermodal connectors, which could help fund access road improvements at ports.
- EPA helps ports reduce air emissions, clean up hazardous materials sites, improve water quality, and consider environmental justice, among other activities.

The "Federal Funding Handbook – Marine Transportation System Infrastructure"[99] identifies a number of federal agencies that offer funding programs and grants that could be used by ports. In addition to those listed above, they include the Economic Development Administration (within the Department of Commerce), the Department of Homeland Security (DHS), the Department of Defense (DOD), and the Department of Transportation (DOT).

In addition to the federal funding sources noted, State DOTs and other agencies, MPOs, and local governments also fund projects that can help to improve inland port resilience.

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[99] Committee on the Marine Transportation System, "Federal Funding Handbook: Marine Transportation System Infrastructure," Washington, D.C., 2013, http://www.cmts.gov/downloads/MTS_Funding_Handbook_(Final).pdf.

Checklist

- ✓ Reach out to private sector funding sources, including private-sector port tenants, port users, shippers, and port-reliant industrial facilities.
- ✓ Consider the full spectrum of possible funding sources for projects that are needed. Broadly consider potential funding sources across relevant federal, state, and local agencies.
- ✓ Assess if there are approaches to funding resilience projects used by other ports that could be applied in this port or port community.

2. Develop a process to include resilience measures in freight transportation planning and port infrastructure projects

Improving resilience in port operations will require a sustained effort. Existing vulnerabilities to extreme weather events already lead to disruptions, and current investment levels are typically not adequate to eradicate them. Since climate change will likely increase the severity and duration of extreme events, the magnitude of the problem—and the budget requirements to address them—will only grow over time. Further, uncertainties associated with how quickly and severely the climate is changing are problematic from an engineering and operations perspective in knowing the appropriate timeframe to address changes in extreme weather in a cost-effective manner.

Building resilience requires adaptive management, in which extreme events and climate change are considered as an ongoing and integrated part of the capital, operations, and maintenance programs developed by port authorities, tenants, and other agencies. Climate change needs to be mainstreamed in existing planning and programmatic processes. If existing processes are inadequate, they may need to be expanded or modified to ensure that critical risks, including climate risks, are addressed. For example, a systems approach to adaptive management will likely be necessary to encompass the many multifaceted aspects of climate impacts on port operations. This will require inter- and intra-agency cooperation among the various actors that operate the port—including the port authority, shippers, utilities, and other service providers—and tenants and users. Coordinated planning processes across these agencies should be developed if they do not exist.

A full range of potential adaptation measures should be considered in the planning process. Incorporate ideas and measures from all relevant departments and other agencies where appropriate. Planning and programmatic processes to consider include:

- **Asset management**, which provides an excellent model for systematic and rigorous data analysis, can lead to better decisions to address risk. It is a comprehensive approach of setting performance goals, collecting and analyzing relevant data over the life of the asset, matching budget requirements to needed investment levels to meet performance goals, and evaluating performance on a routine basis. It is a process for service and data-driven decision-making. Where asset management plans and approaches are employed in port planning and decision-making, climate change considerations and resilience planning should be incorporated. For example, potential freight disruptions from high and low water scenarios can be incorporated into the region's Long Range Transportation Plan.

- **Capital improvement programs** can increase the resilience of the port's infrastructure. Since not all assets or systems are equally critical to the operation of the port, it is useful to assess the criticality of subsystems on which port operations heavily depend. This may not be limited to systems and equipment under the port authority's direct control but may include interdependent infrastructure services, such as electricity, potable water, transportation, and communications. Armed with an understanding of critical infrastructure and current and future vulnerabilities, the port agencies should then consider ways to improve resilience through capital investment and evaluate those measures for cost, effectiveness, and feasibility, among other attributes. Not all capital approaches will be cost-effective or desirable and a complete range of adaptation options should to be considered. Ways to minimize or manage costs can be very important. Therefore, developing planning processes that realistically and appropriately consider climate risk when improvements are needed for rehabilitation or other reasons is a way to strategically invest in resilience.
- **Operations and maintenance procedures and approaches** are equally important to build resilience. It is important to develop and institutionalize coordinated procedures for operations during extreme weather to maximize service performance while maintaining adequate safety levels. This will become even more important as climate change affects the frequency, magnitude, and duration of extreme weather events. Maintenance budgets can be significantly affected, and budgeting for a diverse set of conditions over multiple years can be a particular challenge. For example, extreme heat may require more frequent road and rail maintenance, but could be very episodic over the long term.
- **Plans for port expansions and major improvements** provide opportunities to account for climate change. Less sensitive locations for certain operations could be beneficial to maintaining higher levels of resilience. Design and materials should be chosen with future conditions and risks in mind. Finally, good planning practices include close coordination with affected parties and interested stakeholders, including the community, to result in better resilience and outcomes.

Resources for integrating climate change into engineering and design practices include:

- USACE's Engineering and Construction Bulletin 2016-25, Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects[100]
- FHWA's Transportation Engineering Approaches to Climate Resiliency (TEACR) Study[101]

[100] U.S. Army Corps of Engineers, "Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects," *Engineering and Construction Bulletin 2016-25*, Washington, D.C., 2016, http://www.iwr.usace.army.mil/Portals/70/docs/Climate%20Change/ecb_2016_25.pdf.

[101] U.S. Federal Highway Administration, "Transportation Engineering Approaches to Climate Resiliency (TEACR) Study," *DOT.gov*, last updated December 22, 2016, https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/teacr/.

- Port Authority of New York and New Jersey Climate Resilience Design Guidelines[102]

Resources for integrating climate change into operations and other management systems include:

- FHWA's Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance[103]
- ACRP Project 02-74 (active), Integrating Climate Change Risk into Airport Management Systems[104]
- NCFRP 50 (active), Improving Freight Transportation Resilience in Response to Supply Chain Disruptions[105]

Checklist

- ✓ Incorporate climate change into existing planning and programmatic processes.
- ✓ Consider a full range of potential adaptation measures.
- ✓ Ensure planning processes address development of capital improvement programs that affect the port's infrastructure to make it more resilient.

3. Identify responsible parties for various strategies, and a process to revisit progress on a continuing basis

In Step 3, a number of strategies were identified to improve resilience. This step involves creating organizational accountability for these strategies. In order to ensure that the identified strategies are prioritized for implementation, it is necessary to explicitly assign an organization and/or specific individual to serve as the champion for the strategy. Identifying these "responsible parties" and making clear their roles in achieving the resilience program will foster better leadership. Progress toward implementing the strategies can then be evaluated on a continuing basis with the responsible parties. It may be the case that some strategies require coordination and action by multiple organizations, but even in these cases, a lead organization and person should be identified to take responsibility of coordinating these organizations through a committee or some other mechanism.

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[102] Port Authority of New York and New Jersey, "Design Guidelines: Climate Resilience," *Port Authority of New York and New Jersey*, last updated January 1, 2015, https://www.panynj.gov/business-opportunities/pdf/discipline-guidelines/climate-resilience.pdf.

[103] U.S. Federal Highway Administration, "Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance," *FHWA-HOP-15-026*, Washington, D.C., 2015, http://www.ops.fhwa.dot.gov/publications/fhwahop15026/index.htm.

[104] Airport Cooperative Research Program, "Integrating Climate Change Risk into Airport Management Systems [Unpublished]," *Transportation Research Board*, accessed 2017, http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4020.

[105] National Cooperative Freight Research Program, "Improving Freight Transportation Resilience in Response to Supply Chain Disruptions [Unpublished]," *Transportation Research Board*, accessed 2017, http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4069.

Checklist

- ✓ Identify individuals and organizations that are responsible for the strategies that need to be implemented.
- ✓ Establish a schedule to review progress with responsible parties on a continuing basis.

4. Develop indicators of resilience that can be used to measure progress

Performance measures such as those identified in Step 1.3 can help port and community managers evaluate whether resilience strategies are effective at achieving the desired goals. Resilience is an inherently difficult quality to measure, but certain measurable outcomes can serve as indicators of resilience to help track progress and improve outcomes over time.

These indicators should be directly related to the community's goals, identified in Step 1. The community should also provide feedback as resilience indicators are identified. Understanding the definitions of resilience and sustainability can help elucidate appropriate indicators. Resilience is defined, in part, as a community's ability to withstand and recover from adversity. In the context of this roadmap, it means a port community's ability to maintain a level of economic, environmental, and public health, and social functioning—regardless of river water levels. One way to measure resilience, therefore, would be to measure whether the port community would have the same (or otherwise acceptable) levels of economic, environmental, and social functioning at extreme water levels as at normal water levels.

Notes

The EPA Office of Environmental Justice, as well as the Regional EJ Program Office should be contacted for assistance in incorporating community feedback, and identifying individuals with regional expertise in developing resilience metrics.

Checklist

- ✓ Develop a list of resilience indicators (i.e., performance measures), using community feedback, for the goals and objectives identified in Step 1.
- ✓ Establish processes to collect data and monitor performance of indicators. For example, identify specific individuals responsible for collecting each indicator.

- ✓ Conduct baseline assessments of performance measures.
- ✓ Compile available indicator data and compare them to river levels to determine resilience. Use the data to identify ways to improve resilience.
- ✓ Coordinate with the EPA Office of Environmental Justice, as well as the Regional EJ Program Office regarding the development of resilience metrics.

VII. Step 5 – Implement Strategies and Evaluate Progress

1. Implement strategies

Implementing the resilience strategies identified will involve management, coordination, and execution of all the individual projects identified for implementation. This will likely involve projects across multiple private and public sector agencies. Actions may be required at different levels of government—in local governments, metropolitan planning agencies, and state and federal agencies. In addition, private sector carriers, shippers, and terminal operators may also be involved.

Implementation may require port stakeholders to obtain funding from multiple sources. It is important to note that grants of public money may come with their own requirements and schedules for implementation.

Port stakeholders will need to determine if existing staff can implement the projects required, or if new staff or outside contractors need to be hired to execute some of the projects. In this complex organizational environment, maintaining communication between all of the stakeholders and staff involved in projects to improve resilience will be an important and challenging task. Improving resilience will require strong leadership to ensure that the goals of resilience are met, and that resilience projects receive attention and priority in an often crowded agenda of activities for all of the organizations involved.

Notes

Checklist

- ✓ Identify an overall coordinator for resilience strategies and programs.
- ✓ Determine if port stakeholders need to hire staff or contractors to implement the resilience strategies.
- ✓ Obtain funding to implement the resilience strategies.
- ✓ Establish protocols for enhancing communication between key stakeholders

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2. Continuously evaluate progress

Resilience is an iterative process. Port communities should continuously evaluate their progress and vulnerabilities. Progress toward achieving resilience goals should be communicated with port stakeholders, including updating and publishing indicators of resilience. Showing progress toward goals can help build momentum for the resilience program, and also identify areas that may need additional attention.

Feedback should be obtained from stakeholders on their experiences implementing resilience strategies. Based on experience with implementation, port stakeholders can evaluate what strategies have worked. In addition, comparisons to other inland ports can help identify best practices. Based on the performance of existing strategies, and experience with implementation, adjustments and improvements to the resilience program may be necessary.

Checklist

✓ Publicize progress toward resilience goals and indicators.

✓ Obtain feedback from stakeholders on implementation.

✓ Make adjustments to the resilience strategies and implementation as necessary.

VIII. Conclusions

Improving the resilience of inland ports and the communities that depend on them will become increasingly important in the future as water levels become more variable and extreme. These projections have the potential to disrupt port operations and have broad economic and community impacts.

Resilience is an especially challenging area because it requires coordination and communication across multiple stakeholder groups. In addition, resilience incorporates diverse goals and objectives, including those related to economic performance, human health, environmental quality, port operations, and community well-being. There is a large array of possible strategies to address resilience. Identifying the most appropriate and high value strategies to pursue must be based on the particular operating environment of the port and the characteristics of the port community.

This roadmap lays out a set of steps to conduct outreach, improve communication and coordination, define goals, identify strategies, implement strategies, and evaluate them. The coordination of a resilience program in a complex organizational environment may be the most challenging aspect. The foundational components of a resilience program will require significant work to develop, such as bringing diverse stakeholders together to build consensus and a common understanding of what needs to be done.

Notes

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Appendix A: Memphis Port Community Needs Assessment

This Appendix summarizes the results of a community needs assessment related to drought and flooding events in the port community of Memphis, Tennessee, which was completed as a research component for the Inland Port Community Resilience Roadmap.

1. Summary

The Port of Memphis, including the port as a whole and specific tenants, is very sensitive to variability in river levels on the Mississippi. High water levels can cause destructive flooding and create hazardous safety conditions. Low water levels, alternatively, can restrict freight throughput and have ripple effects throughout the supply chain. River variability has increased in recent years, in addition to the frequency and severity of high and low extremes. Whether this variability is due to changes in weather or due to river management practices is unknown among Memphis stakeholders.

The risks may be increasing. Changes in the frequency, intensity, and duration of extreme weather events such as drought and floods appear likely to increase in the future. Extreme temperatures are expected to increase in the lower Mississippi River basin, which could cause synergistic impacts with changes in seasonal rainfall and contribute to more frequent and severe droughts.[106] While average rainfall is difficult to predict, more rain will likely fall as heavy downpours leading to higher flooding potential.[107]

Though extreme water levels can severely hamper port operations, disruptions at the port are not perceived in the community at large. This could be because community members have little visibility into port activities, because freight diversions are made by individual actors at the port and are not "captured" in data collection, because impacts are not consistent from event to event, or because impacts are longer-term.

However, port disruptions can cause freight diversion to alternate modes, which in turn can increase congestion, road degradation, and air pollution. Perhaps most significantly, port vulnerability to extreme water levels can harm the city's ability to recruit and retain companies to have operations in Memphis, with clear implications for economic development and jobs in the community.

Stakeholders in the Memphis area were not able to discern whether port disruptions from extreme weather caused community social and economic impacts. The extent of diversions to trucks will likely require concerted study as port tenants and shippers make individual decisions regarding diversions to truck or rail. Hence congestion and air pollution impacts from extreme weather are unknown according to focus groups held in Memphis. There are similar

[106] Jerry M. Melillo, Terese (T.C.) Richmond, and Gary W. Yohe, "Climate Change Impacts in the United States: The Third National Climate Assessment," U.*S. Global Change Research Program*, U.S. Government Printing Office, Washington, D.C., 2014, doi:10.7930/J0Z31WJ2.

[107] Ibid.

uncertainties about changes in employment, whether temporary or permanent due to extreme weather. Port officials suggested that extreme events require an “all-hands-on-deck” mentality and thus they maintain employment levels to address the crisis. Employment data were not examined for this study and thus the extent to which employment may be affected is unknown.

Stakeholders identified several needs to help improve community resilience to these events, including additional research needs, specific vulnerabilities to target, and broader policy needs.

2. Community Needs Assessment Process

The community needs assessment included 2-hour workshops with five groups of key stakeholders:

- **Ports** – including representatives from the port authority and private sector port tenants
- **Local Government** – including representatives from multiple City of Memphis and Shelby County departments
- **State and Federal Government** – including representatives from numerous state and federal agencies, including the: such as the Tennessee Department of Environment and Conservation, Department of Economic and Community Development, and Department of Health; U.S. Coast Guard, U.S. Army Corps of Engineers, and FEMA
- **Community and NGO** – including representatives from local NGOs and community leaders representing near-port communities
- **Universities** – including local academic experts from the University of Memphis, University of Tennessee, and Vanderbilt University with expertise in ports, public health, supply chains, and other relevant topics

Separate workshops were held with each group to facilitate candid and detailed dialogue about resilience needs from each different perspective.

Forty-five individual stakeholders participated in the workshops, in addition to EPA and contractor staff.

3. Overview of the Port of Memphis

The Port of Memphis includes five river ports and almost 100 public and private individual terminals. It provides $8.46 billion per year to the Shelby County economy, supports over 20,000 jobs, and moved 12.1 million tons of cargo in 2010. The river ports include the International Port of Memphis and three ports in Arkansas as well as the Port of Cates. The International Port of Memphis handles more than 90% of the traffic. It is the United States' fourth largest inland port, handling cargoes like tar, petroleum, cement, asphalt, coal, steel, fertilizers, salt, rock and gravel, and grains. Almost all of the industries included in the International Port of Memphis are based on President's Island.

Figure 8: Port of Memphis overview (source: Port of Memphis, 2012, Port of Memphis Brochure, available at: http://portofmemphis.com/pdfs/Port%20of%20Memphis%20Brochure%202012.pdf)

The International Port of Memphis contains five public terminals with 11 berths. The public terminals are located at McKeller Lake/Presidents Island, Rivergate Harbor, West Memphis Harbor, Fullen Dock and Warehouse, and Wolf River Harbor. The Fullen Dock and Warehouse is the only terminal in the International Port of Memphis that directly loads containers to and from barges and trucks.[108]

Petroleum products (3.1 million tons) accounted for one quarter of all cargoes in the Port of Memphis and included almost 1.2 million tons of receipts and over 1.6 million tons of shipments. Food and farm products handled in the Port of Memphis were almost equal (also 22%) to coal at 2.6 million tons, including 588 thousand tons of receipts and almost two million tons of shipments. The port handled almost 1.8 million tons (15% of total) of crude materials, including over 1.6 million tons of sand, gravel, rock, and stone. The Port of Memphis handled more than 1.2 million tons (10%) of chemicals and related products.

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[108] World Port Source, "Port of Memphis," *World Port Source,* 2015, http://www.worldportsource.com/ports/commerce/USA_TN_Port_of_Memphis_1805.php.

The Memphis & Shelby County Port facilities are served by five Class I railroad carriers, two barge fleeting services, and a multitude of barge and truck transportation services. The port facility has immediate access to interstate 40 and 55 and is located less than 15 minutes from Memphis International Airport.

4. Impacts of High and Low Water

The Port of Memphis has experienced significant impacts from drought and flooding conditions in the recent past. Significant droughts have occurred in 1988 and 2012. The 2012 event disrupted shipping, closed the public terminal operated by Kinder Morgan, stranded hundreds of barges when the river was closed, and caused Ingram Barge to cut its shipping volume by 40 percent.

The Mississippi River has experienced two 300- to 500-year floods over the past 20 years. One of these events in 2011 resulted in a mile-long and half-mile wide gash down the center of President's Island, costing $9 million to repair. It also precipitated a $20 million investment by USACE to reconstruct the river bank.

Port of Memphis stakeholders and river gauge records indicate that river levels on the lower Mississippi have become increasingly variable over time. In addition to year-to-year variability (Figure 9), in recent years river levels have fluctuated up to 3 feet within a single day, and 7-8 feet over two days (Figure 10).

Variability in river levels disrupts port operations. When river levels are too low, barges need to reduce their tonnage in order to navigate the river. Displaced goods must then either wait out the low water period or be moved onto alternate modes of transportation, such as rail or truck. High water situations can flood port facilities, damage cargo, and create safety risks for port workers.

Port officials and tenants report that upriver management of the Mississippi River has become increasingly variable by the U.S. Army Corps of Engineers (USACE) and Coast Guard. They feel that daily river fluctuations have effectively doubled from approximately 1.5 feet to approximately 3-4 feet, making operations more difficult. They felt that water management had become more difficult for these agencies due to increasing water needs upriver from recreation and riverside development. They acknowledged that weather events may play some role, but could not state the extent to which daily fluctuations were due to changes in management versus changes in rainfall and drought. Port representatives reported that addressing river changes was a daily challenge and that business-as-usual operations were conceptually relevant, but rarely realized. For their part, the federal agencies reported that the Mississippi River was well managed, including the impacts of extreme weather events and gave the impression that disruptions at the Port were controllable.

Impacts of variable water levels on the port have subtle effects on the broader community. Immediate effects may not be noticeable, but concerns about the river's reliability can harm Memphis' economic development and ability to recruit and retain industries.

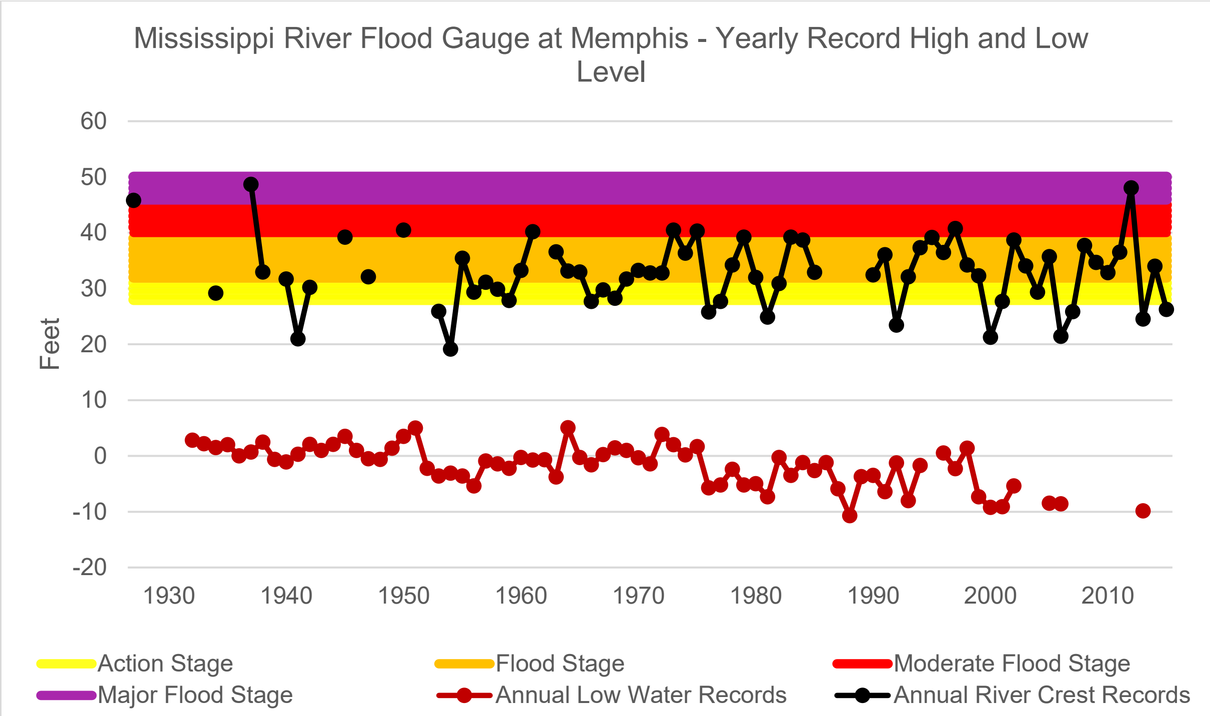

Figure 9: Annual high and low river levels, Mississippi River at Memphis, 1927–2016 (chart developed by ICF using data from National Weather Service Advanced Hydrologic Prediction Service, Mississippi River at Memphis (MEMT1)

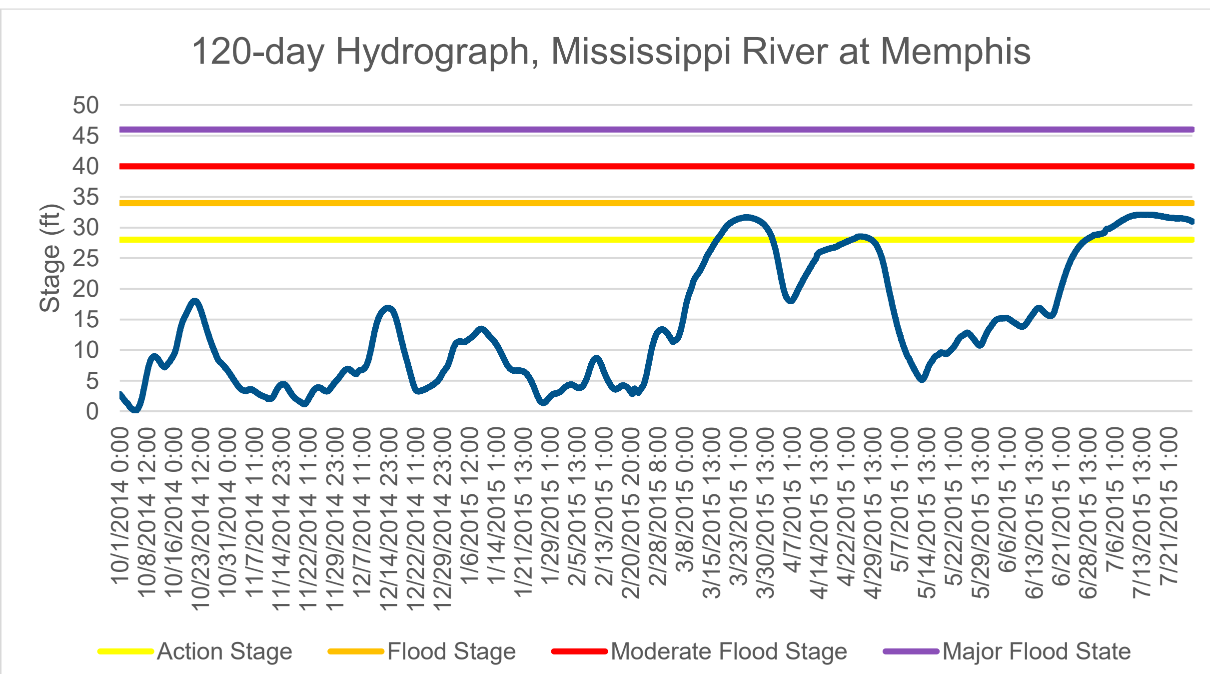

Figure 10: Hourly river levels (120-day period, 10/1/2014-7/21/2015) (data source: USGS National Water Information System, Mississippi River at Memphis)

4.1 Low Water Impacts

4.1.1 Effects at the Port

Changes in Goods Movement

Stakeholders at the Port of Memphis—including the port authority and several major private sector port tenants—indicate that port operations are highly sensitive to variable and extreme water levels on the river.

In low water situations, the Mississippi River has less capacity to handle freight. Barges must reduce their loads and the number of barges that can pass through the river at a given time can be restricted.

When freight cannot pass on the river, shippers have several options, including: wait until water levels rise, divert freight to an alternate port or river, divert freight to rail, or divert freight to truck. Some industries, like oil refining, can only move product by barge (because it is too large or requires specialized containers to transport by any other means), so refineries are forced to limit production until the product can be moved.

The decisions about how to move individual units of cargo rest with the product owners and depend on several factors—many of which may be changing in real-time during a low water event. Relevant considerations include:

- Time-sensitivity of delivery (including perishable goods)
- Global prices for the product
- Capacity of alternate modes
- Prices on alternate modes (e.g., rail, freight)
- Availability of infrastructure to support transfer

Implications of Low Water Levels for Freight Movement

- For every one inch of lost water, each barge is unable to move 17 tons of cargo*
- Typical tow on the Lower Mississippi is 30-45 barges, meaning decreased capacity of up to 765 tons for 1 inch of lost water
- Cargo capacity (dry tons):†
  - Barge: 1,750 tons
  - Rail car: 110 tons
  - Truck: 25 tons

*Inland Waterways User Board, 2004

†Texas Transportation Institute (TTI), A Modal Comparison of Domestic Freight Transportation Effects on the General Public: 2001-2009, prepared by TTI Center for Ports and Waterways for the National Waterways Foundation, 2012

Thus, the outcomes of goods movements may vary from one low water situation to the next.

Economic Impacts

For most industries in Memphis, low water events and associated freight disruptions increase industries' operating costs. Alternate modes of shipping are more expensive than barges during "business as usual" situations, and even more so in low water situations when demand for rail and truck transportation is higher.

Some terminals, such as the Kinder Morgan terminal, simply cannot operate in low water situations because barges cannot reach their docks. During the 2012-2013 low water event, Kinder Morgan entered *force majeure* and was out of service for nine months.

Some industries, such as marine services—which provide refueling and move barges in and out of the port—see increased revenues during low water events.

Economic impacts vary by industry, as shown below.

- Goods Owners: Increased cost to ship goods
- Port Tenants and Users: Increased labor costs, overtime
- Terminals: Reduced freight movements, decreased revenues
- Towing Companies: Increased operating costs
- Marine Services: Increased activities, revenues

These increased costs and market inefficiencies get passed down and distributed across the national and global economies.

Timing of Low Water Impacts

Harvest season (August-October) is the busiest time of year for the Lower Mississippi as grain and other agricultural products make their way down river. Low water levels during the harvest season would have much larger economic disruptions than low water at other times of the year.

4.1.2 Effects in the Community

Economic

Low water conditions on the Mississippi, in general and at the Port of Memphis specially, cause supply chain disruptions that have far-reaching economic implications. However, immediate economic implications in the Memphis community may be limited—or may be unnoticeable beyond the boundaries of President's Island without directed study.

Extreme water levels—low or high—can have long-term economic implications for the community. Stakeholders from the Tennessee Department of Economic and Community Development, City of Memphis, Shelby County, and the Port of Memphis stressed that the resilience of the port to extreme water levels is critical for industry recruitment and retention in the Memphis area. High and low water levels that inhibit goods movement and port operation can damage Memphis' reputation as a reliable transportation hub. Industries choosing not to establish operations in Memphis or existing industries choosing to leave would devastate the local economy. The Port of Memphis contributes an estimated $8.46 billion per year to the Shelby County economy, along with over 20,000 jobs.[109]

Social

When cargo does get displaced onto trucks, it can increase traffic congestion, road and bridge deterioration, and diesel emissions, degrading air quality and causing associated health effects such as decreased lung function, increased heart attacks, and exacerbated asthma. Up to 70 trucks are needed to carry the freight of one barge.[110] Texas Transportation Institute estimated that the hypothetical diversion of current waterway freight traffic to the nation's highways would

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[109] Memphis and Shelby County Port Commission, "The Economic Impact of the Port of Memphis on the Memphis and Shelby County Economy," prepared by Younger Associates for the Memphis and Shelby County Port Commission, August 2014.

[110] C. James Kruse, Annie Protopapas, and Leslie Olson, "A Modal Comparison of Domestic Freight Transportation Effects on the General Public: 2001-2009," *Texas Transportation Institute*, February 2012, http://www.nationalwaterwaysfoundation.org/study/FinalReportTTI.pdf.

add 742 combination trucks (to the current 887) per day per lane on a typical rural interstate. Cost to ship goods via rail would also likely increase.[111]

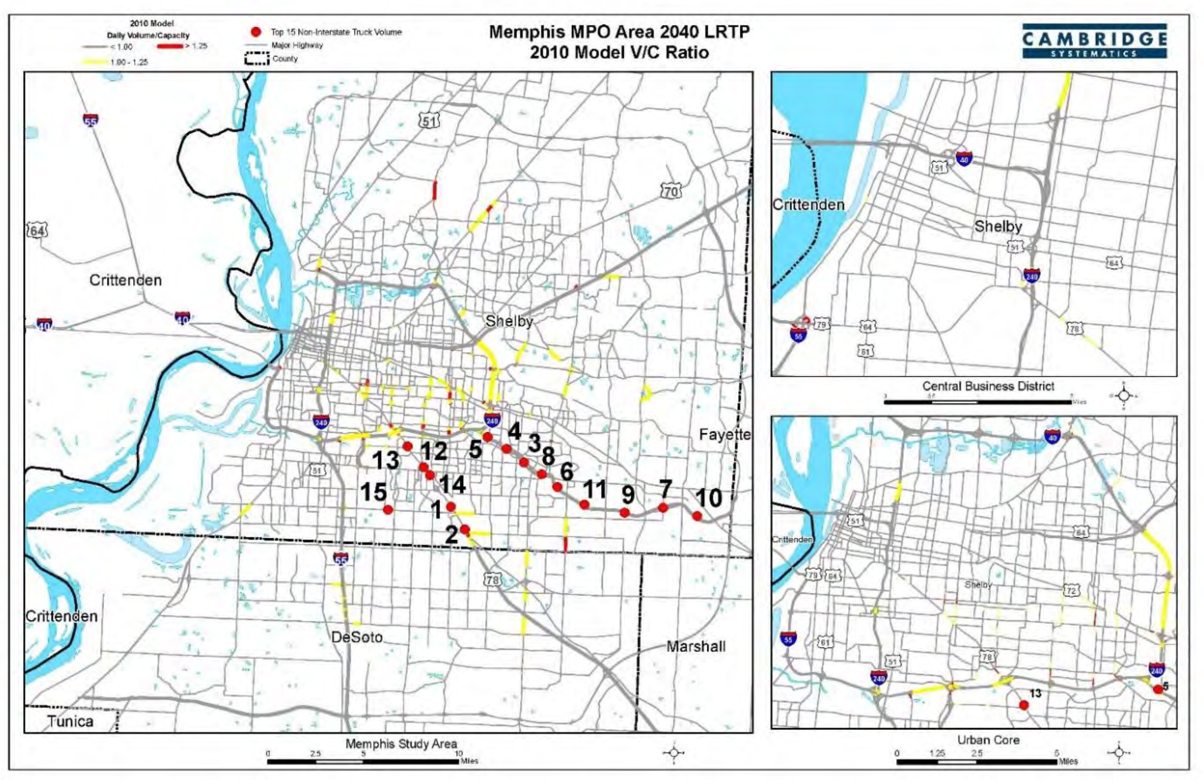
Diversions to truck traffic would likely be accompanied by increases in oxides of nitrogen (NO_x) and particulate matter (both PM-2.5 and PM-10). Memphis has been designated by the EPA as nonattainment for ozone (the product of a reaction between NO_x and hydrocarbons on warm, sunny days) but not for Particulate Matter. Increases in NO_x could lead to higher levels of ozone pollution. Higher concentrations of particulate matter could result in a designation of nonattainment depending on how close to the standard the Memphis area is already. But even without a nonattainment designation by EPA, areas of high PM concentration, also known as “hotspots”, can have significant health impacts.

Stakeholders in Memphis, however, were unable to identify whether any of these outcomes had occurred in Memphis in recent low water periods, such as in 2012. High volumes of truck traffic – even in “normal” times – disproportionately affect neighborhoods in South Memphis, bordered by both Interstate 240 and Interstate 55. South Memphis is a low income, majority African American neighborhood with a high prevalence of childhood asthma. One stakeholder reported on the impacts of truck traffic on south Memphis. He cited potential health impacts from truck emissions and social disruption due to truck congestion but did not know if incremental truck traffic expanded during low water events.

This may be, in part, because Memphis has high baseline levels of truck traffic. Three interstate segments in the region have over 14,000 trucks per day, and several other non-interstate segments carry over 7,000 trucks per day.[112] Of these, several have volume to capacity (V/C) ratios nearing or exceeding 1, meaning they are highly congested. Figure 11 shows a map of truck traffic and highway congestion in the Memphis area. Yellow shading indicates a highway segment has a V/C ratio greater than 1, meaning traffic volume exceeds capacity.

[111] Texas Transportation Institute (TTI), A Modal Comparison of Domestic Freight Transportation Effects on the General Public: 2001-2009, prepared by TTI Center for Ports and Waterways for the National Waterways Foundation, 2012

[112] Memphis MPO, Direction 2040: Direction 2040: Long Range Transportation Plan, “Chapter 4: Existing Conditions and Needs Assessment,” Memphis Metropolitan Planning Organization, 2014



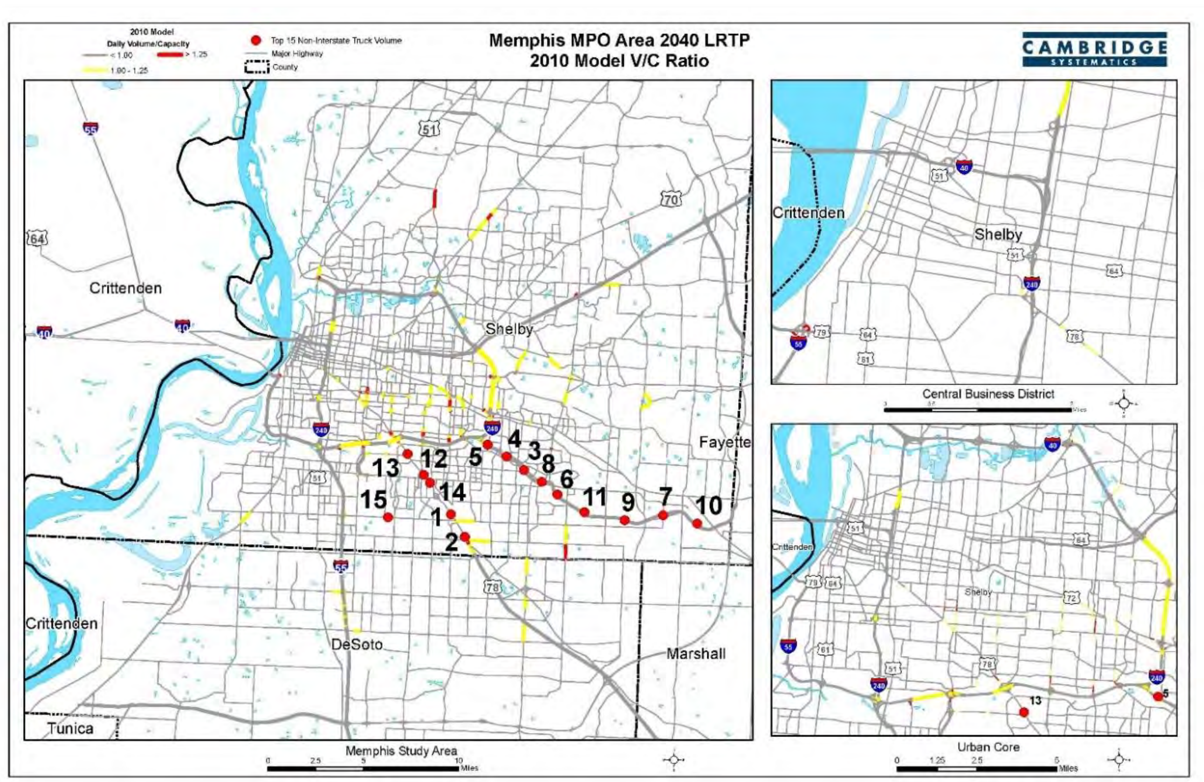


Figure 11: Interstate (above) and non-interstate (below) truck traffic congestion. Red dots indicate the "top 15" segments in the Memphis area by truck traffic volume. Yellow and red shading indicate segments with V/C ratios > 1. Source: Memphis MPO, 2040 Long Range Transportation Plan, Figure 4.34.

Low water events which strand barges and reduce port activity could result in lower community employment levels, reduce income, and have undesirable social impacts on the community. Port officials recognized the potential but stated that retention of well-trained employees was more important than short term reductions in labor costs. They also described low water (and high water) situations as times when it was necessary to have full employment to deal with the crisis at hand. Low water events can result in unusual conditions that require more labor, such a stranded barges or attempting to load under low water conditions. City and county officials, and community leaders were not cognizant of any employment changes from extreme weather. They did not dispute the impacts reported by the Port representatives. While changes in employment during extreme weather events may occur, it may be necessary to verify them through data collection and analysis, since the perceptions of community and city representatives may be too general in nature to discern any such impacts.

4.2 High Water Impacts

High water levels on the Mississippi River (flood stage is defined at 34 feet) can cause flooding along its banks and those of its tributaries in the Memphis area—including the Wolf River, Loosahatchie River, and Nonconnah Creek.

4.2.1 Effects at the Port

Flooding can damage cargo, electronic equipment, and port facilities if water reaches them. The river can also deposit extensive debris and silt that requires cleanup. For example, in 2011 water levels reached 48 feet. The U.S. Geological Survey (USGS) estimates this flood has an annual exceedance probability (AEP) of 0.4%, or about a 1-in-250 year flood.[113] The flooding was extensive in the Memphis area, including in President's Island (Figure 12). The flooding caused $9 million of damage to President's Island in erosion and structural damage to the island itself.[114] Several port facilities and some cargo were damaged.

[113] Daniel G. Driscoll, Rodney E. Southard, Todd A. Koenig, David A. Bender, and Robert R. Holmes, Jr., "Annual exceedance probabilities and trends for peak streamflows and annual runoff volumes for the Central United States during the 2011 floods," *U.S. Geological Survey Professional Paper 1798–D*, Reston, VA, 2014, http://dx.doi.org/10.3133/pp1798D.

[114] Wayne Risher, "Port of Memphis needs $9 million for flood fix," *Commercial Appeal*, December 2, 2011, https://www.pressreader.com/usa/the-commercial-appeal/20111202/281913064931512.

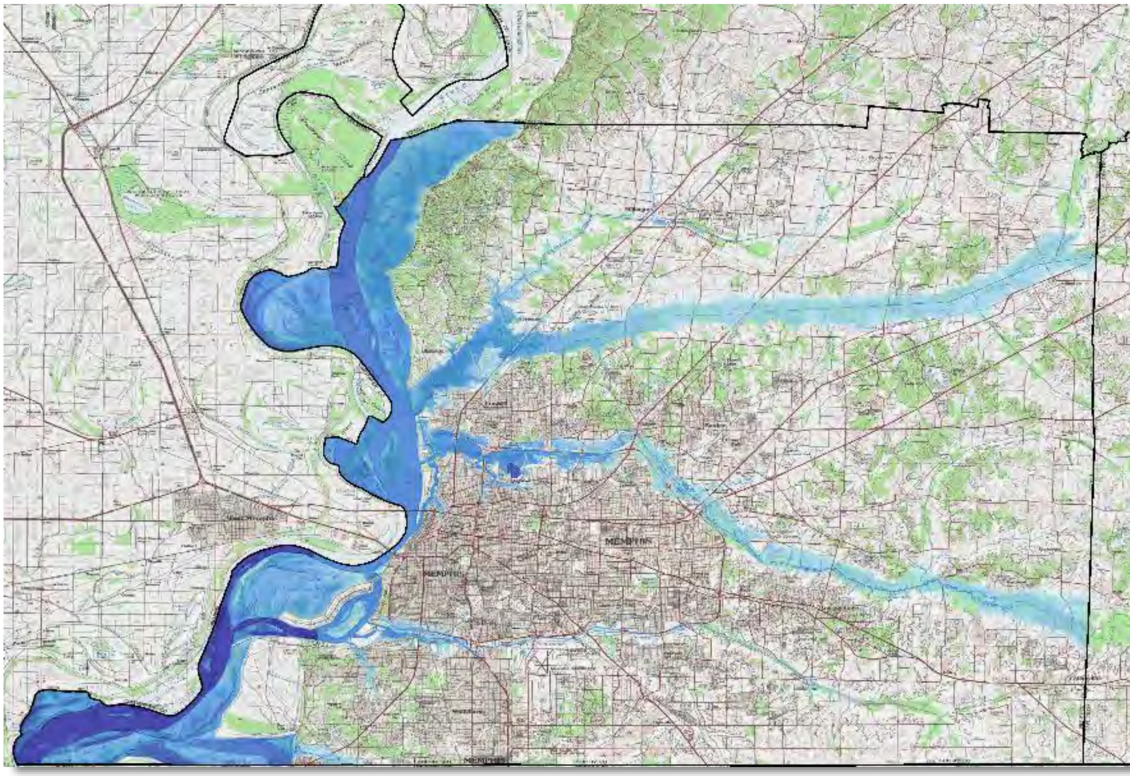


Figure 12. Peak flood inundation, 2011 Mississippi River Flood – preliminary map (source: David Ladd, USGS TN Water Science Center, 7/29/11)

High water can also reduce access to President's Island and Pidgeon Industrial Park. City government officials noted that in 2011, roads to Pidgeon Industrial Park flooded, so the city had to add material to elevate the road base in order for employees to get to work. Both areas have little redundancy in terms of access, so flooding on those access roads (I-55 and Jack Carley Causeway for President's Island, and Paul R Lowry Road for Pidgeon Industrial Park). Other access issues were hinted at but not directly expressed highlighting the potential need for a vulnerability analysis that includes access points.

High water levels also pose a threat to the health and safety of employees working at docks and on barges. At high water, the river flows more quickly, which can create dangerous conditions and fleet breakaways.

Finally, damage to terminal facilities and fast-moving water can also shut down port operations and disrupt commerce on the river. For example, in 2011, the U.S. Coast Guard closed a 15-mile stretch of the river to reduce pressure on the levees, which caused an estimated $300 million in economic losses per day.[115] As in low water situations, river closures or terminal disruptions can cause goods to shift to alternate transportation modes, though the precise outcomes are variable.

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[115] John Manners-Bell, "Supply Chain Risk: Understanding Emerging Threats to Global Supply Chains," *Kogan Page Publishers*, 2011, p. 96.

4.2.2 Effects in the Community

Stakeholders indicate that flooding at the port does not directly affect the community at large (with the exception of harming potential business recruiting, as discussed above). Memphis and surrounding areas are largely protected by levees which have not been breached by recent events. Nonetheless, flooding does directly affect the community during high water events, and floodwaters—particularly in Frasier, Millington, and North Memphis—can damage homes and businesses. High waters on the Mississippi effectively back up other rivers and streams that feed into it. City, county and community representatives report that flood control measures have been rendered less effective by damage from previous floods and debris. Such floods have numerous economic, health, and social consequences, and were of considerable concern to city, county and community representatives, but are not the focus of this study.

It is possible that Port activities would increase during high water events, leading to increases in diesel emissions in the immediate vicinity. No stakeholders reported this as a concern. Given the attainment status for PM of the Memphis area, however, hotspot pollution may still be a cause for concern at the Port.

Port representatives reported that high water conditions can cause employment to increase, as loading and unloading may become more difficult and Port operations can increase. In particular, the need for trained personnel on barges increase and the costs increase since demand is high and the supply of trained and certified pilots is relatively fixed. As in the case of low water conditions, changes in employment due to high water were generally not noticed by city, county, and community representatives interviewed. This may be due to the fact that such changes are small in comparison to overall employment levels, or that the interviewees were simply unaware of these impacts.

5. Potential Impacts of Climate Change

According to the Third National Climate Assessment (NCA), the incidence and severity of both droughts and floods could increase over the next 50 to 100 years. Short-term (seasonal or shorter) droughts are expected to intensify in most U.S. regions, including the lower Mississippi region. Longer-term droughts are expected to intensify in large areas including the Southeast, and annual runoff and related river-flow are projected to decline in the Southeast.[116]

The U.S. Army Corps of Engineers commissioned a series of literature reviews on climate change potentially affecting operations in various river basins. In Region 8, the lower Mississippi River basin, they reported on Joetzjer et al. (2013) who compared drought indices calculated using historical data and General Circulation Model (GCM) projections.[117] Using an ensemble projection from five GCMs, Joetzjer et al. found significant increases in the frequency and areal extent of droughts (of at least 12 month duration) in the region, for the majority of modeled

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[116] Jerry M. Melillo, Terese (T.C.) Richmond, and Gary W. Yohe, "Climate Change Impacts in the United States: The Third National Climate Assessment," U.*S. Global Change Research Program*, U.S. Government Printing Office, Washington, D.C., 2014, doi:10.7930/J0Z31WJ2.

[117] E. Joetzjer, H. Douville, C. Delire, P. Ciais, B. Decharme, and S. Tyteca, "Hydrologic benchmarking of meteorological drought indices at interannual to climate change timescales: A case study over the Amazon and Mississippi river basins," *Hydrology and Earth System Sciences* 17, (2013): 4885-4895, doi.org/10.5194/hess-17-4885-2013.

scenarios, for the latter half of the 21st century. These results reflect the impacts of projected temperature and extreme temperature increases.

The NCA also cites the potential for increased flooding. "Inland waterways may well experience greater floods, with high flow velocities that are unsafe for navigation and that cause channels to shut down intermittently. Numerous studies indicate increasing severity and frequency of flooding throughout much of the Mississippi and Missouri River Basins." The Ohio River basin which feeds the lower Mississippi River is projected to experience increases in overall annual precipitation as well as in the heaviest rainfall events (the 90th percentile of all events) according to the US Geological Survey National Climate Change Viewer.[118] The heaviest rainfall events would increase by 6.2% under a moderate emissions scenario (RCP 4.5) and by 13.1% under a high emissions scenario (RCP 8.5) by the end of the century.

The USACE literature review also indicates increases, albeit relatively small, in the number in the number of high (>10 mm) precipitation days for the region, the number of storm events greater than the 95th percentile of the historical record, and the daily precipitation intensity index (annual total precipitation divided by number of wet days).[119] Voisin et al. (2013) looked at results in the Upper Mississippi, Missouri, and Ohio River regions (the Ohio River region includes Water Resources Region 5 as well as Water Resources Region 6, the Tennessee Region). Results include simulated average monthly flows for the Ohio River at Metropolis, IL (Figure 3.18), indicating an increase in future streamflow.[120]

While the Mississippi River is highly managed, changes in heavy precipitation events leading to flooding, along with the potential for increased droughts could exacerbate challenges to existing operations at the Port of Memphis. These events could also create further disruptions in the social and economic conditions within the surrounding community.

6. Needs Identified

Stakeholders in Memphis identified several needs that, if met, could help improve community resilience to extreme water levels on the Mississippi. Surprisingly, few needs requiring investment for resilience were identified. Other investment needs would probably surface if examined more explicitly. Several research needs were identified to understand the impacts of extreme weather on Port operations, and resulting economic and social effects.

Needs Requiring Investment

Increase port access redundancy. Flooding can block access to President's Island and Pidgeon Industrial Park because each only have one primary access route. Protection of those

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[118] Calculated from the USGS National Climate Change Viewer (see http://www.usgs.gov/climate_landuse/clu_rd/apps/nccv_viewer.asp). The results reported here are from the "mean model," which provides the ensemble projections of 30 General Circulation Models.

[119] U.S. Army Corps of Engineers, "Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions: Lower Mississippi Region 08," *U.S. Army Corps of Engineers*, September 1, 2015, http://www.corpsclimate.us/docs/rccvarreports/USACE_REGION_08_Climate_Change_Report_CWTS-2015-01_Lo.pdf.

[120] Ibid.

existing access routes (through flood barriers or elevation) or the creation of redundant access routes would increase the port's resilience to flooding events and allow port staff and emergency responders to access the area. It may be necessary to first conduct additional research to identify where redundant access is needed.

Use flexible infrastructure, where possible. Individual port facilities in Memphis have begun to make capital investments to increase their resilience to variable water levels. Infrastructure that can function regardless of water levels—or at least in a wider range of water levels—such as floating docks and flexible conveyors are more resilient to river fluctuations and extremes.

Increase rail capacity. Extreme water levels have far-reaching economic consequences when the freight cannot be cheaply or easily transported by other means. One possible way to mitigate these impacts is to incentivize excess or redundant rail capacity that can absorb barge cargo when necessary.

Operational Needs

Increase coordination between the U.S. Army Corps of Engineers, the U.S. Coast Guard, and the Port of Memphis. USACE and the Coast Guard manage water levels and traffic on the Mississippi River. Stakeholders at the Port of Memphis indicated that improved coordination—such as regular communication, open communication lines, or periodic meetings—could improve their ability to cope with fluctuating river levels. For example, port stakeholders felt that river level variability could be driven by river management rather than by weather events, and wanted their needs heard before river management decisions are made.

Document and track impacts. Data were not available to answer the questions of whether the 2011 flood event or 2012 drought increased truck traffic, road degradation, pollutant emissions, asthma-related hospitalizations, or other negative outcomes. The city could monitor these conditions over time and correlate them with river levels to inform decision-making. Monitors can also help improve situational awareness and improve response during events.

Increase availability of river pilots. Demand for experienced river pilots exceeds supply, particularly in times of extreme high or low water levels. The training time required to become a river pilot has increased and many river pilots have left because of medical issues, meaning the industry is losing numbers. Port stakeholders indicated a need to increase the supply of river pilots, whether through outreach to encourage more people to enter the profession, or changing training requirements.

Update processes for disposing of silt after floods. When the river floods, it deposits large amounts of silt that could be contaminated with hazardous chemicals. Environmental regulations prevent the silt from being deposited back in the river, and cleanup is expensive. City, county, and port stakeholders suggested that streamlining the process of post-flood cleanup would be helpful to reduce costs and speed recovery.

Ensure reliability of city flood pumps. Stakeholders with the City of Memphis and Shelby County noted that the city's backwater pumps are working well, but 50-70 years old, so replacement parts are not easily available if it were to malfunction. In addition, the Ensley pumping station has no backup power source. The city would be better protected against flooding if they had replacement parts and backup power ready to respond during an event.

Incorporate potential freight disruptions from high and low water into the region's Long Range Transportation Plan (LRTP). The Memphis MPO's LRTP includes a chapter on freight "existing conditions and needs assessment." If extreme water levels are projected to occur more frequently, the MPO may need to incorporate scenarios where freight is limited through the port into their long-range planning.

Adopt floodplain management best practices. Practices such as building above the base flood elevation, stream abatement, elevating and securing backup generators, drainage maintenance, and others can reduce flooding vulnerabilities across the community, including and beyond the port. Clearing debris from storm drains was cited as a particular example.

Research Needs

Research relative contributions of river management and weather events to river level variability. River levels in Memphis are influenced by what happens upstream—including, weather events (snow, rainfall, drought, etc.), but also river management decisions such as whether to store or release water in reservoirs. River management decisions can also help smooth out the impacts of weather changes and seek to maintain river levels at a predictable stage. Port stakeholders identified a research need to determine how river management and weather events have each contributed to the recent increase in river level variability in Memphis. This knowledge could help inform decisions about whether and how river management may need to adapt to a changing climate.

Conduct a vulnerability analysis of the Port of Memphis to future extreme weather. Direct analysis of the potential changes in temperature and weather affecting the Lower Mississippi, as well as the Ohio and Upper Mississippi, River basins—and their impacts on Port operations—would provide a greater understanding of the Port's resilience to climate change. Points of access to the Port would be of special concern. It could provide insights into needed investments, and change to operations and maintenance, to enhance resilience. It would also raise awareness on the importance of climate change to Port representatives some of whom considered climate change to be of negligible concern.

Research economic impacts of variable water levels. Port representatives and others felt that a better understanding of the economic impacts of extreme weather events was necessary. Some research has been done in this area but more is needed. In particular, the disruption to supply chains is not understood, and a better understanding would identify the criticality of improving the resilience of Port operations.

Examine diversions to truck and rail during extreme weather events. None of the interviewees were able to provide a sense of the extent to which diversions to truck and rail occur during extreme weather. As such, the social and economic impacts of such diversions are unknown. If diversions are common or important in magnitude, then research into social and economic impacts should follow. Specific examinations into congestion and emissions levels at potentially sensitive locations, such as south Memphis, could be examined.

Increase community awareness of the Port of Memphis' economic and social impacts and vulnerabilities. Several stakeholders—within and beyond the port—expressed that many Memphians have limited awareness of the port, its economic impacts, and the community implications of port disruptions. Because the port is located on President's Island and away from downtown, it is "out of sight, out of mind," for most residents. Stakeholders suggested that an educational program about the value of the port to the community and the vulnerabilities it faces due to extreme water levels could increase the political will to improve port resilience. This will likely require research to better understand social, economic, and environmental connections to the Port.

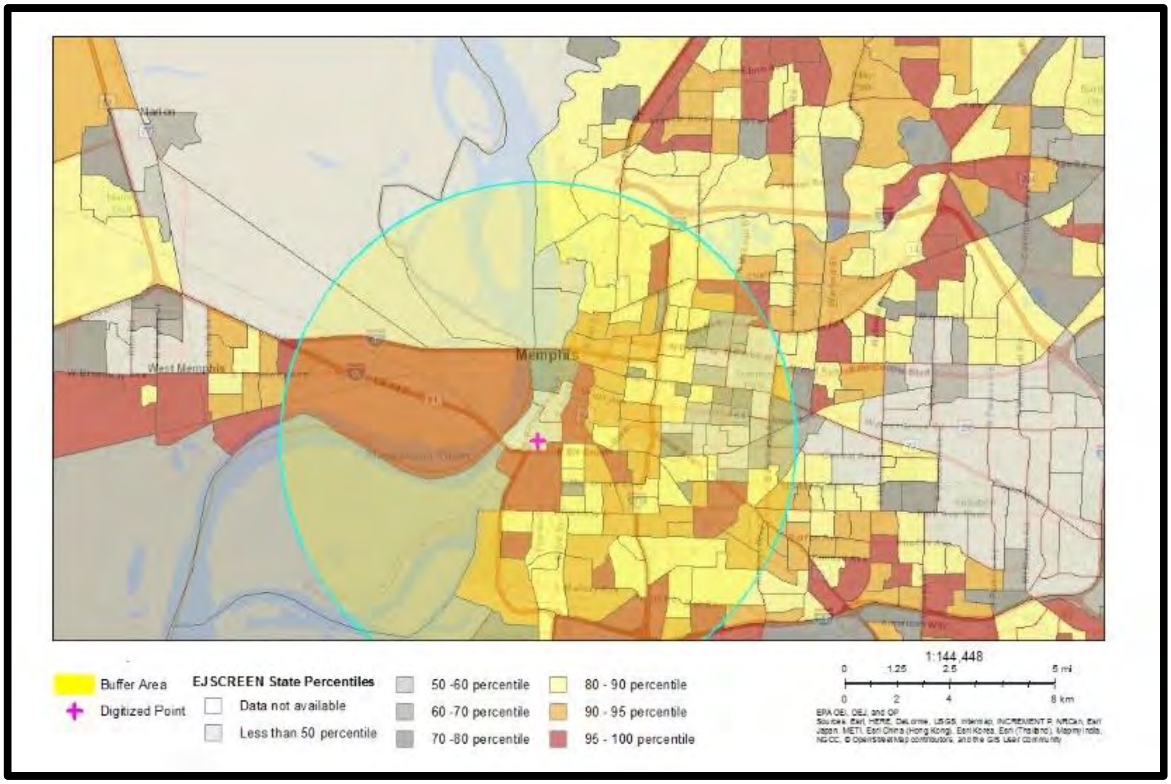
Reduce truck fleet emissions. The potential air quality and health effects of freight displacement onto trucks would be mitigated if said trucks were more fuel efficient or used alternative fuels.

Appendix B: EPA Science Tools

This Appendix provides use case examples to introduce datasets of specific EPA science tools, and demonstrate their use in supporting community decision making processes.

1. EJSCREEN

EJSCREEN, as a screening tool, is useful as a **first step** in understanding or highlighting locations that may be a candidate for analysis, outreach, and in some cases further review.



EJSCREEN provides numerical estimates for a specified location, for both environmental and demographic data, such as the traffic proximity indicator, or the percentage of local residents who are racial/ethnic minorities. This map summarizes the demographics of residents and environmental indicators, and EJ index values within a 5-mile buffer of the Memphis tri-port region.

Explore the environmental, demographic, and EJ characteristics of a block group or buffer area

EJSCREEN uses "percentiles" to compare a community to the rest of the state, EPA region and nation. As a relative term, percentiles are a way to see how local residents compare to everyone else in the United States. This table provides the 11 environmental indicators and 6 demographic indicators for residents within the 5-mile buffer of the Memphis tri-port region.

Sites reporting to EPA	
Superfund NPL	1
Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDF)	1

Selected Variables	Value	State Average	Percentile in State	EPA Region Average	Percentile in EPA Region	USA Average	Percentile in USA
Environmental Indicators							
Particulate Matter (PM 2.5 in µg/m^3)	9.86	9.46	85	8.46	84	9.14	67
Ozone (ppb)	38.5	38.5	49	36.4	85	38.4	58
NATA* Diesel PM (µg/m^3)	1.49	0.812	89	0.754	90-95th	0.938	80-90th
NATA* Air Toxics Cancer Risk (risk per MM)	54	43	93	42	90-95th	40	90-95th
NATA* Respiratory Hazard Index	3.8	1.6	98	1.7	95-100th	1.8	95-100th
Traffic Proximity and Volume (daily traffic count/distance to road)	840	210	94	290	91	590	85
Lead Paint Indicator (% pre-1960s housing)	0.61	0.2	93	0.16	95	0.29	82
Superfund Proximity (site count/km distance)	0.28	0.068	96	0.083	94	0.13	90
RMP Proximity (facility count/km distance)	0.98	0.52	84	0.59	81	0.73	76
Hazardous Waste Proximity (facility count/km distance)	0.14	0.071	90	0.067	90	0.093	84
Wastewater Discharge Indicator (toxicity-weighted concentration/m distance)	0.011	0.096	81	0.26	86	30	81
Demographic Indicators							
Demographic Index	66%	32%	90	38%	85	36%	85
Minority Population	74%	25%	89	37%	83	38%	81
Low Income Population	58%	39%	82	39%	81	34%	84
Linguistically Isolated Population	1%	2%	74	3%	59	5%	52
Population with Less Than High School Education	17%	15%	64	14%	66	13%	71
Population under Age 5	6%	6%	55	6%	55	6%	53
Population over Age 64	12%	15%	39	15%	43	14%	47

*The National-Scale Air Toxics Assessment (NATA) is EPA's ongoing, comprehensive evaluation of air toxics in the United States. EPA developed the NATA to prioritize air toxics, emission sources, and locations of interest for further study. It is important to remember that NATA provides broad estimates of health risks over geographic areas of the country, not definitive risks to specific individuals or locations. More information on the NATA analysis can be found at: https://www.epa.gov/national-air-toxics-assessment.

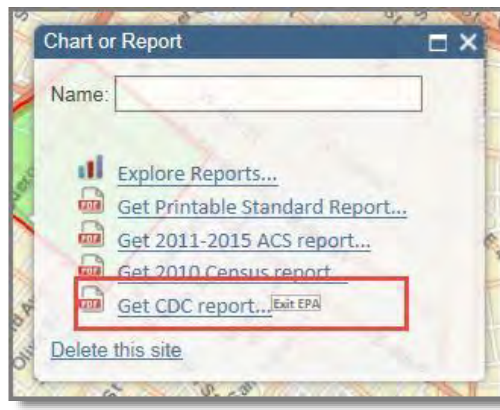
For additional information, see: www.epa.gov/environmentaljustice

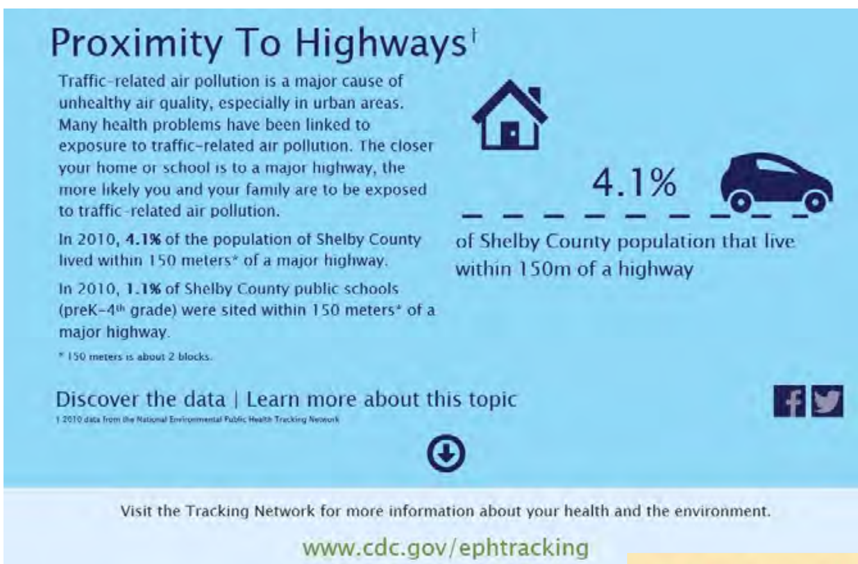
EJSCREEN allows users to print a **Standard Report** which includes the following information:

- The current date
- The block group that the data represents (Block group selection)
- The latitude and longitude of the center of the buffered ring (Buffer ring selection)
- The state and EPA region that the data is encompassed by
- Input area (in square miles)
- A table of the number of sites reporting to EPA

- A table of all the variables available in the widget and for each variable the following:
  - Raw value (except EJ Indexes)
  - State average (except EJ Indexes)
  - State percentile
  - Regional average (except EJ Indexes)
  - Regional percentile
  - National average (except EJ Indexes)
  - National percentile

EJSCREEN also links to a **Center for Disease Control and Prevention (CDC) report** generated through the **Environmental Public Health Tracking Network** with environmental health issues for the selected location's county.

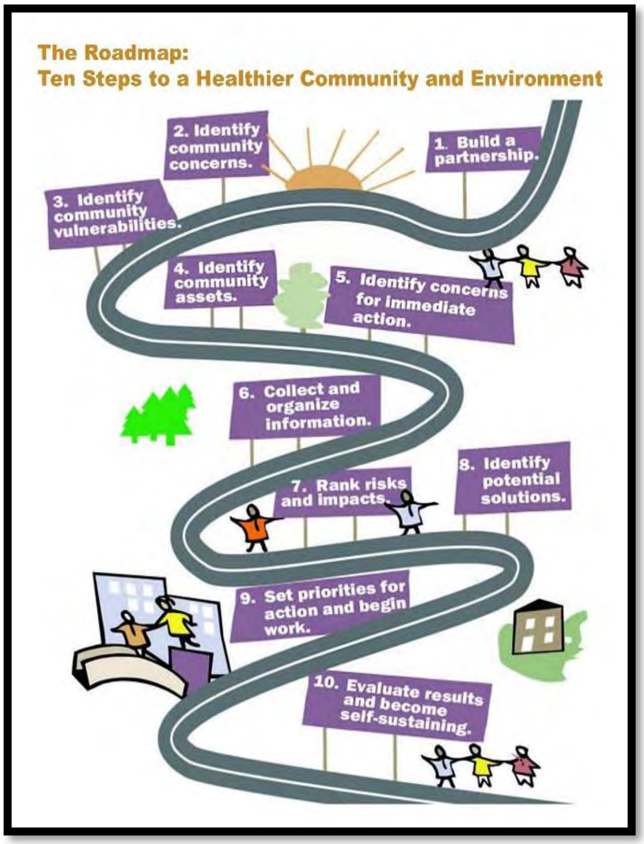




2. C-FERST

Guides to help build effective partnerships and scope community assessments

With such a wide range of stakeholders in the Memphis Tri-Port Region, communication and information-sharing is critical for effective resilience planning. C-FERST features two step-by-step guides for use in collaborative community efforts: **EPA Community Action for a Renewed Environment (CARE) Roadmap and the CDC and NACCHO Protocol for Assessing Community Excellence in Environmental Health (PACE-EH) Guidebook.**



The C-FERST resources describe the steps to be taken to conduct a community assessment, including how to build partnerships, identify community concerns, learn about environmental issues, and identify actions to improve community health.

Identify potential issues in a census tract to further explore

The City of Memphis serves as a major intersection point of freight operations with the river meeting rail, road, and runway. With most of the industries of the port based on President's Island, key sources of point and mobile emissions should be considered when estimating environmental and human health impacts to the port community. The C-FERST Community Data Table (CDT) provides a summary of environmental conditions for a community, including estimated concentrations, exposures and risks for select pollutants, as well as demographic information.

Community Data Table

The default indicators in the table are based on EPA-related issues, stakeholder feedback, and available data.
There may be other important issues that are not currently included in this table.

Indicators and Indices	Tract 020221	Shelby County	Tennessee	Data Info/Notes
▶ Environmental Concentration Estimates				
▶ Human Exposure Estimates				
▼ Health Risk Estimates				
Cumulative Air Toxics Cancer Risk[1] (risk per one million persons)	44.3	48.6	42.8	2011 NATA
Outdoor Air - Acetaldehyde Cancer Risk[1] (risk per one million persons)	6.3	6.7	5.9	2011 NATA
Outdoor Air - Arsenic Cancer Risk[1] (risk per one million persons)	0.3	0.2	0.2	2011 NATA
Outdoor Air - Benzene Cancer Risk[1] (risk per one million persons)	2.6	3.8	3.4	2011 NATA
Outdoor Air - Butadiene Cancer Risk[1] (risk per one million persons)	0.79	1.48	1.03	2011 NATA
Outdoor Air - Chromium Cancer Risk[1] (risk per one million persons)	1.4	0.4	0.3	2011 NATA
Outdoor Air - Formaldehyde Cancer Risk[1] (risk per one million persons)	28.0	30.4	26.7	2011 NATA
Outdoor Air - Naphthalene Cancer Risk[1] (risk per one million persons)	0.6	1.1	0.9	2011 NATA

The CDT estimates Chromium health risk of the specified census tract at 4X that of Shelby County.

The C-FERST Environmental Issue Profiles allow users to gather information and fill any knowledge gaps about the sources of environmental exposure identified in the CDT.

Explore

- Explore and Learn
  - Environmental Issues
  - Exposure and Risk Reduction Options

Pollutants

Environmental Media

Health Effects

Other Community Issues

Alphabetical List

C-FERST Issue Profile: Chromium

Chromium is an odorless, tasteless metallic element found naturally in rocks, plants, soil, volcanic dust and animals. The two most common forms of chromium found in the environment are Trivalent chromium (or chromium-3) and Hexavalent chromium (or chromium-6).

Chromium-3 is an essential human dietary element found in many vegetables, fruits, meats, grains and yeast. Chromium-6 occurs naturally in the environment from erosion of natural chromium deposits. It can also be produced by industrial processes. There are demonstrated instances of chromium being released into the environment by inadequate industrial storage and waste disposal practices.

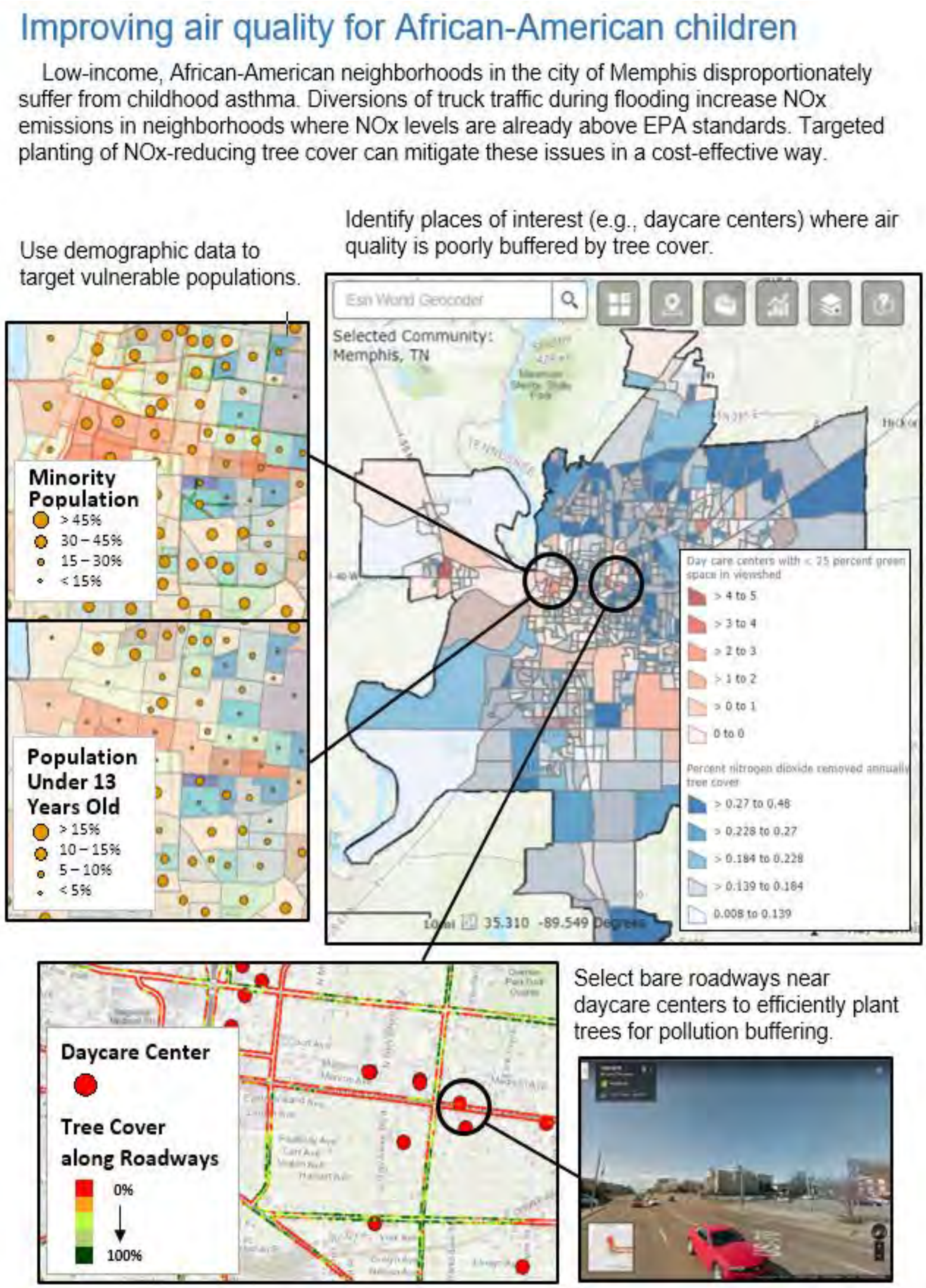
EPA classifies chromium-6 as a human carcinogen via inhalation exposure. There is not enough data to classify chromium-3 as a human carcinogen.

Learn more about chromium by exploring the links below.

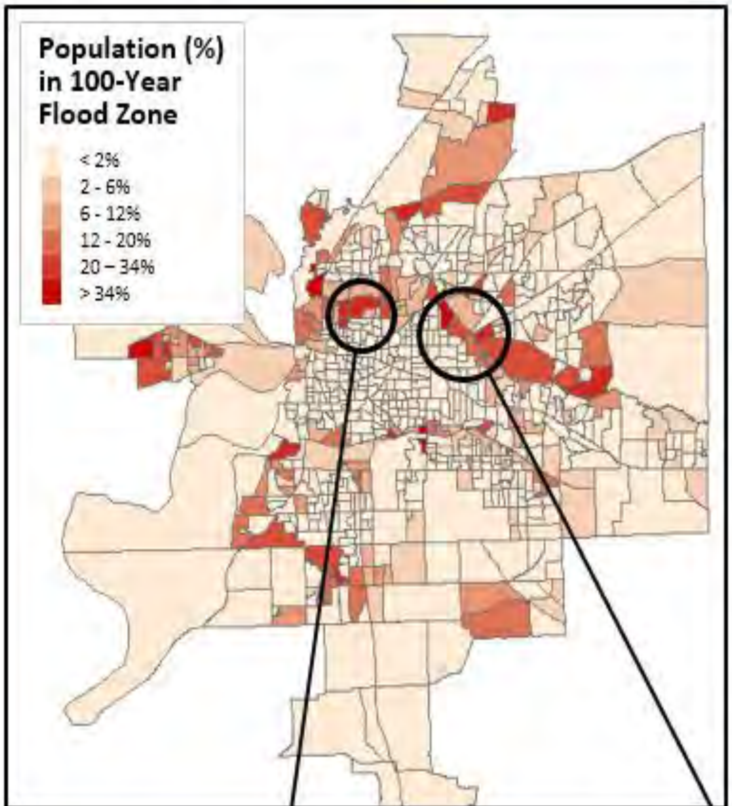
General Information

- Agency for Toxic Substances and Disease Registry ToxFAQs for Chromium
- Basic Information about Chromium in Drinking Water
- NLM ToxTown: Chromium
- Clu-In.org Contaminant Focus: Chromium VI EXIT
- Chromium Compounds Hazard Summary (PDF) (6 pp, 70 K, About PDF)
- Tribal Air and Climate Resources

3. EnviroAtlas

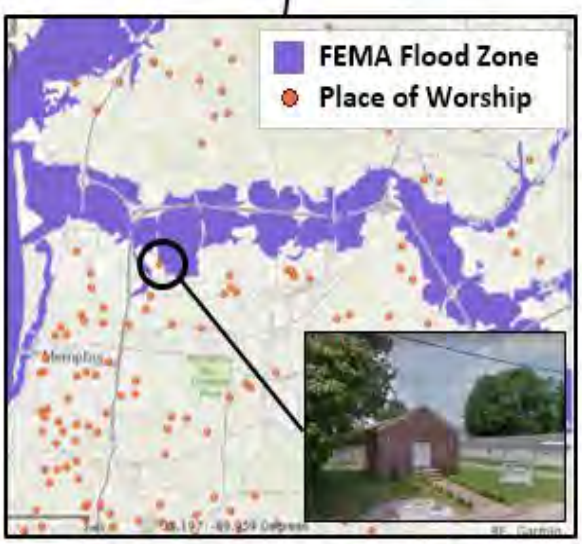


Assessing flood risk and mitigating its impact



High water events in major rivers cause flooding at ports and in port communities by causing back-ups in tributary streams and rivers. It is essential for port communities to assess regions susceptible to flooding so that preventative measures may be enacted both to mitigate potential damage and to identify the likely location of populations especially vulnerable to extreme flood events for assistance or evacuation.

EnviroAtlas has recently developed maps that help identify populations and infrastructure likely to experience flood damage during 100 and 500-year floods. These maps allow users to target, for example, neighborhoods with dense populations living in the 100-year flood zone (left panel).



Available local data can be used in the EnviroAtlas interactive map to help identify potential gathering spaces of flood victims to help target relief efforts.

Restoring lands back to wetlands helps mitigate flooding extent and duration, while also benefiting the water quality of local impaired streams.

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United States
Environmental Protection
Agency

Washington, DC 20460