

# Coastal Defense Megaprojects in an Era of Sea-Level Rise: Politically Feasible Strategies or Army Corps Fantasies?

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**Abstract:** Storm surge barriers, levees, and other coastal flood defense megaprojects are currently being proposed as strategies to protect several US cities against coastal storms and rising sea levels. However, social conflict and other political factors add a layer of complexity that casts doubt on their status as practical climate adaptation options. The specific mechanisms responsible for some projects not progressing beyond initial planning stages remains unclear. In this study, we examined the outcome of two USACE storm surge barrier proposals to explore the political reasons why some coastal flood protection megaprojects break ground in the US, while others do not. Using original archive research, we concluded that storm surge barriers are politically challenging climate adaptation options because of modern environmental laws that provide avenues for expression of oppositional views within the decision process and the allure of alternative options that are more aesthetically pleasing and cheaper and faster to implement. To better allocate public resources and utilize the expertise of USACE, future flood protection megaprojects should first achieve broad support from the public, nongovernmental organizations (NGOs), and elected officials before beginning serious planning. This support could be achieved through new innovative designs that simultaneously address adverse environmental impacts and provide cobenefits (e.g., recreation). New designs should be studied to better understand the level of protection offered and their associated reliability so that USACE has confidence in their use. **DOI: 10.1061/(ASCE)WR.1943-5452.0001613.** This work is made available under the terms of the Creative Commons Attribution 4.0 International license, <https://creativecommons.org/licenses/by/4.0/>.

## Introduction

Megaprojects are large-scale, complex public works projects that typically cost >\$500 million US dollars (USD), take years to plan and construct (sometimes longer than the tenure of government leaders), involve a diverse group of public and private stakeholders, and promise great benefits to some interests, sometimes at the expense of others (Altshuler and Luberoff 2003; Flyvbjerg et al. 2003b).

Storm surge barriers and levees are coastal flood defense megaprojects that are technically viable options for many densely populated areas to manage rare coastal flood events (e.g., a 100-year flood; including floods made worse by sea-level rise, e.g., the Fox Point Hurricane Barrier in Providence, Rhode Island; Fig. 1) (Aerts et al. 2014; Jonkman et al. 2013; Mooyaart and Jonkman 2017; Morang 2016; US National Research Council 2014). For example, in 2012, the Stamford (Connecticut) storm surge barrier prevented an estimated \$25 million USD (unadjusted) in damages to businesses and homes from high waters produced by Hurricane Sandy. Stamford's mayor said, "[The barrier] was extremely effective in protecting areas that would have been flooded completely by this

storm. It made all the difference in the world" (Navarro 2012). Densely populated cities, like Stamford, often lack the space to take advantage of natural defenses (e.g., mangrove or wetland restoration) and other coastal adaptation options (e.g., managed retreat, informed land-use planning, building codes, and insurance) may conflict with goals for local development.

The Civil Works program of USACE, the principal federal agency responsible for studying and designing coastal flood defense infrastructure (USACE 1998), is well positioned to manage sea-level rise and coastal flooding given that it has a wealth of knowledge in scientists and engineers, more than 60 years of experience with coastal risk reduction, a direct connection to Congress and the powerful fundraising ability of the federal government, and, to some extent, coastal jurisdiction through its permitting authorities. USACE is currently proposing storm surge barriers and levees for several US cities, including New York City, Norfolk, Miami, and the greater Houston metropolitan area (Table 1) (USACE 2016, 2018a, b, 2019b, 2020a, b, c). Non-USACE entities have also proposed similar projects (City and County of San Francisco 2016; City of New York 2013, 2020); for example, Galveston Bay Park, a vision for Houston and Galveston Bay (Galveston Bay: SSPEED Center 2020; Sustainable Solutions Lab 2018). In total, these efforts are projected to cost between \$70 and \$193 billion USD. To date, only a few of these coastal flood protection megaprojects have broken ground, despite most being designated as technically feasible (from an engineering standpoint) and economically beneficial (i.e., benefits greater than costs). One would conclude that sound engineering and favorable economics are necessary but, by themselves, insufficient for implementation.

Recent media attention has highlighted the political contentiousness of coastal flood protection megastructures. In Miami, a USACE proposal for a levee system received strong opposition from the public and government officials, who instead advocated for nature-based solutions. The chair of Miami's Downtown Development Authority proclaimed, "[N]obody wants to see the Berlin wall in the middle of Biscayne Bay" (Allen 2020; Harris 2020).

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**Fig. 1.** (Color) The Fox Point Hurricane Barrier following completion in March 1966 (Providence, Rhode Island). (Image by US Army Engineer Division, New England, courtesy of US National Archives and Record Administration, Waltham, Massachusetts.)

**Table 1.** An incomplete list of proposed public works coastal flood protection projects in the US

| Project                                                       | Location                             | Strategy                    | Year proposed | Lead agency           | Project cost           | Status (as of 2020)   |
|---------------------------------------------------------------|--------------------------------------|-----------------------------|---------------|-----------------------|------------------------|-----------------------|
| Boston Harbor Surge Barrier                                   | Boston                               | Levee/barrier               | 2018          | UMass Boston          | \$6.5 to 11.8 billion  | Proposed              |
| East Side Coastal Resiliency Project                          | New York                             | Levee/nonstructural         | 2014          | NYC/HUD               | \$1.5 billion          | Under construction    |
| Lower Manhattan Climate Resiliency Project                    | New York                             | Coastal advance/fill        | 2019          | NYC                   | \$10 billion           | Proposed              |
| Embarcadero Seawall                                           | San Francisco                        | Seawall                     | 2018          | City of San Francisco | \$5 billion            | Proposed              |
| Red Hook Integrated Flood Protection System                   | New York                             | To be determined            | 2013          | NYC                   | \$0.1 billion          | Undergoing a redesign |
| Coastal Texas Protection and Restoration Project              | Coastal Texas                        | Levee/barrier/nonstructural | 2015          | USACE                 | \$23.1 to 31.8 billion | Proposed              |
| Galveston Bay Park                                            | Galveston, Texas                     | Levee/barrier/nonstructural | 2020          | SSPEED                | \$2.3 to 2.8 billion   | Proposed              |
| South Shore of Staten Island CSRM Project                     | New York                             | Levee/nonstructural         | 1993          | USACE                 | \$0.6 billion          | Under construction    |
| Charleston Peninsula: A Coastal Flood Risk Management Project | Charleston, South Carolina           | Levee/seawall               | 2020          | USACE                 | \$1.1 billion          | Proposed              |
| City of Norfolk CSRM Project                                  | Norfolk, Virginia                    | Levee/barrier/nonstructural | 2015          | USACE                 | \$0.9 to 2.3 billion   | Authorized            |
| Miami-Dade Back Bay CSRM Project                              | Miami                                | Levee/barrier/nonstructural | 2020          | USACE                 | \$0.9 to 5.2 billion   | Proposed              |
| Collier County CSRM Project                                   | Naples, Florida                      | Levee/barrier/nonstructural | 2020          | USACE                 | \$2.2 billion          | Proposed              |
| Fairfield and New Haven Counties, CT CSRM Project             | Fairfield and New Haven, Connecticut | Levee/seawall/pumps         | 2019          | USACE                 | \$0.05 to 0.3 billion  | Proposed              |
| New York–New Jersey Harbor and Tributaries Project            | New York                             | Levee/barrier/nonstructural | 2019          | USACE                 | \$15 to 119 billion    | Planning suspended    |

Note: CSRM = coastal storm risk management; HUD = department of housing and urban development; NYC = New York City; and SSPEED = severe storm prediction, education, and evacuation from disasters center.

In New York City, a detailed plan developed over several years between city officials and several Lower East Side advocacy groups was abruptly replaced with a new design that was less popular with locals. City officials defended the new plan saying it could be

completed quicker (in three years as opposed to five) and would not lead to costly traffic restrictions that would have been necessary under the original proposal (Hanania 2019). In February 2020, an in-progress USACE study of coastal flood protection within New



York Harbor and its tributaries was abruptly halted just weeks after President Trump expressed his disapproval of the project, leading to speculation that his opinion may have influenced agency staff (Barnard 2020). If coastal flood protection megaprojects are to remain politically feasible climate adaptation strategies, a better understanding of the complexity that politics adds to these projects is needed (Javeline 2014). This may give coastal managers a priori information regarding the political feasibility of storm surge barriers, levees, and other coastal megaprojects.

In this study, we use archive materials and process tracing to evaluate whether existing megaproject theories can explain why one USACE storm surge barrier project broke ground and why another did not advance beyond the planning stage. We also propose other plausible mechanisms for explaining megaproject outcomes. The first project, the Fox Point Hurricane Barrier, was completed in January 1966 at a cost of \$16.2 million (unadjusted) and currently protects roughly 1.1 km<sup>2</sup> of downtown Providence and \$2 billion worth of property (Kuffner 2019) (Fig. 1). The second case, the Narragansett Bay Barriers, was a \$90 million proposal (unadjusted) for three massive rock barriers with ungated navigational openings placed at the entrance to Narragansett and Mt. Hope Bays (Fig. 2). Narragansett Bay is a coastal estuary consisting of 456 km<sup>2</sup> of total water area and about a dozen islands of various sizes. Roughly 26 cities and towns dot the shoreline of Narragansett Bay (17 in Rhode Island and nine in Massachusetts). Providence, the capital and most populated city of Rhode Island, sits at the head of the bay, while the city of Newport lies at the entrance of the east passage. Narragansett Bay is noted for its shell fishing industry, prevalence of vacation homes, boaters, and being home to a large naval base in Newport. President Eisenhower's summer White House was also

located in Newport in 1958 and 1960 (Hitchcock 2018). The Narragansett Bay Barrier project was ultimately cancelled in 1966 after 10 years of study, despite being deemed technically feasible and economically justifiable by USACE (Fig. 3).

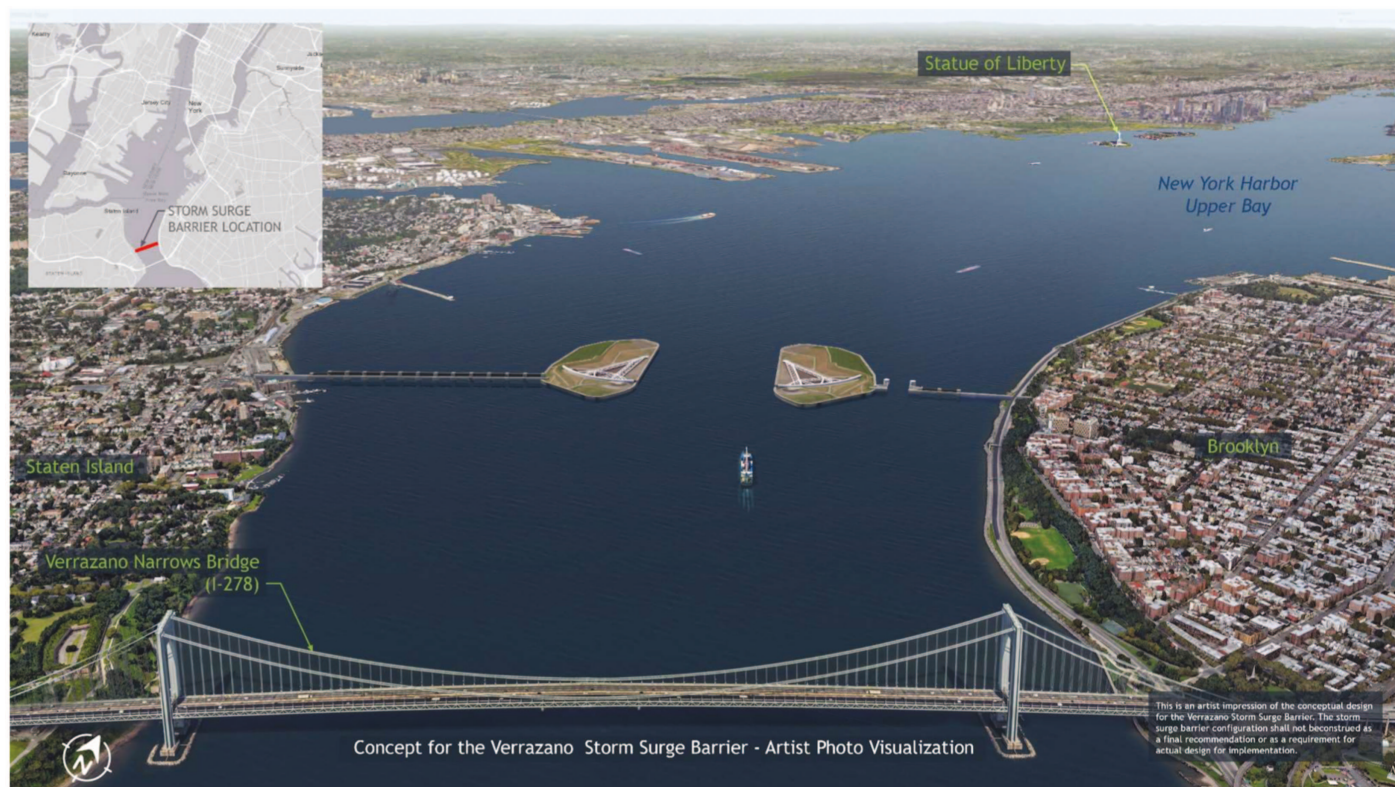
Similar empirical case studies have opened the "black box" of politics and identified plausible mechanisms and processes that have determined when climate adaptation projects do and do not break ground (Biesbroek et al. 2014; Bisaro and Hinkel 2016; Hinkel et al. 2018; Measham et al. 2011; Sieber et al. 2018; Wellstead et al. 2014). Doing so may give coastal managers a priori information regarding the political feasibility of projects. While some studies exist for Dutch flood projects (Bijker 2002; Disco 2002), to our knowledge, no such assessment has been performed specific to USACE coastal megaprojects. The USACE has been well-studied (Ferejohn 1974; Maass 1951; Mazmanian and Nienaber 1979; O'Neill 2006; Pilkey and Dixon 1996), including some political aspects of conceiving, designing, and implementing coastal flood defense megaprojects (US National Research Council 1999, 2004, 2011, 2014). However, no detailed case studies have been presented, and little attention has been given to siting-related opposition.

The remainder of this paper is organized as follows. We first give an overview of existing theories for why some megaprojects have advanced beyond the planning stages and others have not. Then, using process tracing and original archive research, we present an analysis of the Rhode Island storm surge barrier cases and describe plausible mechanisms that led to each project outcome. A detailed written timeline of events is given in Appendix S1 in the Supplemental Materials. Next, we examine the ability of existing megaproject theories to explain each case outcome and identify other potential mechanisms that could inform why some projects



**Fig. 2.** (Color) Revised plans for the Narragansett Bay Barriers, April 1964. (Image by US Army Engineer Division, New England, courtesy of US National Archives and Record Administration, Waltham, MA.)





**Fig. 3.** (Color) Artist rendering of a proposed storm surge barrier at the entrance to New York Harbor. (Reprinted from USACE 2019b, courtesy of US Army Corps of Engineers.)

advance while others do not. Last, we provide some recommendations to the USACE and conclude.

### Existing Theories on Why Megaprojects Do or Do Break Ground

Social scientists and legal scholars have put forward multiple explanations for why some megaprojects get built while others do not. We broadly classify these into two categories: strategic manipulation and siting conflicts.

#### Strategic Manipulation

Analyses that support planning efforts are not entirely objective and impartial. For example, analysts may have significant latitude with respect to estimating cost of construction and to whether and how to include indirect benefits. Investigators have shown that biased planners and analysts working in the “fish bowl” of politics and public policy making have strategically manipulated benefit-cost analysis (BCA) and other decision-making frameworks to get public projects approved and built (Flyvbjerg et al. 2003b; Wachs 1989). Specific tactics for strategic manipulation include exaggerating benefits and excluding or underestimating costs to make projects appear more attractive (Wachs 1989)—for example, enumerating indirect benefits or not accounting for environmental impacts, such as the loss of ecosystem services.

Similarly, Altshuler and Luberoff (2003) suggested that megaprojects sometimes originate locally by “rent-seekers” who aim to reap private gains at the public’s expense, resulting in a “tragedy of the commons” scenario when projects fail to deliver the benefits that were forecast. Ultimately, strategic manipulation and rent

seeking have led to project cost overruns, delays, and other shortcomings that have negatively impacted government balance sheets and the public (Flyvbjerg et al. 2003b; Wachs 1989). While strategic manipulation is hard to prove for any particular project, USACE’s general approach to BCA has been scrutinized. Specifically, environmental nongovernmental organizations (NGOs) and other critics claim that USACE’s BCA exaggerates project benefits (Ferejohn 1974) while downplaying both environmental harm (Taylor 1984) and the benefits of ecosystem services and biodiversity; the latter are not currently quantified (Chambwera et al. 2014; Davis et al. 2009; Koller 2019; USGAO 2019; A. Weber, personal communication, 2020).

#### Siting Conflicts

Other megaproject theories have focused on siting conflicts [sometimes referred to as not-in-my-backyard– (NIMBY-) related opposition], which can arise when governments attempt to construct megaprojects that aim to increase the general welfare of their citizens but coincidentally impose local adverse impacts (e.g., eminent domain, decreases in property value, deterioration of the natural environment, and lost amenities) (Aldrich 2008; Devine-Wright 2011; Kraft and Clary 1991; McAvoy 1999; Munton 1996; Smith and Klick 2007). Infrastructure siting disputes are part of a broader debate in the political science literature over the role of bureaucracies, experts, and the public in policy making (Aldrich 2008; Dear 1992; Devine-Wright 2011; Dewey 1927; Fischer 2000; Inhaber 1998; Kraft and Clary 1991; Lindblom 1990; Lippmann 1922; Mazmanian and Morell 1994; McAdam and Boudet 2012; McAvoy 1999). For instance, modern democracies often rely on government agencies, like USACE, to administer technical decisions that can sometimes impact the public in adverse ways (e.g., higher tax

burdens, degrading environmental quality). These agencies are filled with policy experts that attempt to make informed, good-faith decisions on behalf of citizens. However, conflicts arise when agencies, elected officials, experts, and the public come to a different understandings of what good policy solutions are (Lindblom 1990). For example, variations in risk perception can make it challenging to amass a majority that agrees that the costs associated with a given project are justified (Huber 1986; Kahan et al. 2011; Kunreuther and Slovic 1996; May 1991; Slovic et al. 1982). The risks could be risks that a project purports to reduce (e.g., coastal flood risks) or potential adverse outcomes associated with the project itself (e.g., risk to marine life and recreational boating). Ultimately, megaprojects that are not favored by the public are unlikely to generate the necessary support needed to pass referendums to finance local cost shares or encourage their congressional delegates to support project authorization and appropriation (Samet 2009). In addition, adverse impacts associated with some projects can raise environmental justice concerns if they fall predominantly on those with less political power (Aldrich 2008; Devine-Wright 2011; Kraft and Clary 1991; McAvoy 1999; Munton 1996; Smith and Klick 2007).

Siting conflicts have also led to regulatory battles in court between public and federal agencies, resulting in project deadlock, delays, and failures (Bligh 2006; Buzbee 2014; Kagan 1991; Kysar and McGarity 2006; Luther 2006; Murchison 2007). Many of these battles have been facilitated by modern environmental laws that empower minority interests to legally challenge federal projects (Buzbee 2014). Those in opposition to megaprojects comb through lengthy feasibility studies and/or environmental impact statements (EISs) to find technical flaws that can be used as arguments against a project (Buzbee 2014; Flyvbjerg et al. 2003a; USACE 2019c). As long as critics believe that a project fails to meet scientific and legal criteria, the EIS can be challenged in court (Buzbee 2014; Kagan 1991; Luther 2006). In some cases, this has led to long delays in bringing about coastal risk reduction (Bligh 2006; Kysar and McGarity 2006; Luther 2006). Altshuler and Luberoft (2003) went so far as to say that due to the potential for legal challenges, contemporary megaproject proposals are unlikely to leave the drawing board if they propose even trivial costs on the natural environment.

## Methods

### Data Collection and Analysis

We used a case-oriented approach to (1) test existing theories on megaproject development, and (2) propose new plausible reasons for why some megaprojects move beyond the drawing board and others do not. While case studies are limited to context-dependent knowledge, they can provide a lens through which to view real-life situations, and multiple case studies taken together can form the basis of expert knowledge for practitioners (Flyvbjerg 2006a). Case studies also provide depth that generalizable theories cannot (Gerring 2004; Peattie 2001), and they serve as a natural bridge between rich empirical evidence and theory building (King et al. 1994a).

For both Rhode Island projects, we used written materials from archives and process tracing to identify plausible causal mechanisms regarding USACE megaproject outcomes. Process tracing seeks to analyze sequences of events as they unfold over time, from initial conditions to a given outcome. This involves searching for evidence about the process by which a certain outcome was produced, such as reading written records from archives (as in this study). By observing the underlying relationships between actors and other variables, process tracing can uncover what plausible causal mechanisms may have been at work to explain cause and

effect. This can both produce plausible theories and also uncover observations that refute existing theories (Beach and Pedersen 2013; Gerring 2007). The collected documents included primary sources such as memos between government agencies and elected officials, technical reports from federal agencies and academic institutions, speeches, transcripts of congressional hearings and town hall meetings, letters to senators and congressman, newspaper articles that recounted the previous day's events, editorials, and op-eds. Document scans are available on Zenodo (See Data Availability Statement).

The decision regarding when to start process tracing is important (Beach and Pedersen 2013). We used the aftermath of Hurricane Carol in 1954 as the critical juncture at which the Corps, the city of Providence, and the state of Rhode Island all began to consider coastal flood protection in earnest. While projects can fail during the construction process itself, we limited our analysis to the events leading up to breaking ground on a project. An analysis of two projects that arose simultaneously but had different outcomes can help identify reasons why each outcome occurred. Because the two Rhode Island surge barriers studied here were over a half-century old, we supplemented our findings with anecdotal evidence from more recent projects in the discussion.

### Methodological Caveats

While process tracing can identify plausible causal mechanisms, it is unlikely to produce strong causal inferences, because (1) it does not identify a counterfactual situation to what was observed, and (2) it does not differentiate between the various effects and relative strengths of multiple explanatory variables and causal mechanisms (King et al. 1994c). Consequently, we consider our analysis to provide minimally sufficient explanations for each storm surge barrier outcome (Beach and Pedersen 2013). In other words, our methodological approach is descriptive and exploratory rather than confirmatory or inferential. It is based on details learned from both cases and did not attempt to identify causal mechanisms or produce causal inferences. That said, King et al. (1994b) noted that mere description is one of the two primary goals of social science (in addition to causal inferences). Our identified plausible mechanisms serve as hypotheses that can be tested in subsequent studies, and because our findings are not generalizable, we recommend that this study's lessons and conclusions be limited to other comparable cases to address external validity concerns.

### Applicability of Mid-20th-Century Projects to Inform Climate Adaptation

The political environment for megaprojects has changed significantly since the mid-20th century. The years between 1950 and the late 1960s have been described as "The Great Megaproject Era" (Altshuler and Luberoft 2003). During this time, unprecedented levels of federal aid poured into cities and states. Public confidence in government was high, and projects often had support from businesses, labor groups, and the media because they generated economic activity (Altshuler and Luberoft 2003). In the 1950s, projects were primarily evaluated in economic terms. Since then, multiobjective planning has emerged to take a more wholistic view and balance multiple social dimensions (e.g., environmental quality, regional development, social well-being, and national income). This change, as well as the proliferation of new laws and regulations, has added complexity to megaproject development (Altshuler and Luberoft 2003; Major and Stakhiv 2019).

The 1960s saw a broad expansion of opposition by citizens and organized groups against the deleterious impacts of megaprojects, including environmental harm. USACE was a commonly cited



offender (Douglas 1969; Drew 1970; Mazmanian and Lee 1975; Porter 1971; Reuss 1971; Sargent 1972; St. Louis Globe-Democrat 1971). These protests eventually led to a new approach to federal water resource development, outlined in the Water Resource Council's *Principles and Standards for Planning Water and Related Land Resources* (P&S) (Major and Stakhiv 2019; WRC 1973). P&S committed federal agencies to a multiobjective planning approach and called for the involvement of a broader set of government agencies and actors in project review. While these changes produced more wholistic decision making, they also made water resource development more difficult in some respects (Altshuler and Luberoff 2003; Major and Stakhiv 2019).

While decision making for megaprojects has changed significantly since the 1950s, many aspects of USACE's process leading up to breaking ground on megaprojects have largely remained the same, including close involvement with Congress, state and local elected officials, and other federal agencies (although the list of those involved has grown). First, local interests are still required to initiate all surveys performed by USACE; USACE cannot act unilaterally. [Although there are exceptions. Congress can order the USACE to act in an emergency (e.g., flood protection in New Orleans post-Hurricane Katrina). The law that authorized the USACE to carry out the study of the Rhode Island barriers is still invoked today (Public Law 71, 84th Congress).] Second, in addition to the involvement of local public interests, state and federal agencies are still required to review USACE plans (Samet 2009). Third, the cost of USACE projects is still split between the federal government and local interests (the local cost burden has increased from 30 to 35 percent of total project cost). Fourth, congressional authorization is still required for all projects (now through the Water Resources Development Acts, previously the River and Harbor or Flood Control Acts). Fifth, Congress must still appropriate project funds (Carter and Stern 2010).

## Results: Mechanism-Based Explanations of Each Rhode Island Storm Surge Barrier Outcome

### Background: Rhode Island Requests the USACE's Help with Coastal Flood Protection

The Great New England Hurricane of 1938 was the first major storm in over 120 years to strike Rhode Island. It caused \$57.8 billion in damage to New England (2017 normalized USD) (Brown 1938; Weinkle et al. 2018) and was particularly devastating to Rhode Island. Much of downtown Providence flooded, and damages there accounted for roughly one-third of the state's total losses (Hurricane Tidal Flood Protection in Narragansett Bay 1959). Over 250 Rhode Islanders drowned (US Army Engineer Division, New England 1963). Just six years later, the Great Atlantic Hurricane of 1944 ravaged the region. The 1944 hurricane was not as destructive, causing just \$19.6 billion in damage across several east coast states (2017 normalized USD), including Rhode Island (Weinkle et al. 2018). While Rhode Island began to consider flood protection after the 1944 storm (Providence Journal 1954c), serious and sustained government action did not occur until the next major hurricane, a decade later. On August 31, 1954, Hurricane Carol brought devastating floods to Rhode Island once again (Brooks and Chapman 1945), causing roughly \$23.5 billion in damage across New England (2017 normalized USD) and killing 19 in Rhode Island alone (Hale 1955). The destruction in Rhode Island amounted to roughly 7.4% of the state's gross domestic product (GDP) at the time (J. E. Fogarty, personal communication, 1959). Much of the damage resulted from severe flooding throughout Narragansett and Mt. Hope Bays (Secretary of the Army 1966).

As a result of these repeat disasters striking Rhode Island, USACE presented initial drafts of two projects in 1956, a storm surge barrier at Fox Point and a series of rock barriers in lower Narragansett Bay (Pawtucket and Times 1956). Other solutions were proposed, such as rezoning and retreating from the coastline (Providence Journal 1954b), temporary flood protection measures (e.g., sandbags), and flood proofing the lower levels of buildings. Congress also attempted and failed to establish a public flood insurance program (Providence Journal 1957).

### The Fox Point Hurricane Barrier

#### The Public and Elected Officials Broadly Supported Local Flood Protection Megaprojects in Providence

The demand for the construction of permanent flood protection emerged locally in the days following Hurricane Carol from the public, businesses, and elected officials. It remained strong until approval was given by Congress in 1958. Just one week after Carol, the governor of Rhode Island wrote to President Eisenhower to ask USACE to conduct a "prompt, preliminary survey of the construction and other means needed to protect Rhode Island Shore areas." (Governor Roberts justified the request by citing Public Law 875 of the 81st Congress, which facilitates federal assistance in developing state and local plans to cope with major disasters.) The governor emphasized the specific goal of protecting downtown Providence (D. J. Roberts, personal communication, 1954). He later remarked, "[T]he enormity of the loss suffered by our people justifies a substantial investment in (permanent flood) protection" (Providence Journal 1954a). The Rhode Island congressional delegation also supported pursuing local flood protection in the wake of the previous three hurricanes (Providence Journal 1958). Congressman John E. Fogarty wrote in his replies to letters from the public calling for action, "[Flood control] is uppermost in the minds of the Rhode Island congressional delegation," (J. E. Fogarty, personal communication, 1955) and, "I will certainly do everything I possibly can to see to it that the United States Government gives the City of Providence and the State of Rhode Island every possible assistance" (J. E. Fogarty, personal communication, 1954).

Elected officials were not the only ones demanding that something be done about recurring flooding in both Providence and elsewhere in the state. Several waterfront property owners (Residents of Touisset, personal communication, 1954), business associations such as Chambers of Commerce (T. F. Gilbane, personal communication, 1954), and individual businesses inside and outside of Providence (Jr. J. K. Quinn, personal communication, 1954) wrote to the Rhode Island congressional delegation expressing a strong desire for government action on flood issues, including specifically calling for permanent flood protection (Providence Journal 1954d). In the first few months after Carol, the Providence Chamber of Commerce passed a resolution calling for an official plan for flood control "at the earliest possible time," and said that the need for flood control should be "kept uppermost in our minds until a control project becomes a reality" (Providence Chamber of Commerce 1954). The governor echoed the sentiments of many Providence business owners: "[P]eople cannot be expected to make large capital investments in an area where their investments are threatened by recurring disaster. The only thing we can do to make Rhode Island safe for the investment we need—is to begin actual construction to prevent flooding of our river valleys and shores" (Evening Bulletin 1955). Local businesses also formed a hurricane protection committee in the hopes of maintaining interest in Providence's flood problem and to also serve as a link to elected officials. Public support was perhaps most strongly expressed during a hearing about the Fox Point Barrier in Providence in 1956. During

the hearing, an overwhelming (but not unanimous) majority urged immediate construction of the Fox Point Barrier. The only recorded dissenter was the Allens Avenue Businessmen's Association, a group of 122 Providence businesses (J. C. Dinsmoor, personal communication, 1956; *Providence Journal* 1964). They opposed the Fox Point Dam because their properties were not in the proposed protection zone (*Providence Journal* 1956d).

Multiple close calls with other storms in the years after Carol helped sustain public interest in flood protection in Providence. Additionally, local and state-wide election drives kept public attention elevated enough to pass two referendums needed to cover the non-federal share of the barrier cost. A key element in obtaining state-wide approval (i.e., from those who would not directly benefit from protection) was promoting the belief that protecting Providence was important to the overall economic well-being of the state.

### **Elected Officials Shepherded the Fox Point Barrier Project through a “Long, Slow Obstacle Course”**

Support from the Rhode Island congressional delegation was critical in pushing the Fox Point Barrier toward authorization and appropriation; in particular, Congressman Fogarty and Senator Pastore played critical roles in amassing support in Congress to bring flood protection to Providence. The congressional process for approving and funding the Fox Point Barrier was described by the *Providence Journal-Bulletin* as “a long, slow obstacle course” (Dunbar 1956), in part because of the many policy issues that the US government was giving attention to at the time (e.g., rising Cold War tensions). At multiple decision points, the fate of the project seemed to hang in the balance, but Rhode Island's congressional delegates kept it in play. Obtaining approval from President Eisenhower also was necessary. Back in Rhode Island, the governor and mayor of Providence provided leadership for local efforts to encourage support for the Fox Point Barrier, including for covering local cost shares.

### **The Narragansett Bay Hurricane Barriers**

#### **The Potential for Environmental Harm Led to Public Objection to the Narragansett Bay Barriers**

While the Fox Point Barrier received near unanimous support at public hearings, the initial reception for the Bay barriers was lukewarm. Several concerns were raised by the public. Among them were concerns related to the effects of the barriers on maritime navigation, water quality, salinity, fish and wildlife, and recreational activities in the bay (*Providence Journal* 1956c). Further understanding was requested regarding these issues, which the public deemed underfunded and understudied (Zinn 1956). However, even after several years of additional analysis, these concerns were still held.

When a reworked plan for the Bay barrier project was released in 1964, it was met with near unanimous opposition. Resistance was again expressed through public hearings, but this time also in editorials and op-eds in the *Providence Journal-Bulletin* (Evening Bulletin 1964a, b, c; *Providence Journal* 1964) and letters to the governor, the Rhode Island congressional delegation, and USACE. Senators and congressmen were alarmed by the mail they were receiving. Senator Pastore described the public's response as “heavy and overwhelmingly opposed.” He reported he had received letters to his office at a rate of at least ten to one against the barriers. Congressman Fernand J. St. Germain said he answered at least 200 letters from Rhode Island residents opposed to the project and had received none in favor (Van Dusen 1964). Unlike the Fox Point project, no Rhode Island congressional delegate promoted the Bay barriers. Congressman Fernand J. St. Germain said, “I see no reason for promoting or pushing for the construction of this barrier.” Senator Claiborne Pell had similar thoughts: “I do not believe a

project of this sort should go ahead unless a majority of the community wishes it” (Van Dusen 1964).

Despite the strong opposition, several Rhode Islanders who opposed the Narragansett Bay barriers stated that they were still in support of nonmegaproject-based coastal risk reduction. These residents suggested alternative strategies that would have involved less environmental harm, would have been cheaper (i.e., lower tax burden), and would have been faster to implement. This included dedensification of the coastline, rezoning, establishing a public flood insurance program, implementing shore-based strategies like levees, and implementing building-by-building measures such as flood proofing and temporary flood barriers. Ultimately, the chief of Rhode Island's Division of Harbors and Rivers requested stopping the Narragansett Bay barriers because he was unable to foresee voters passing future referendums to pay for the nonfederal cost share (H. Isé, personal communication, 1965).

### **Rhode Islanders Increasingly Mistrusted USACE, Viewing the Agency as an Adversary**

Residents noted that the USACE's analysis of the bay barriers had been heavily focused on engineering; little attention was given to assessing environmental impacts. Consequently, there was almost no scientific evidence the public could use to oppose the barriers, particularly considering the barriers' potential effects on marine life. This caused displeasure among many residents, who wanted assurance that the barriers would not ruin commercial and sport fishing in Narragansett Bay (both shell and finfish).

During later public hearings in 1964, several residents became angered after noting an obvious bias in USACE's depiction of itself as a savior. This included showing a film in which USACE was portrayed as the hero in the fight against villainous New England hurricanes (Hawkes 1964). A resident expressed displeasure to USACE: “I resent the biased presentation of the project . . . the presentation turns out to be a massive campaign to force the barrier upon us; distorted opinions and exaggerated damage figures compiled by persons whose main concern is to assure themselves of continued employment. Your agency should serve the taxpayers, not force your will upon us (at our expense)” (F. W. Thomas, personal communication, 1964). Despite overwhelming public opposition, USACE continued to push the bay barriers toward authorization, citing the irrationality of project critics. The New England Division's chief engineer, Brigadier General Fleming, called the opposition “self-appointed” flood control experts, promoting their own “woefully inadequate” views of technical aspects of projects rather than relying on the conclusions of USACE's expert-authored studies. Previous USACE leadership had even called the public a “threat” to their projects (Goodrich 1956). In the mid 1950s, Brigadier General Fleming observed that many projects aimed at addressing flood issues in Rhode Island had not been dealt with in the past because of objections from “certain minority groups” (“minority” meaning small political interests) and that public opinion had been the “determining factor” in the fate of any flood control effort (Goodrich 1956).

### **Lengthy and Complex Decision-Making Procedures and Fading Memories of Flood Disaster**

Deliberation over the impact of the bay barriers carried on for almost a decade, during which time public interest in permanent flood protection diminished. Some who had initially favored the barriers ended up changing their minds. In op-eds and letters to both USACE and elected officials, several Rhode Islanders made it clear that they would rather live with the risk of a repeat disaster than pay for expensive flood protection that also had the potential to degrade their experience of living on the water. Brigadier General Hyzer, the New England Division's chief engineer, contended that some of the opposition had come from those who had previously supported



the barriers: “I am puzzled that memories are so dimmed that few now appear to want the protection which, in 1956, they considered so necessary in the bay areas” (P. C. Hyzer, personal communication, 1964). In an op-ed, a resident of Fall River, Massachusetts, argued that opponents of the bay barriers needed to recall the disastrous effects of both Carol and the 1938 storm and then “re-examine their position (against the proposal)” (Conroy 1964).

The loss of public interest was somewhat expected. In 1956, the *Providence Journal-Bulletin* wrote, “[T]he biggest immediate danger facing the barrier project is public apathy fostered by the passage of time and the absence of storm threats. It took 20 years to get action on river flood projects that might have made Hurricane Diane a harmless rainstorm. The bay project deserves a better fate than death by disinterest” (Providence Journal 1956b). USACE also knew that time was not on their side for getting something built. Lieutenant Colonel Miles L. Wachendorf, the Assistant New England Division Engineer, said, “[E]xperience shows that the public in the past has had a tendency to lose interest in flood control as the last major disaster fades in their memory” (Providence Journal 1956a).

## Discussion and Applicability to Modern-Day Storm Surge Barrier Efforts

We find that existing theories of megaproject outcomes related to siting disputes and strategic manipulation can, in part, explain the outcomes of USACE’s Rhode Island megaproject proposals. We also propose additional plausible factors that can play a role. First, strong and consistent public demand for flood protection appears to encourage support from elected officials; the latter is critical for shepherding projects through Congress. Second, the passage of time can cause memories of disaster to fade, leading to decreased public support for flood protection megaprojects. Flood risk reduction tactics that are smaller, cheaper, more aesthetically pleasing, and faster to implement can also cause decreased support for megaprojects.

### Siting Disputes and NIMBY Concerns

The Narragansett Bay barrier project had several features of a siting dispute. USACE faced loud and relentless opposition from the public, businesses, and some elected officials. Significant opposition to the project resulted from the public’s concerns over the risk of degrading Narragansett Bay’s unique natural beauty (e.g., structures themselves are aesthetically displeasing, increased water pollution), threats to maritime travel (recreational, commercial, and naval), and risks of adverse impacts on complex ecosystems (including marine life). In response to public opposition, elected officials were unwilling to move the project forward.

NIMBY concerns were absent from the Fox Point barrier project. The siting of the barrier in Providence impacted few of the same organized interests that opposed the Bay barriers (e.g., maritime and environmental interests). The Providence River, across which the barrier was built, was already polluted, so there was no increased threat to marine life. The water behind the barrier also had no maritime navigational purpose. The only opposition came from property owners outside the planned protection area. Such conditions are unlikely to exist after over half a century of improvements in water quality (Robinson et al. 2003; Smith et al. 1987).

The placement of storm surge barriers across waterways continues to raise concerns regarding environmental impacts (Royte 2019; K. Ong, personal communication, 2018; J. Roff and P. Gallay, unpublished data, 2018; S. M. Stringer, personal communication, 2019; USACE 2019a), including but not limited to impeding natural tidal flows, habitat destruction, changes in sedimentation rates, trapping pollutants, and degrading water quality (salinity, temperature,

circulation, dissolved oxygen, nutrient concentrations, and algal blooms). Studies conducted on the environmental impacts of the Delta Works Projects in the Netherlands and the mobile flap gate system (Mo.S.E.) in Venice, Italy, support these concerns (Bakker et al. 1994; Eelkema et al. 2011; Nienhuis and Smaal 1994; Smaal and Nienhuis 1992; Tognin et al. 2021; van der Tol and Scholten 1997), but impacts remain hard to forecast with the accuracy and precision desired by both modern environmental laws and those in opposition (e.g., the public and environmental NGOs) (Flyvbjerg et al. 2003a; Fukuyama 2017; Ortolano and Shepherd 1995).

Some scenic regions, such as Narragansett Bay, may be inherently politically unfit for coastal megaprojects due to heavy recreational boating use, commercial fisheries, and cherished natural beauty. The importance of preserving unique natural beauty has been brought up by those opposed to engineered projects in New York City [past (Nolan 1972; US National Research Council 1971) and present (Royte 2019; K. Ong, personal communication, 2018; J. Roff and P. Gallay, unpublished data, 2018; S. M. Stringer, personal communication, 2019)]. Recently, Riverkeeper, an environmental NGO, declared that a USACE storm surge barrier proposal for the New York Harbor region would “threaten the very life of the Hudson River” (Riverkeeper 2018). Also, in Miami, critics argued that a seawall would block views and hinder access to the water (Allen 2020, p. 6; A. Weber, personal communication, 2020). Similar claims were made during the planning of the Eastern Scheldt Barrier in the Netherlands (Bijker 2002; Disco 2002), suggesting that these experiences are not unique to the US.

While USACE projects are still required to be reviewed by the public, modern environmental protection laws, such as the National Environmental Policy Act (NEPA), the Clean Water Act (CWA), and the Endangered Species Act have made megaproject planning a more complex legal process (Mazmanian and Nienaber 1979; US National Research Council 2011). For example, under NEPA, USACE projects that pose significant harm to the quality of the natural environment must analyze and publicly disclose a proposal’s environmental impacts through an EIS and receive public comment on the proposal and its alternatives (Luther 2008). Some states and cities duplicate powers and add more project hurdles (e.g., New York City and California) (Buzbee 2014; Steinhauer 2005). While this process is not a direct legal barrier to project implementation, the transparency of potential ecological harm it provides can trigger public opposition and legal challenges (Buzbee 2014). However, some environmental laws can block projects altogether. Under Section 404 of the CWA, projects cannot be built in coastal waterways unless (1) the sponsoring agency proves they need to be built in the water, or (2) the project will not cause “significant degradation” to important aquatic habitats (Copeland 2016). Despite the complexity these laws add, the Narragansett Bay barrier experience proved that the current stricter review process is not necessarily to blame for past and ongoing megaproject siting disputes.

Environmental concerns do not block all coastal flood protection megaprojects outright; they do not always even emerge at all. For example, the South Shore Staten Island Project has progressed from an initial feasibility report in 2015 to congressional approval. Construction is slated to begin in early 2021 (Michel 2020). Also in New York City, the East Side Coastal Resilience Project (not affiliated with USACE) recently received approval, despite considerable community opposition, and in Norfolk, a USACE project consisting of a series of structural defense measures, including storm surge barriers, has been congressionally authorized [Section 401. Project Authorizations in H.R. 133, 116th Congress, 2nd Session <https://www.govinfo.gov/content/pkg/BILLS-116hr133enr/pdf/BILLS-116hr133enr.pdf>]. Future work should examine these cases and



better understand why these projects progressed without significant environmental concerns while others did not [e.g., other projects in New York City, such as storm surge barriers in Jamaica Bay (Secretary of the Army 1965; US National Research Council 1971) and New York Harbor (Barnard 2020) and a levee proposed for Coney Island (Nolan 1972)]. For example, naval installations in Norfolk may have increased the federal government's interest in flood protection there.

Concerns over environmental harm incite debate over how to balance environmental protection with the socioeconomic benefits from infrastructure projects. Some scholars who study infrastructure argue that there is too much emphasis on environmental regulation over public safety and economic growth (Fukuyama 2017; Howard 2015; Kagan 1991, 2001), while others suggest it is warranted (Ortolano and Shepherd 1995), particularly in light of USACE's history of understating environmental impacts (Taylor 1984). In this regard, USACE often finds itself trying to achieve goals and objectives that are not consistent or compatible with one another (e.g., both credible protection from rare storm surge events and improvement in environmental quality) (US National Research Council 2011).

### **Strategic Manipulation**

Strategic manipulation of BCAs or other decision-making analyses is a tactic for project proponents to advance megaproject proposals. Unlike most examples of strategic manipulation that go undetected, we found that Rhode Island residents increasingly believed USACE was intentionally biasing its analysis in support of the Narragansett Bay Barrier project. A critical element was downplaying adverse environmental impacts that the public perceived or intuited to be likely. We also found evidence of USACE leadership calling the public an adversary in their project development efforts. These factors alienated the public and led to strong opposition of the bay barrier project and, ultimately, its cancellation. Such sentiments continue today. Critics of the storm surge barriers planned for New York and New Jersey derided USACE for a lack of transparency, poor public outreach, and a short comment period (Fallon 2018; Hellauer 2018). Critics have also called USACE's public outreach process "woefully inadequate" (Riverkeeper 2018).

### **Public Demand for the Fox Point Hurricane Barrier Increased Support from Elected Officials**

The Rhode Island storm surge barrier projects highlight the intricate and important role that elected officials play in advancing USACE megaprojects. Elected officials heeded demands from local businesses for permanent flood protection by continuing to support the Fox Point Barrier years after Hurricane Carol. In the case of the Fox Point Hurricane Barrier, the absence of opposition from community boards, civic organizations, and environmental groups proved beneficial for amassing support from the public. Support from Rhode Island's congressional delegation proved to be critical for pushing the Fox Point Barrier through Congress; without it, the project had little chance of being authorized or appropriated.

Support from congressional delegates is still needed to shepherd projects through Congress (Knopman et al. 2017). (Generally, at least four acts of Congress are required between study authorization and appropriations.) USACE's ongoing South Shore Staten Island Project in New York City (a system of levees and raised embankments estimated to cost \$615 million) (USACE 2016) recently highlighted the importance of congressional support in federal projects. New York Congressman Max Rose and Senator Chuck Schumer led an effort to pass new legislation that allowed USACE

to build a section of the seawall in Great Kills Park, part of Gateway National Recreation Area (Michel 2020), and in Virginia, the entire congressional delegation recently requested additional planning funds for a series of USACE projects in Norfolk (13News Now Staff 2020).

### **Alternative Risk Reduction Measures that Are More Environmentally Friendly and Faster to Implement Are Often Preferred over Storm Surge Barriers and Other Megaprojects**

The slow speed at which storm surge barriers and other USACE megaprojects move from an initial proposal to implementation has also encouraged support for alternative strategies that some believe can be implemented faster (Cusick 2020; PlaNYC 2013; S. M. Stringer, personal communication, 2019; Sustainable Solutions Lab 2018). Even in the 1950s, the media and public viewed USACE's megaproject protocols as notoriously slow. In the wake of a third major flood in under two decades, Rhode Islanders lamented at the thought of a long, political "obstacle course" that would accompany any USACE-led flood protection effort. Today, environmental laws have added even more steps to what some water infrastructure experts have described as a "remarkably inefficient" process (Knopman et al. 2017). Lengthy planning times have caused flood concerns to fade and projects to stall (Fanta et al. 2019; Jacobs and Matthews 2012). Ultimately, no other projects received serious consideration besides the bay barriers. When the barriers were cancelled, interest in flood risk reduction had waned, and ultimately large-scale action was not taken.

During the time when the Narragansett Bay Barriers were being considered, USACE was not required to propose alternative strategies. When the barriers failed to advance, coastal risk reduction efforts failed with it. There was not another active project alternative to consider. Today, USACE is required to consider multiple project alternatives, including green/nature-based risk reduction measures (e.g., wetlands, dunes, and living shorelines) (USACE 2017) and engineered structures along shorelines (e.g., buried levees), both lauded by environmental NGOs (K. Ong, personal communication, 2018; Riverkeeper 2018; USACE 2019c).

Alternative flood risk reduction approaches often receive greater support because their proponents argue that they involve less environmental harm and are cheaper, faster to implement, and have cobenefits, such as recreational amenities and addressing social justice issues. For example, a Boston study unaffiliated with USACE found that shore-based strategies would be more cost effective, provide flexibility and adaptability, offer social justice cobenefits, and cause minimal impact to the environment (Kirshen et al. 2020; Sustainable Solutions Lab 2018). However, even shore-based strategies like levees have failed to gain support due to concerns over aesthetics and environmental degradation (Harris 2020; Nolan 1972).

Today, concerns over lengthy storm surge barrier construction times have resulted in calls for support for alternative strategies. In a letter to USACE, the New York City comptroller advocated for shore- and nature-based approaches that could be built faster: "I also am concerned that the long timeline associated with the construction of these barriers—amounting to 25 years—will leave our City all too vulnerable to storms in the decades ahead." [However, the purpose of nature-based strategies is primarily to reduce wave energy and limit erosion, not to provide reliable flood protection from extreme storm surges (Narayan et al. 2016; Oppenheimer et al., 2019; USACE 2015; USGAO 2019)]. The comptroller used the example of Venice's Mo.S.E. barriers to support his argument; these barriers took nearly two decades of construction before they

were operational (S. M. Stringer, personal communication, 2019). Megaproject construction times are also often longer than initial forecasts (Flyvbjerg et al. 2003b; Flyvbjerg 2006b, 2007); the Thames Storm Surge Barrier in London (England), also took almost a decade to construct, following roughly two decades of planning (Horner 1979). In Houston, designers of a smaller-scale surge barrier argued for their design over USACE's under the belief that their project could be built faster: "[O]ur biggest concern is the length of time it will take to build. We get a major storm in here about every 15 years. The last one was 2017, so we could see another one before this project is complete" (Cusick 2020).

In some cases, alternatives are not directly comparable. For example, they may not offer equivalent levels of protection for the same area (or address the same variety of flooding, e.g., frequent and minor tidal flooding versus devastating and rare storm surges) (USACE does not have authority to address frequent floods, because this infringes on zoning laws, which are local issues), provide the same level of reliability, or occupy the same spatial footprint (Boyd and Shabman 2019). A common example is comparing green/nature-based solutions with concrete and steel projects (Temmerman et al. 2013; USACE 2015) [what USACE calls natural and nature-based Features (NNBF)]. USACE has comparatively little experience with ecosystem solutions and views their effectiveness as more uncertain, in part due to a lack of previously successful projects and a poor understanding of reliability, failure rates, and protection levels. Nature-based solutions often require significantly more space to be effective and require time to develop (Boyd and Shabman 2019). These factors make them harder to justify implementing in dense urban areas where the stakes are high in cases of nonperformance.

## Conclusions and Recommendations for the Corps

In the US, the conception, design, and implementation of storm surge barriers, levees, and other coastal flood megaprojects are not simply matters of federal agencies drawing up technically feasible designs that are economically justified. Experience with coastal megaprojects in Rhode Island and elsewhere indicates that decision making is immersed in legal procedures that involve coordination and cooperation from the public, all levels of government, and organized interests (e.g., professional and civic organizations, NGOs). Conflict between these groups has resulted in deadlocks, delays, and failures that have wasted taxpayer money and government agencies' time and technical expertise. These scarce resources could instead have gone toward projects that are deemed more palatable by these groups, improving the efficiency with which coastal risk reduction strategies are deployed.

We are pessimistic that storm surge barriers will be politically feasible climate adaptation options because of (1) modern environmental laws that provide avenues for expression of oppositional views within the decision process, (2) the allure of alternative options that are more aesthetically pleasing and cheaper and faster to implement (even when they do not offer equivalent levels of protection—e.g., green/nature-based solutions), and (3) a shift in water resources planning that adds considerable complexity by considering multiple objectives that are sometimes in conflict (Major and Stakhiv 2019). These impediments have been historically overcome by strong leadership (especially to shepherd projects through Congress) and limited opposition by the public and environmental NGOs.

From our assessment we make the following recommendations to USACE to increase the efficiency with which public resources are allocated to coastal risk reduction projects:

1. Obtain support from the public, NGOs, and elected officials before pursuing projects beyond the initial scoping phase. This could come in the form of USACE requesting that local cost shares be covered earlier in project timelines to reflect local commitment to projects (e.g., the public voting on a municipal bond) or increasing public interest in flood risk reduction measures by incorporating desirable cobenefits (e.g., a buried levee that doubles as a bike path or promenade).
2. Increase the transparency of both the effectiveness and reliability of different coastal risk reduction designs, especially green/nature-based approaches. Where applicable, research should be undertaken to quantify these important performance measures. A greater understanding of green/nature-based approaches could increase USACE's confidence in their flood risk reduction capabilities and encourage implementation.
3. Revisit regulations and internal USACE guidance to encourage and facilitate the consideration of new and innovative coastal flood risk reduction infrastructure designs, including green/nature-based approaches and designs that are nature-concrete/steel hybrids (e.g., buried levees).

USACE plays a major role in coastal adaptation given its wealth of technical expertise, more than 60 years of experience with coastal risk reduction efforts, and coastal jurisdiction in terms of navigation, dredging, and filling (Moritz et al. 2016; Samet 2009). [The Corps was involved in two projects in the early 20th century (Table 2), but studying coastal flood protection was not officially added to their jurisdiction until 1955 (Public Law 71, 84th Congress, 1st session)]. Studying USACE's experiences could reduce the number of project delays, deadlocks, and failures and better allocate public resources toward coastal risk reduction projects that stand a better chance of being implemented. Given the current level of national interest in these strategies for managing sea-level rise (City and County of San Francisco 2016; City of New York 2013;

**Table 2.** An incomplete list of erected USACE coastal flood protection projects

| Flood protection public works                                     | Location                   | Completed                   | Agency | Cost (unadjusted) |
|-------------------------------------------------------------------|----------------------------|-----------------------------|--------|-------------------|
| Galveston Seawall                                                 | Galveston, Texas           | 1904                        | USACE  | \$1.5 million     |
| Herbert Hoover Dike                                               | Lake Okeechobee, Florida   | 1938                        | USACE  | Unknown           |
| Pawcatuck Hurricane Protection Barrier                            | Pawcatuck, Connecticut     | 1963                        | USACE  | \$851,000         |
| New Bedford Hurricane Barrier                                     | New Bedford, Massachusetts | 1966                        | USACE  | \$18.6 million    |
| Fox Point Hurricane Barrier                                       | Providence, Rhode Island   | 1966                        | USACE  | \$16.2 million    |
| Stamford Hurricane Protection Barrier                             | Stamford, Connecticut      | 1969                        | USACE  | \$14.5 million    |
| Charles River Dam                                                 | Boston                     | 1978                        | USACE  | \$61.3 million    |
| New London Hurricane Protection Barrier                           | New London, Connecticut    | 1986                        | USACE  | \$12.0 million    |
| Lake Pontchartrain and Vicinity Hurricane Protection (Levee/Dike) | New Orleans                | In progress, then destroyed | USACE  | \$760 million     |
| Inner Harbor Navigation Canal Lake Borgne                         | New Orleans                | 2013                        | USACE  | \$1.1 billion     |



Sustainable Solutions Lab 2018; USACE 2016, 2018a, b, 2019b, 2020c), such an effort is warranted.

## Data Availability Statement

We collected nearly 2,000 primary and secondary documents from public and private archives between September and November 2019 to reconstruct event sequences associated with the surge barriers as accurately and completely as possible. The documents included internal memos; project-related materials; newspaper clippings from the New England District of USACE archived at the US National Archives and Records Administration facility (Waltham, Massachusetts); personal papers from Congressman John E. Fogarty, Senator John Pastore, and Governor Dennis J. Roberts archived at Providence College; over three decades of newspaper articles on microfilm from the *Providence Journal* and *Evening Bulletin* archived at both the Rhode Island Historical Society and the Providence Public Library; and additional materials associated with the Fox Point Hurricane Barrier at the Providence City Archive (Providence, Rhode Island). Scans of all archive documents collected are available on Zenodo; an organized subset containing only the artifacts cited in this study is also available (<https://zenodo.org/record/6037787>).

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## Supplemental Materials

Appendix S1 and Figs. S1–S7 are available online in the ASCE Library ([www.ascelibrary.org](http://www.ascelibrary.org)).

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