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The Economics and Politics of "Green" Flood Control

A Historical Examination of Natural Valley Storage Protection by the Corps of Engineers

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RESOURCES FOR THE FUTURE

The Economics and Politics of “Green” Flood Control: A Historical Examination of Natural Valley Storage Protection by the Corps of Engineers

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Abstract

Between 1972 and 1994, the New England Division of the US Army Corps of Engineers undertook five studies evaluating the benefits and costs of protecting natural valley storage (NVS) areas as a flood mitigation strategy in various watersheds. NVS lands function as natural reservoirs, temporarily storing floodwaters. In only one case—along the Charles River in Massachusetts—were the benefits found to outweigh the costs. Along the Charles, the Corps acquired approximately 8,500 acres of floodplain land to keep as open space in perpetuity. This paper reviews the five studies in detail to inform ongoing interest in green approaches to flood control. The analysis finds that large-scale land acquisition to contain major riverine flood events is difficult to justify by avoided flood damages alone. For such a project to generate net benefits, there must be significant amounts of NVS lands still undeveloped, substantial development pressure on those lands, and downstream areas that would sustain high levels of damage in the event of a flood. Perhaps more importantly, however, these studies raise two fundamental institutional questions: (1) Should the Corps, or the federal government more broadly, be involved in land acquisition? (2) Should regulating land use be preferred over purchasing NVS land? The economic and political issues uncovered in the historic examination of these five studies suggest an explanation for the current focus on other approaches to green flood control, such as multipurpose projects, levee setbacks, and green infrastructure to manage stormwater.

Key Words: floodplain conservation, flood mitigation, Corps of Engineers, natural valley storage, cost-benefit analysis

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1. Introduction

There has been growing interest in "green" approaches to flood control, whereby structural measures are eschewed in favor of floodplain conservation. This has taken a number of forms around the world. One approach is the protection of what the New England Division of the US Army Corps of Engineers has referred to as "natural valley storage" (NVS). NVS areas are lands, often wetlands, which temporarily store floodwaters, acting as natural reservoirs. While the Corps has been involved in most large investments in structural flood control in the United States, it has a limited history with NVS protection. In the 1970s, it acquired roughly 8,500 acres of NVS lands along the Charles River and its tributaries in Massachusetts to protect against increases in flooding. After the approval of this project, the Corps evaluated the benefits and costs of NVS projects in four other New England watersheds between 1972 and 1994. In none of these other cases was a NVS approach found to merit federal investment.

This paper examines in detail the five studies undertaken by the New England Division of the Corps of Engineers to ascertain what made NVS protection economically and institutionally attractive in the Charles River case but not in the other watersheds. Analysis of these studies and supporting documents demonstrates many ways in which the Charles River case was unique. While some findings are historical, in that they are no longer applicable to today's conditions or current Corps study procedures, the analysis does uncover several lessons that can inform today's efforts at green flood control. These should extend beyond the Corps to the growing number of public and private entities pursuing natural approaches to flood risk management. For example, the Greenseams program in Milwaukee is acquiring streamside properties to reduce flooding; the Blue Acres program in New Jersey acquires floodplain lands, including those that provide flood mitigation for neighboring properties; and The Nature Conservancy has projects

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targeting floodplains for conservation. Beyond the United States, the Netherlands, for example, is making use of natural approaches in its Room for the River project.

The first key finding of the analysis is that large-scale acquisition of land to function as a natural reservoir for the containment of large riverine flood events is unlikely to be economically justified solely by consideration of avoided flood damages downstream. There were three circumstances that led the Corps to conclude there were net economic benefits for protecting NVS lands in the Charles River case: (1) significant amounts of NVS lands remained undeveloped, (2) those lands faced substantial development pressure such that the counterfactual in the absence of the project was the loss of those lands, and (3) downstream areas would sustain high levels of damage in the event of a flood. All three of these conditions were not present in the other watersheds studied.

That said, the fact that the Charles River NVS project was not replicated elsewhere may have had less to do with economics and more to do with institutional concerns. The Charles River project raised fundamental questions about whether the Corps—and perhaps the federal government more broadly—should be involved in acquiring large amounts of land for flood control purposes, or whether this type of land acquisition should be the purview of local governments instead. In addition, in the years between approval of the Charles River project and the other Corps studies, both the federal government and several states passed legislation providing higher levels of protection to wetlands, thus reducing the likelihood that they would be lost if not purchased. Such regulations were less costly to the government and made land purchases for flood control appear redundant.

Note that this paper is focused on analyzing how the assumptions, approaches, and arguments in the Corps reports influenced the decision of the Corps to pursue NVS projects in these watersheds or not. This paper is not seeking to evaluate ex-post whether any of the assumptions for particular studies ultimately proved justified or not. Further, as several Corps study procedures have changed since those evaluated here, analysis of outdated approaches is not undertaken.

The paper proceeds as follows. The next section provides background on NVS as a flood control strategy, information on the Corps and cost–benefit analysis (CBA), and an overview of each of the five cases. Section 3 then turns to an analysis of the economics of NVS based on the five studies. Section 4 takes up the institutional questions surrounding large-scale land acquisition for flood control. Section 5 concludes.

2. Background

2.1. Natural Valley Storage (NVS) for Flood Control

Qualitatively, three different types of flood mitigation strategies for large riverine flood events make use of natural systems.[1] The one discussed in this paper, preserving NVS areas, is explained in more detail in this section. Of note, however, there are two other approaches that would similarly be classified as green strategies for flood control: (1) reconnecting rivers to their floodplains through levee setbacks (e.g., Opperman et al. 2009); and (2) reducing exposure in floodplains (e.g., Kousky and Walls 2013). In the first approach, the channel of the river is widened, giving more room for conveyance of floodwaters. This is done in conjunction with structural measures; that is, levees may be pushed back farther from the river but are still in place to protect development behind them. In the second approach, development is prevented in flood-prone areas or is actively removed once there (such as through federal buyout programs). The goal of this approach is not to alter the hydrology of a system, although that might occur, but simply to remove from harm's way structures that could be damaged by floodwaters. The acreage conserved from such buyout programs is substantially less than that envisioned with NVS protection. These approaches have been more commonly employed than NVS protection, and the analysis in this paper may suggest why that is the case.

"Natural valley storage" (NVS) is a term that appears to be used almost exclusively by the New England Division of the Corps in the studies reviewed in this paper. These studies use the term to refer to lands in a watershed that can temporarily store floodwaters acting as natural reservoirs —referred to as off-channel storage, and may also move floodwater (New England Division of the Corps of Engineers 1993). As described in one of the reports for the Charles River project, NVS areas are marshes and swamps that "modify and desynchronize flood flows in a manner similar to a series of reservoirs" (New England Division of the Corps of Engineers 1976c, 1). NVS areas essentially lag and reduce the flood peak.

The ability of an area to store floodwaters effectively is a function of soil, topography, vegetation, and location in the watershed (New England Division of the Corps of Engineers 1993). Clay soils do not store floodwaters as effectively as organic matter, for example, and

[1] In addition, interest has been growing in so-called green infrastructure, a term that largely refers to land use changes designed to increase infiltration of stormwater. This paper focuses on managing large riverine flood events, not managing stormwater, although there could be overlaps in the policies and approaches.

steep slopes do not hold water either. Vegetation slows down floodwaters. Finally, note that natural storage is more effective for floods that peak and recede quickly (New England Division of the Corps of Engineers 1990, 1993). For floods of a long duration, storage areas will fill and then fail to provide additional storage benefit.

2.2. The Corps and Cost–Benefit Analysis

The work of the Corps work building flood control projects in the United States goes back to the early twentieth century on the Sacramento and Mississippi Rivers. In 1936, Congress passed the Flood Control Act, which stated that flood control is a proper activity of the federal government. This act also mandated that the benefits of Corps projects outweigh the costs and that the localities benefiting from the project bear a small portion of the total costs. Initially, the Corps undertook only so-called single-purpose projects, which were authorized and constructed for a single reason, such as flood damage reduction. With the passage of legislation in 1944 authorizing several multipurpose dams, this began to change. Multipurpose projects include the provision of other benefits, such as recreation or conservation, for instance, and the Corps has since undertaken many such projects.

Carter and Stern (2011) describe the process of Corps projects from start to finish. Flood control projects begin with a local sponsor requesting Corps involvement. Congress then authorizes a reconnaissance study to gauge federal interest in a project and the extent of support among possible nonfederal sponsors. If the project is favorably reported, then the Corps conducts a feasibility study on the project. The feasibility study formulates solutions to the problem and evaluates them, with an engineering analysis and a CBA as well as a review of environmental impacts pursuant to the National Environmental Policy Act of 1969. Congress must then authorize and appropriate funds for construction of the project. In 1986, Congress passed legislation that updated certain Corps practices. Of note, the cost sharing by local sponsors was increased from 25% to 35%, and the local partner was directed to share in the costs of the planning stages.

The Corps has been directed by Congress to consider projects in the national interest. Thus, Corps CBAs evaluate benefits and costs to the country as a whole, not from the more narrow perspective of the locality. Current practice for these studies is found in the 1983 *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* and related Corps guidance documents. The Corps is to choose a project that maximizes “national economic development,” or the economic value of the national output of goods and services, unless there are overriding reasons to do otherwise. Corps studies also calculate impacts on national environmental quality. Congress mandated an updating of the *Principles and Guidelines* in 2007, and a final draft revision was released in 2013; these new documents did not apply to any of the cases examined in this paper. The new guidelines address the inclusion of environmental impacts and improved treatment of uncertainty, among other things.

In the years covering the studies here, and subsequently, the Corps' mission began to expand to include a greater emphasis on environmental protection and restoration. Water Resource Development Acts passed in 1986, 1990, 1992, and 1996 all included provisions to this end (see National Research Council 1999). These acts, and others since, have altered Corps practice, such that the examination in this paper needs to be viewed purely as a historical examination. That said, there are still lessons to be learned for today's activities in green flood control. Because of changes in Corps analysis procedures and activities, however, this paper does not analyze practices that have since been updated or are no longer relevant and instead aims to highlight findings that can be useful to consider in today's environment.

2.3. The New England Cases

This paper presents the results of detailed analyses of five different NVS case studies undertaken by the Corps in New England between 1972 and 1994. Some of these reports are reconnaissance studies and some are feasibility studies, so the detail of the analysis varies. In addition, in 1991 the Corps was authorized to undertake a study of NVS in Massachusetts under its Planning Assistance to States Program. This report provides a higher-level discussion of the economics of NVS, including a review of the Charles, Spicket, and Taunton reports, and was thus reviewed along with the specific case documents (New England Division of the Corps of Engineers 1993). The original studies and all supporting documentation were obtained for each case and were carefully reviewed and examined. In addition, any relevant gray literature on the studies or references that were pertinent to analysis of the studies were obtained and evaluated. The five rivers and the states in which they are located include the following:

1. Charles River; Massachusetts (reports in 1971, 1972, and 1976)
2. Connecticut River; Connecticut, Massachusetts, New Hampshire, and Vermont (reports in 1974 and 1994)
3. Neponset River; Massachusetts (reports in 1979 and 1982)
4. Taunton River; Massachusetts (report in 1978)

5. Spicket River; Massachusetts and New Hampshire (report in 1990)

A brief overview of each case is given in this section.

2.3.1. Charles River Basin

The Charles River runs 80 miles from Echo Lake to its mouth at Boston Harbor and has a drainage area of 307 square miles. According to the Corps, the basin is divided into three hydrologically dissimilar sub-watersheds (New England Division of the Corps of Engineers 1976b). The lower basin, where the Charles empties into the harbor, is a highly developed urban area that includes the cities of Boston and Cambridge. The middle and upper sections are more suburban or rural. In 1955, Hurricane Diane spawned a devastating flood, causing approximately $5.5 million worth of damage, largely in the lower basin (New England Division of the Corps of Engineers 1978b). This spurred demand for flood control. In 1965, Congress authorized a feasibility study. In 1968, the New England Division finished the first part of the study, which recommended upgrading of a dam built in 1910 at the mouth of the river. This dam was completed in 1978.

In 1968, another storm caused a flood close to the level of the 1955 flood. The Corps was able to examine the flooding firsthand, finding that in the upper and middle portions of the watershed, the flood crest moved extremely slowly; ultimately, it took a month for all of the stormwater to reach the dam (Chandler and Doyle 1978). This confirmed the Corps' belief that wetlands were effectively controlling flooding in the middle and upper basins. After examining multiple flood control options for these basins, the Corps ultimately recommended fee simple purchase or conservation easement acquisition of wetlands in the watershed. The recommended project involved the acquisition of wetlands in 16 communities along the Charles and its tributaries that together would "retard flood flows and act as a reservoir system in retaining and de-synchronizing flood flows" (New England Division of the Corps of Engineers 1976b, 8). Many public meetings were held, including 12 sponsored by a citizen advisory committee that more than 600 people attended (Chandler and Doyle 1978). In the final 1971 meeting at the completion of the study, the Corps' plan was endorsed unanimously and received support from the US Department of the Interior, the Fish and Wildlife Service, and the governor of Massachusetts (Chandler and Doyle 1978; New England Division of the Corps of Engineers 1976c). The 1972 report recommended the Charles River NVS project (CRNVSP) on the middle and upper portions of the watershed.

The next step was obtaining federal authorization, which came in the Water Resources Development Act in 1974. The CRNVSP was the first of its type to be authorized (New England

Division of the Corps of Engineers 1976c). It protected, through federal acquisition, roughly 8,500 acres of NVS lands for the flood mitigation benefits those lands provided. The lands are also used for light recreational activities and managed for fish and wildlife. Corps studies suggest a benefit-to-cost ratio of more than 2:1 for these investments. Land acquisition began in 1977, and the NVS project was completed in 1984. It remains the only Corps flood project in New England to use wetlands to reduce flood damages (New England Division of the Corps of Engineers 1993).[2]

2.3.2. Connecticut River Basin

The Connecticut River basin drains 11,250 miles and includes areas of four states: New Hampshire, Vermont, Massachusetts, and Connecticut. An early study of nonstructural flood control options on the Connecticut River included acquisition as part of the strategies examined, but found they were not economically justified (Cheney 1974).

In 1994, however, the Corps undertook a reconnaissance study at the request of the Connecticut River Valley Flood Control Commission to evaluate the impacts of development on NVS and whether the Corps could help preserve NVS areas (New England Division of the Corps of Engineers 1994). Seven NVS areas were identified, four along the main stem and three along tributaries. The main stem areas, representing 83% of total storage, were studied in detail. The study evaluated obtaining easements on 22,750 acres of land but did not evaluate structural alternatives. The report found protecting NVS to have a benefit-to-cost ratio of 0.11 to 0.23, depending on the scenario, and thus it was not recommended (New England Division of the Corps of Engineers 1994).

2.3.3. Neponset River Basin

The Neponset River has its headwaters in Foxborough, Massachusetts; from there, it flows toward Boston Harbor, forming the southern boundary of the city. It drains roughly 115 square miles and is bordered to the north by the Charles River basin. In 1979, the Corps undertook a reconnaissance study for the Neponset River basin, which recommended further analysis in a second phase of both structural and nonstructural alternatives, with an emphasis on NVS (New England Division of the Corps of Engineers 1979). The reconnaissance study

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2 Personal communication with the chief of the Planning Branch of the New England Division of the Corps of Engineers indicated that no natural storage projects have been undertaken since the Charles River case. However, the Corps has used other nonstructural approaches to flood control.

identified a large amount of existing wetlands in the basin and expressed concern that their development could increase flood damages.

The phase II study examined three potential alternatives: structural local protection; a combination of floodproofing, elevation of some properties, and an early warning system; and protection of NVS areas. The study concluded that preserving the NVS lands would ensure the most widespread protection, but that it should be done through zoning and existing legislation. An extensive program of land acquisition was considered to be "prohibitively costly and unnecessary" (New England Division of the Corps of Engineers 1982). Since regulations were deemed to be sufficient to protect the land, the Corps did not evaluate land easements or acquisition in detail.

2.3.4. Taunton River

The Taunton River basin lies just south of the Neponset basin. It drains 570 square miles, primarily in southeastern Massachusetts. The Corps completed a study of the basin in 1978. The report evaluated several alternatives but concluded that there was no federal role in the basin. It did stress, however, that existing regulations should be used to protect NVS areas. The study noted that the basin was not highly developed at the time, which is part of the reason why it had not had major flood problems, but that residential and industrial development pressures were growing (New England Division of the Corps of Engineers 1978a).

2.3.5. Spicket River

The Spicket River, a tributary of the Merrimack River, is located in northwestern Massachusetts and southern New Hampshire. It is roughly 15 miles long, draining 78 square miles. In 1990, the Corps completed a general investigation study for the basin (New England Division of the Corps of Engineers 1990). The investigation was spurred by serious flooding in 1987, which generated interest in the development of a flood loss reduction plan. The study examined several flood reduction options, including one that would minimize the loss of NVS. The Spicket River had sizable NVS areas at the time of the study—roughly 2,220 acres—two-thirds of which were located in Salem, New Hampshire, and Methuen, Massachusetts. The study found that a flood warning system would generate net benefits, but protection of NVS lands would not.

3. The Benefits and Costs of NVS

This section reviews the CBAs undertaken in the five studies. Section 3.1 provides an overview of how the economics of NVS investments were in general evaluated by the Corps and then Section 3.2 turns to three reasons NVS protection was found to generate net benefits in the Charles River case, but not in the other studies.

3.1. Overview of the Corps CBAs

Corps CBAs for flood damage reduction projects compare the benefits of a project—measured as avoided flood damages—with the full costs. The studies compare “with-project” conditions to “without-project” conditions: the benefits of the projects are defined as the difference between flood damages with the project and flood damages without the project. All benefits and costs are reported and compared in annual terms. Benefits accrue through the useful life of the project and are discounted back to present values. Most flood control projects use a project life of 50 to 100 years. For the CRNVSP, the Corps assumed a useful life of 100 years and used a discount rate of $6^{1}/_{8}$% (New England Division of the Corps of Engineers 1976b). This is similar to the Taunton study, which assumed 100 years and used a $6^{5}/_{8}$% rate (New England Division of the Corps of Engineers 1978a). Both of the Connecticut River studies assumed 50 years; they differed in the discount rate, with one using $5^{7}/_{8}$% and the other using 8% (Cheney 1974; New England Division of the Corps of Engineers 1994). The discount rate is clearly critical in determining how great a weight future benefits play in the overall net benefit calculation. Much has been written on the Corps practice and choice of a discount rate (see, for example, Powers (2003)), and that discussion is not rehashed here.

Benefit estimations for flood control projects are based on guidelines from the US Water Resources Council. An overview of this process is provided by the New England Division of the Corps of Engineers (1993). First, a study area is defined, which is, at a minimum, the 100-year floodplain. Structures in the study area are catalogued. Elevations are determined for all structures so that damages can be estimated for multiple flood elevations. Stage–damage functions are used to relate flood stage levels to dollars of damage. The stage–damage function is coupled with a hydrologic and hydraulic analysis that estimates stage–frequency curves that relate stages to probability of occurrence for both with- and without-project conditions. Coupling these functions gives a damage–frequency curve, which can be used to derive estimates of expected annual damages.

Three things play a role in determining the flood damage reduction benefits of NVS protection:

1. projected development of NVS areas in the without-project condition;
2. the effect of storage areas on flood levels; and
3. the relationship between flood levels and flood damage.

We return to (1) in the paragraphs below. Corps hydrologic modeling determines (2). This is not a focus of this paper; that said, a few relationships have been found in the literature that are worth mentioning. A substantial amount of land is required to control a hundred-year flood event. Exactly how much land varies by watershed size, typography, and conditions, but it is much larger than the amount needed to contain stormwater, for example, or when simply buying out a few flood-prone structures. EPA provides a rough estimate that a one-acre wetland can store around three-acre feet of water (EPA 2006). In addition, because wetlands drain slowly, their full storage potential may not be available during any given storm event; this is especially important for large, regional floods of long duration (Potter 1994). For this reason, wetlands are most likely to be effective in mitigating the effects of smaller floods and may not substantially attenuate peaks for very large flood events. That said, at least one study has found that flood attenuation increases as wetland area in the watershed increases, but that wetland areas covering only a small percentage of the watershed can still provide substantial reductions in peak flows (De Laney 1995).

The outcome of (3) is based on the chosen depth–damage curve—a stair-step function by foot of water depth that calculates damage as a percentage of building value for each depth level. Such functions are developed for groups of structures that are likely to face similar damage, such as two-story residential units that have a basement. Preferably, depth–damage functions should be used that are specific to a given locality, are based on the specific type of structure, and have been validated against past damage. This is rarely the case, however, and national averages are often applied. The difference in damage estimations across depth–damage functions can be quite large (see, for example, Merz et al. 2004), but none of the studies included any sensitivity analysis on this.

The estimated costs of a project include all expenditures to build and operate the project. For NVS studies, the vast majority of the costs are for property acquisition through fee simple purchase or purchase of easements. Other costs include those associated with land acquisition (e.g., mapping, surveying, appraisals, negotiations, legal costs, and title costs, as well as recording and transfer fees). Since a large amount of land is required, these costs can be quite high. For instance, in the Charles River case, 8,500 acres were preserved, and in the Connecticut River case it was estimated that easements would be needed on 22,750 acres of land. In all studies reviewed here, the costs of purchasing land were calculated at market value. For the Charles River study, the market value was estimated using comparable sales, appraisals, and assessments. For both the Taunton and Spicket River studies, a per-acre estimated value was calculated and used with little justification. The 1993 report compared the average per-acre costs of land acquisition, in constant 1990 dollars, used in several of the studies and found that they were lowest for the Taunton case at $880 and highest for the Spicket River case at $5,000; the Charles was in the middle at $2,400 (New England Division of the Corps of Engineers 1993). (Translated to 2013 dollars, these are $1,581 per acre for the Taunton study, $8,982 per acre for the Spicket study, and $4,311 per acre for the Charles study.) Higher land costs can be justified when the benefits are also higher.

While easements lower the costs of using NVS, it is usually impossible to determine a priori which, if any, property owners would choose an easement. For the CRNVSP, the Corps valued all lands for fee simple purchase, stating that this would "ensure absolute protection," although they did note that, when requested by landowners, they might pursue easements instead (New England Division of the Corps of Engineers 1976c, 4). However, contrary to this reasoning, the Connecticut River analysis assumed that all acquisition would be through easements, as this would provide the same protection at lower cost (New England Division of the Corps of Engineers 1994). Neither report calculated and compared the costs of all land acquisition being fee simple versus through easements.

3.2. Achieving Net Benefits

In four of the five case studies, setting aside significant amounts of land to manage large riverine flood events was not economically justified by the benefits of avoided flood damages alone. The studies varied in the level of detail in their economic analysis—they were different types of Corps studies—and the assumptions made varied across them, as well. While it is not possible to have an apples-to-apples comparison, then, examining the pattern and implications of the various assumptions made still suggests some overarching findings. These are discussed here. In particular, it appears that three factors combined in the Charles River case to produce avoided flood damages that outweighed project costs:[3]

[3] A report for the Charles River case highlighted three related, but slightly different, criteria for NVS preservation to be recommended as the preferred alternative: (1) extensive NVS still in existence, (2) currently only minor flood damage, and (3) an imminent threat to the loss of NVS (New England Division of the Corps of Engineers 1976a).

1. extensive NVS still in existence;
2. significant development pressure on NVS lands; and
3. downstream areas that would sustain considerable damage should a flood occur.

In addition, and perhaps even more important, there was no institutional opposition for the Corps to engage in land protection; this issue is discussed further in Section 4. This section discusses the three criteria just listed in turn.

First, a plan to use NVS for flood mitigation must be pursued before all NVS lands have been lost to development. Although this seems obvious, the strategy will not be possible to implement in many watersheds that are already heavily developed. (Note: these reports did not consider restoration, so it is not discussed here, although the Corps now undertakes restoration projects. Restoration would create new floodwater storage areas, as well as other ecological benefits.) According to the New England Division of the Corps, one way in which the Charles River project was "remarkable" was that it was undertaken "early enough to implement an optimal solution" (1972, i). The Corps found that around 10,000 acres of the watershed had "superior flood retention capabilities" (1972, 52). The 17 areas ultimately chosen for the project were estimated to control 75% of Charles River watershed wetland and lake storage, equivalent to about 42,000 acre-feet.

In other studies, the Corps also found substantial amounts of NVS in existence; this is a necessary but not sufficient condition for justifying a NVS approach. For example, the Corps found that 13% of the Neponset basin was still in wetlands, much of it along the river, where it provided additional capacity in the channel for detention of floodwaters; if lost, this was estimated to increase peak flood flows by anywhere from 25% to 70%, depending on the site (New England Division of the Corps of Engineers 1982). The Spicket River basin was also found to have substantial amounts of NVS areas still in existence; if these were developed, this could similarly lead to increases in flood damages downstream (New England Division of the Corps of Engineers 1990). As discussed below, other factors prevented the Corps from recommending the protection of these areas through land acquisition.

The justification for an NVS approach is slightly different than that for structural flood control measures[4] in that NVS is not implemented to reduce today's flood damage, but to prevent

[4] Or for restoration projects, which would similarly be adding new protection.

an increase in future flood damages. This was stated as the specific design purpose of the CRNVSP: "communities in the Upper Charles are not now susceptible to destructive flooding but as the watershed becomes developed flood damages will occur"(New England Division of the Corps of Engineers 1976b, 9). Under this framing, the projected loss of storage under the "without-project" condition becomes critical.

A key assumption for the calculation of benefits for an NVS project is the assumed rate of development of NVS lands in the absence of their protection. The different reports used various arguments to justify the assumptions made regarding without-project development of NVS lands. In the main report for the Charles River case, the Corps noted that a 1967 study by the Massachusetts Department of Natural Resources estimated 1% annual wetland loss for the state as a whole, but the Corps estimated a loss rate of more than double that in the upper and middle portions of the Charles River watershed (New England Division of the Corps of Engineers 1972). The report justified this assumption with references to local conditions: the watershed's location near metropolitan Boston and the construction of two new circumferential interstate highways (New England Division of the Corps of Engineers 1976b). This led the Corps to assume a 30% loss of storage by 1990. As an example of the development pressure at the time, while the Corps was scoping the Charles River project, it had to drop two of the locations under consideration for preservation because development occurred there, reducing them to less than the determined 100-acre minimum size and lessening their floodwater retention capacity. A sensitivity analysis was done on their assumed rate of wetland loss, with loss ratios of 10%, 20%, and 40% all examined (New England Division of the Corps of Engineers 1976b). Benefits exceeded costs for down to a 20% loss. The projected loss of 30% by 1990 of NVS areas was estimated to increase damages 34% (New England Division of the Corps of Engineers 1993).

That said, while 30% was a high rate of loss, the Corps assumed an even higher rate of 50% loss of wetland areas as the without-project condition in the 1990 Spicket River study. No justification was given for this choice, although the report also examined loss rates of 10%, 20%, 30%, and 40% (New England Division of the Corps of Engineers 1990). For no scenario were the benefits found to exceed the costs, but the report recommend the creation of a basin wide management plan to ensure the protection of these lands nonetheless. This result appears to be due to a very high cost of land acquisition, indeed, as stated above, the highest land cost of all the studies. A discussion of this value or sensitivity on it was not provided, although the report stressed the high rate of growth in some towns in the study area. In addition, the study made assumptions that existing regulations could protect the wetlands, as discussed in Section 4.

While a high rate of loss increases estimated benefits for a project since it makes the gap between flood damages in the with- and without-project estimates greater, it should also increase costs. In areas of high development pressure, the price of land should in general be driven up, making the project more costly. For a project to generate net benefits, the increased benefits from projected land conversion must outweigh higher land costs. No study discussed this point, although it appears the benefits outweighed the costs for the Charles case, where the average per acre land cost was an intermediate value, but not in the Spicket case, where land costs were highest.

The role of other regulations is also important in defining the without-project conditions, because if storage areas are unlikely to be lost, there is little justification to pay for their protection. The CRNVSP analysis was done before the adoption of several state and federal laws that were designed to slow the rate of conversion of wetlands. These include the Massachusetts Wetlands Protection Act, regulations promulgated under Section 404 of the Clean Water Act, regulations required by communities participating in the National Flood Insurance Program, and Executive Order 11988. These laws and regulations were invoked to argue in subsequent studies that land acquisition was not needed since, if laws were enforced, the without-project condition would not see dramatic conversion of NVS lands. This is discussed further in Section 4.

In the 1994 Connecticut River basin study, two scenarios of development, a moderate or existing growth trends scenario and a "worst-case scenario," were estimated. These were informed by the existing regulations and laws, as well as historical population growth, projections from the various states, employment rates, and current land use. Despite considering the role of regulations, the study projected positive development of NVS lands on a community-by-community basis. The Corps estimated development growth at 5% for most communities, with some communities experiencing rates between 6% and 12%. For communities participating in the National Flood Insurance Program, the report assumed that 35% of the undeveloped and unprotected floodway fringe would be developed in areas with floodways mapped by the Federal Emergency Management Agency (development in the floodway is prohibited but can occur in the fringe if the first floor is elevated above the base flood level) and 20% of the entire undeveloped and unprotected 100-year floodplain would be developed in the other communities (New England Division of the Corps of Engineers 1994). (The report presented details on the assumptions for each river reach.)

This project was determined to be uneconomic because it did not meet the third criterion of areas that would sustain high levels of damage in the event of a flood. The benefits of NVS conservation come not just from the ability of these lands to hold floodwaters, but also from their ability to hold floodwaters *that otherwise would have damaged property*. The early Connecticut River analysis noted that the downstream population centers were already protected against floods greater than the 100-year event by dikes and floodwalls. For NVS protection to provide benefits, it would need to protect against much rarer flood events, but the use of NVS for such events would require such enormous amounts of land conserved that the costs would far outweigh the benefits (Cheney 1974). As noted earlier, several studies highlight that NVS protection is best for floods of short duration that peak quickly, not large scale flooding. In the Spicket River study, for example, the Corps noted that "…when flood discharges remain high for a long period, the effect of storage becomes minimal because once the storages are filled to the stage required to sustain the peak flow, outflow equals inflow" (New England Division of the Corps of Engineers 1990, 25). That said, NVS protection could potentially lessen pressure on structural flood control measures. The report did not discuss whether failure of the structural flood control measures would generate enough avoided flood damages to warrant containment of higher magnitude flood events.

In the Neponset River study, the Corps also determined that loss of NVS in the upper watershed would not have large impacts downstream. This was because a large downstream area of NVS could absorb any loss of the upstream areas (New England Division of the Corps of Engineers 1993). As noted in the reconnaissance study, "[u]nless most wetland areas in a basin are located upstream of existing or potential damage areas, they have little effectiveness in mitigating floodflow" (New England Division of the Corps of Engineers 1979, 23).

Likewise, in cases that simply have little development to protect from flooding, protecting NVS will not generate high benefits in terms of avoided flood damages. In the Taunton case, for example, little development downstream meant that any impact of protection on damage reduction would be minimal. The report concluded that "[b]asinwide acquisition of the larger swamps within the basin by the Federal Government is not economically justified due to the relative lack of downstream development and the high potential of flooding due to tidal influence," which would not be mitigated by NVS protection (New England Division of the Corps of Engineers 1978a, D-30). The Corps examined two smaller areas for acquisition where the benefits were thought to potentially be the highest. Some of this land was already protected. In the unprotected area considered, the Corps found that, to generate net benefits, protection would have to reduce damages by more than 50%, an amount that was found unlikely given projected future growth and development in the area. This was due to the high costs of the project (the report estimated land acquisition to cost $350,000 (at $500/acre)) but low benefits (New England Division of the Corps of Engineers 1978a, D-31).

By contrast, the existence of highly populated and developed areas in the Charles River watershed that would experience serious damages in the event of a flood made the NVS project generate much larger benefits. In addition, in the CRNVSP analysis, the Corps assumed future growth in the areas at risk from flooding, as it was a time of increasing development and real income growth; in contrast, the Corps did not make this assumption for the Spicket River analysis, the Connecticut River analysis, or the Neponset River study (Cheney 1974; New England Division of the Corps of Engineers 1993, 1982). In 1993, a report by the Corps noted that the assumptions in the Charles River case were made as a result of "extreme developmental pressures" at that time, and that "[s]imilar assumptions would be difficult to justify today" (New England Division of the Corps of Engineers 1993). This assumption of increasing damages in the Charles resulted in larger benefits being found for NVS protection.

4. Is the Corps a Land Protection Agency?

Following the CRNVSP, two institutional concerns were raised that pushed toward a subsequent rejection of NVS protection projects by the Corps: (1) existing regulations provide sufficient protection for NVS lands, such that the "without-project" condition in Corps CBAs should realistically show little conversion of these areas, and (2) even if there is not existing regulatory protection for NVS lands, their protection should not be accomplished through land acquisition by the Corps. The latter argument embeds both the issues of whether land acquisition per se is the best tool for protecting NVS lands, and if it is, whether the Corps should be the one to acquire land or whether such protection should be the responsibility of local governments.

Regarding the first argument, following the CRNVSP, many laws were passed that decreased the likelihood that wetlands would be filled, offering greater protection for NVS areas. This included federal regulations, such as Section 404 of the Clean Water Act and those required for community participation in the National Flood Insurance Program, as well as state and local regulations. For example, Massachusetts passed the Wetlands Protection Act, which requires review of work that could alter wetlands and other resource areas, including 100-year floodplains, riverfronts, and waterways. In addition, some communities in the studies had adopted local zoning ordinances that provided protection for at least some NVS areas. Consideration of these new protections fundamentally changed what the Corps assumed as the without-project condition. For example, in the study for the Neponset River, the Corps concluded that if existing regulations were enforced, most storage areas would be protected; thus the Corps never even undertook an economic analysis for protecting these areas (New England Division of the Corps of Engineers 1979, 1993). The report for the Taunton River also noted that existing regulations should provide sufficient protection (New England Division of the Corps of Engineers 1978a).

The reports subsequent to the CRNVSP also discussed the second point, that is, whether the Corps should be involved in land acquisition. As noted by Shabman, the CRNVSP raised the issue of “whether the Corps ought to be involved at all in just purchasing and holding land, even if this is the only technically sound means of providing flood control” (1972, 93). The CRNVSP had many supporters, as demonstrated by letters written in favor of the project and appended to the main report (New England Division of the Corps of Engineers 1972). Still, it has been noted that administration officials were concerned at the time about whether flood control authority within the Corps should include land acquisition on a large scale, and this delayed approval of the project (Platt and McMullen 1979). The Office of Management and Budget also was worried about the burdens such an approach could place on the federal government (Larson and Dingman 1981). Beyond the widespread public support, one reason the CRNVSP prevailed amid these concerns could have been its nexus with an already constructed Corps project; the Corps found that if many more NVS areas were lost in the watershed, runoff would become so great that it could exceed the flood control abilities of the pumping facilities and dam at the mouth of the Charles (Shabman 1972). (This did not, however, help justify NVS investment in the Connecticut River case.) In any event, after the CRNVSP, the view appears to have emerged that large-scale land acquisition—in fee simple, or through easements, particularly if not tied to a structural Corps project, was not the role of the Corps. For example, in the Spicket River basin, the Corps concluded that “[i]mplementation of sound land use measures is, for the most part, a community responsibility” (New England Division of the Corps of Engineers 1990, 19).

Despite these statements and the shift of the Corps away from substantial investments in land preservation, the reports for many of the studies nonetheless raised questions about whether local regulations would actually be effective. At times, these statements appear at odds with the conclusions of the studies that NVS protection was not warranted. For example, the Phase II report for the Neponset River noted that “[e]xtensive filling of natural storage in wetlands has occurred in the past and is continuing,” and “[c]ommunities throughout the Neponset River Basin do not have the means to implement and enforce [existing] legislation,” yet the report concludes with a recommendation for stricter enforcement of regulations, not land acquisition (New England Division of the Corps of Engineers 1982, 2-23, 2-29). In the first main report on the Charles River project, the Corps noted that absent “external coordination, municipalities will pursue independent development plans, nibbling away at marsh storage areas piecemeal until in the aggregate effect of their expansion is felt as a major flood disaster” (New England Division of the Corps of Engineers 1972, 30). These sentiments were echoed by scholars who observed that basins contain multiple jurisdictions, and controlling externalities related to flood risk are challenging and made even more difficult by the low probability of major floods and the spatial separation between land use changes and their impact (Platt and McMullen 1979).

Removing NVS protection as a Corps activity also creates an apparent inequity in that federal dollars are used to cost-share the construction of structural flood protection through the Corps, but there is no equivalent program to cost-share land acquisition, should a community prefer it (Larson and Dingman 1981). Some localities may prefer some amount of land acquisition, even if not fully justifiable economically by avoided flood damages because of the myriad other benefits such lands provide. These concerns may be part of the shift that began occurring in this time period and continues today, away from simple NVS protection to Corps projects that unite environmental protection and restoration of floodplains with limited structural flood control and enhancement of riverine recreational activities. Such projects are now under way in several communities, as highlighted in the next section.

5. Conclusion

This paper has examined five studies completed by the New England Division of the Corps of Engineers between 1972 and 1994 where the Corps investigated acquiring NVS lands for the flood damage reduction doing so could provide. The benefits of this approach were only found to outweigh the costs of acquiring land in the Charles River watershed of Massachusetts; that case was unique in many respects. The middle and upper portions of the watershed had much NVS land still undeveloped, and yet pressure to develop this land was arguably strong and growing. This led to a without project assumption of a substantial loss of NVS lands and also led to an assumption that downstream damages would be getting worse over time—in an already highly developed area where a flood would be quite costly. Later Corps documents noted that the development pressure would have been hard to justify in later years or other locations. The other watersheds examined did not share all these characteristics.

The Charles River project was also undertaken before many federal and state regulations were in place, which, if assumed to be enforced, would limit the conversion of wetlands to development over time. The Corps argued in subsequent reports that these regulatory tools should be used to protect NVS lands rather than land purchase by the federal government. This was in part an economic argument: regulation is cheaper and if it is working, there are no additional benefits to conservation. It was also in part an institutional argument: land conservation on a large scale should not be a function of the Corps. While two distinct issues, these both served to push the Corps away from replicating the CRNVSP in the years following its approval.

These economic and political realities surrounding substantial investments in land protection for the purpose of avoided flood damages may partially explain the growth in other green approaches to flood control by both the Corps and other agencies and groups. More limited floodplain buyouts or use of green approaches for managing smaller-scale events, such as urban stormwater management, seem to have gained more traction in recent years, and have different economics (see, e.g., Shabman et al. 1997; Valderrama et al. 2013). In addition, there is growing interest in projects with multiple purposes that combine floodplain conservation with improvements in recreational opportunities along rivers and a combination of structural and nonstructural flood control measures. The Corps has been involved in several of these projects, such as in Napa, California; along the Truckee River in Nevada; and in Dallas, Texas.[5] These projects are examples illustrating that, since the cases examined here, the Corps has moved increasingly in the direction of combining more limited land preservation with other flood mitigation strategies, as well as including a larger range of benefits in projects, such as using ecosystem restoration and recreation as benefits of a project (Buss 2005). Combining all these benefits can help offset the costs of the project.

Analysis of these types of approaches would be a useful next step in understanding the economics and politics of green flood control (Kousky 2010). They raise questions of whether the "national interest" should be redefined in terms of a broader range of benefits, regardless of the main project purpose, and also how to choose projects when the Corps and local stakeholders may not agree—particularly if the local government is paying more of the cost or is willing to pay additional costs to meet other goals. Local governments may be particularly interested in "recreation-induced regional economic development," but this is traditionally viewed as a transfer by the Corps and not an increase in national income (New England Division of the Corps of Engineers 1993, 36). Cross-agency, cross-jurisdiction projects with multiple funding sources can be challenging but may be part of the future of integrating natural approaches into flood control.

[5] For more information on these projects see: http://www.countyofnapa.org/Pages/DepartmentContent.aspx?id=4294971816; http://www.truckeeflood.us/; and http://www.trinityrivercorridor.com/flood-control/dallas-floodway-project.html.

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