Site of the former Off Billington Street Dam, Plymouth, MA

Economic & Community Benefits from Stream Barrier Removal Projects in Massachusetts

Report & Summary

Massachusetts Department of Fish and Game
Division of Ecological Restoration
March 2015

Charles D. Baker
Governor
Karen E. Polito
Lt. Governor

George N. Peterson, Jr.
Commissioner
Tim Purinton
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Secretary

Economic & Community Benefits from Stream Barrier Removal Projects in Massachusetts

DEPARTMENT OF FISH AND GAME
Division of Ecological Restoration

The Massachusetts Department of Fish and Game, Division of Ecological Restoration (DER) works with partners "to restore and protect the Commonwealth's rivers, wetlands and watersheds for the benefit of people and the environment." Restoration projects, such as dam removal, culvert replacement, river daylighting, and streamflow enhancement, provide many benefits to local communities in the form of improved ecosystem services.

As part of our examination of the growing restoration economy in Massachusetts DER contracted with Industrial Economics to conduct a cost comparison of alternatives facing the owners of failing dams and undersized culverts. Costs for three dam removals were compared to repairing and maintaining the dams in place over 30 years. Similarly, the costs for replacing three culverts with identical structures and maintaining them over 30 years were compared with the costs of upgrading the crossings to meet the MA Stream Crossing Standards.

On average, removal of the 3 dams in the study was **60% less expensive** than repair and maintenance over 30 years.

On average, upgrade of the 3 culverts in the study was **38% less expensive** than in-kind replacement and maintenance over 30 years.

DER works hard to leverage as much as **$12** for every state dollar spent.

$1.2 Million
Saved by Cascade School Supplies in the removal of the Briggsville Dam

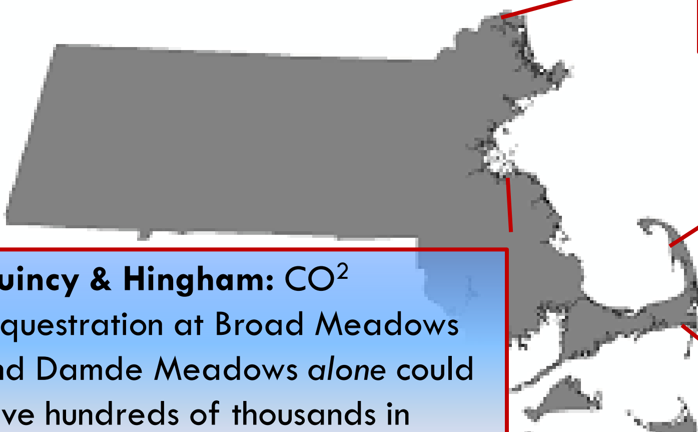
$1.5 Million
Estimated costs of 2005 Taunton evacuation due to Whittenton Dam (now removed).

$740,000
Estimated annual tax revenue from development associated with the Hill Street culvert upgrade in Raynham

Industrial Economic also provided guidance on DER's project tracking in order to facilitate future assessment of economic effects from projects. In addition, Industrial Economics identified **23** Commonwealth activities contributing to over **20** different ecosystem service benefits that make Massachusetts a better place to live and work.

Previous Work

What are ecological functions worth? In 2012-2013, DER contracted with ICF International to help begin answering that question by analyzing the economic benefits of four ecosystem services enhanced by DER projects. The study found that restoration of aquatic habitats and the services they provide can generate significant economic value. While these example ecosystem service values are impressive in their own right, they represent only one of many services improved by each project. Thus, the total per-project value of all ecosystem service enhancements combined is anticipated to be much higher.



Salisbury: Coastal storm protection from the restored Town Creek marsh will avoid nearly $2.5 million in damages.

Wellfleet & Truro: Restoring 1,000 acres of the Herring River Estuary could result in over $10 million increase property value.

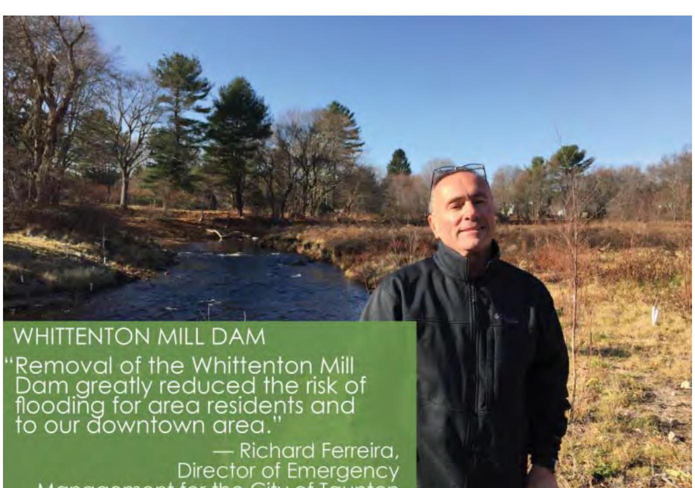
Quincy & Hingham: CO^2 sequestration at Broad Meadows and Damde Meadows *alone* could save hundreds of thousands in climate impacts.

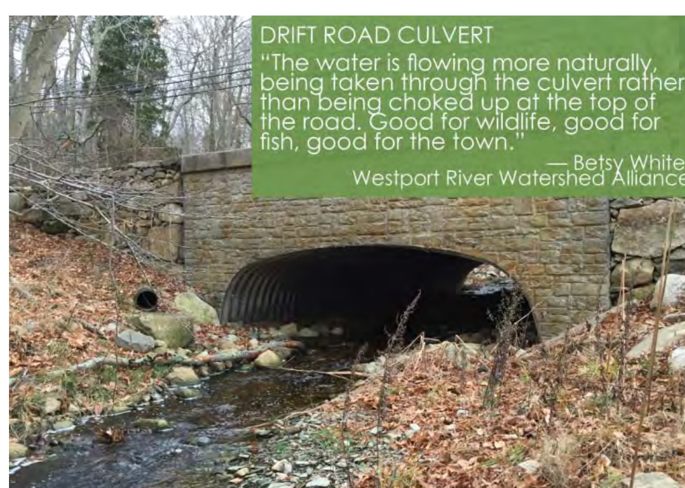
Chatham & Harwich: Restoring tidal flow in the Muddy River will attain water quality goals AND save approx. $3.9 million.

A previous DER study found that DER projects produce an average employment demand of **12.5 jobs** and **$1,750,000** in total economic output from each $1 million spent, contributing to a growing "restoration economy" in Massachusetts.

In the Community

Its not only sportsmen and anglers who benefit from healthier rivers and wetlands. Ecological restoration projects have wide-ranging impacts for all types of people.





Community Benefits of Stream Barrier Removal Projects in Massachusetts: Costs and Benefits at Six Sites

FINAL REPORT | JANUARY 2015

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EXECUTIVE SUMMARY

Dams and culverts exist in abundance across the State of Massachusetts. Many of these structures are in poor condition, having outlived their intended design life. Although removing stream barriers may require considerable up-front costs, these stream restoration efforts may also mitigate flood risks, improve ecosystem function, and relieve long-term financial burdens. Qualitative information on the consequences of dam removal and culvert improvements (i.e., stream barrier removals) is relatively available; however few detailed analyses have attempted to evaluate the socioeconomic impacts of these projects.

To gain insight on the socioeconomic implications of its restoration projects, the Massachusetts Division of Ecological Restoration (DER) conducted an analysis in 2011 to estimate the regional economic impacts of spending on restoration projects across the Commonwealth. The study found that each $1.0 million dollars spent on its restoration projects (including stream barrier removals, as well as salt marsh restoration) supported 10 to 13 jobs and $1.5 to $1.8 million in regional economic output (2009 dollars).[1] As this study focused on the short-term impacts of spending on these projects (i.e., economic activity precipitated by spending on engineering and construction labor and materials), it represented a first step in understanding how DER's projects affect communities.

The purpose of the current analysis is to improve understanding of the long-term socioeconomic implications of stream barrier removals in Massachusetts.[2] Toward this end, we evaluate six recent stream barrier removal projects in the Commonwealth. To describe how projects in Massachusetts have affected, and continue to influence, social and economic conditions in communities following their implementation, we evaluate two dimensions of the projects: 1) cost comparisons of implementing the ecological improvements (removing dams and upgrading culverts) versus continuing to repair and maintain existing structures; and 2) evaluating the long term changes in economic activity and the social character of the surrounding communities.

This information will provide a strong foundation for DER to communicate the importance of these actions in terms of the ecological, economic, and social benefits they provide.

For our six case studies, we created a financial and ecosystem service benefits comparison of scenarios with and without project implementation. These scenarios are

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1 Massachusetts Division of Ecological Restoration. "The Economic Impacts of Ecological Restoration in Massachusetts." March 2012.

2 In this document, the term "culvert upgrade" refers to the replacement of a culvert with an improved, stream-friendly structure able to accommodate fish passage and storm water flows.

the backbone of this analysis. To achieve this, we collected and reviewed available cost data for each site, developed engineering estimates of missing data, and conducted interviews with stakeholders familiar with the projects.

The study sites are as follows:

- Briggsville Dam removal, Clarksburg, MA;
- Bartlett Pond Dam removal, Lancaster, MA;
- Whittenton Mill Pond Dam removal, Taunton, MA;
- Dingle Road culvert upgrade, Worthington, MA;
- Hill Street culvert upgrade, Raynham, MA; and
- Drift Road culvert upgrade, Westport, MA.

Exhibits ES-1 and ES-2 summarize the findings of our case study analyses. Overall, we conclude that these investments in ecologically friendly, sustainable stream barrier removal projects were cost-effective. Furthermore, communities and project owners benefitted from DER staff project management experience, strong relationships with potential funders, and expertise in guiding projects efficiently and cost-effectively. DER staff provided technical assistance, grant writing, and permit support that these communities could leverage, along with other public and private funding sources, to minimize their own costs while gaining the full suite of ecological, social, and economic benefits.

DAM SITES

1. **Removing the dams was less expensive than repairing and maintaining them**. The up-front costs of dam removals were less than or equal to repair estimates. Factoring in estimated future maintenance costs for the structures over 30 years, each of the removals cost considerably less than the counterfactual maintenance and repair scenario. Costs of repair and maintenance ranged from 27 percent greater than removal at Briggsville Dam to more than four times the cost of removal at Whittenton Dam.

2. **The dam removals substantially reduced flood risk to surrounding properties**. All of the study site dams caused some levels of localized flooding due to storm water accumulation behind the dam or from a downstream surge due to a dam break. Removing the dams reducing the flood risk and, at each site, flooding has not been an issue since the dam was removed.

3. **Decreased flood risk reduced costs of flood response and management and potentially increased property values**. The reduced risk of area flooding generated a variety of positive social and economic outcomes, including avoided costs of infrastructure damages, avoided travel delays on area roads, avoided costs of emergency response operations and business closures, and potential increases in property value both for private dam owners and neighboring property owners.

4. **The dam removals increased the quality and availability of stream habitat**. In each case, the dams presented a passage barrier for recreationally or commercially valuable fish species. For example, at Whittenton Dam, the removal increased habitat connectivity for herring and American Eel, two native and sensitive species.

5. **Improved habitat conditions may enhance recreational opportunities and benefit the regional economy**. Improved stream habitat for recreationally valuable species, as well as improved conditions for recreational angling (e.g., at the site of the former Briggsville Dam) may attract additional recreational activity at or near these sites. Recreational benefits may also accrue up the food chain due to improved habitat conditions for recreationally valuable terrestrial species that rely on the fish and other riverine species as a food source. Increased recreational activity can stimulate regional economies (e.g., promoting business expansion through trip-related expenditures).

6. **The socioeconomic benefits were realized while minimizing costs to municipalities and dam owners due to available public and private funding and technical support.** Funding and technical support from agencies, such as DER and private organizations minimized the costs of the project to the property owner while ensuring ecological, social, and economic objectives were realized. All three sites received significant funds from outside sources to support the dam removal projects. Because these funds were from conservation partners, these funds would not have been available for repair and maintenance of the outdated dam structures.

CULVERTS

1. **Culvert upgrades were less expensive than repairing and maintaining the structures at two of three sites**. Up-front costs of culvert upgrades were greater than the up-front costs of replacing the structure with a similar "in-kind" structure. As the upgraded culverts resulted in much lower future maintenance costs, however, long-term costs of the upgrade were less than in-kind replacement for both Dingle and Drift Road culverts.

2. **The culvert upgrade projects reduced flood risk in surrounding communities**. All of the outdated culvert structures resulted in some level of localized flooding. Since the upgrade projects, flooding has not been an issue at any of the sites.

3. **Decreased flood risk reduced incidences of interruption to community activities and potentially increased property values**. The reduced risk of area flooding generated a variety of positive social and economic outcomes, including avoiding road closures and associated travel delays, and enabling industrial development at one site. In addition, reduced flood risk to area residential properties potentially increases property values.

4. **Culvert upgrade projects opened up new riverine habitat to native aquatic species**. For example, the upgraded culvert at Drift Road greatly enhances fish and wildlife passage to a small upstream pond. This stream supports both American eel (a commercially valuable species) and brook trout (a recreationally valuable species).

5. **Improved habitat conditions may enhance recreational opportunities and benefit the regional economy**. As described above for dam removals, improved habitat conditions can attract recreational spending in the region, supporting local businesses.

6. **Socioeconomic benefits were realized while minimizing cost to municipalities**. For the case study projects, the municipalities contributed approximately 14 to 20 percent of total project costs. Funds from conservation partners would likely not have been available for in-kind replacements. Leveraging available funding and technical support, for example from DER, allowed these projects to achieve the ecological, social, and economic benefits while minimizing the costs to the municipalities.

EXHIBIT ES-1. SUMMARY OF DAM REMOVAL CASE STUDY FINDINGS

CATEGORY		BRIGGSVILLE DAM	BARTLETT POND DAM	WHITTENTON DAM
Background on Project	Dam Owner	Cascade School Supplies (private)	Town of Lancaster	Individual (private)
	Year of Dam Removal	2010	2014	2013
Costs	Removal Costs	$920,000	$320,000	$440,000
	Cost to Owner (percent of total costs)	$31,000 (3%)	$270,000 (82%)[1]	$11,000 (0.5%, in-kind contribution)
	Other Funding Sources (percent of total costs)	USDA NRCS: $440,000 (47%) Other Conservation Partners: $320,000 (35%) Other Sources: $130,000 (14%)	DER: $60,000 (18%)	NOAA, American Rivers, The Nature Conservancy, Coastal America Foundation: $440,000 (99.5%)
	Total Cost Savings Relative to Costs of Dam Repair	$250,000	$560,000	$1,900,000
	Owner Savings Relative to Costs of Dam Repair[2]	$1,200,000	$610,000	$2,200,000
Benefits	Social and Economic Benefits	• Avoided flooding of multiple businesses adjacent to dam and downstream residences along one street. • Potential for increased property values due to reduced flood risk. • Potential for increased regional economic activity due to increased opportunity for recreational activities and improved aesthetic appeal. • Preservation of 150 jobs in the community. • Improved habitat conditions for brook trout and better access to stream for recreational fishing.	• Avoided costs of repeatedly repairing park infrastructure, including the parking lot. • Avoided travel delays that potentially affected thousands of travelers multiple times per year. • Created 18 miles of stream habitat for brook trout and other wildlife species, likely benefit for recreational angling. • Potential recreational benefits, avoided closures of the conservation area.	• Removed public safety threat. • Avoided costs of emergency response due to dam failure potential on the order of hundreds of thousands of dollars over the next 30 years. • Avoided costs to regional businesses of closures due to flooding or evacuations. • Potential for increased property values due to reduced flood risk. • Increased habitat connectivity for native, sensitive species, including herring and American eel.

Notes: Reported costs are adjusted to 2014 dollars using the Engineering News-Record Construction Cost Index and rounded to two significant digits. Present values are calculated over a 30-year time period assuming a 3% discount rate.

1 The Town of Lancaster received a $150,000 low interest loan from the Dam and Seawall Repair or Removal Fund (this funded 45% of total project costs).

2 These figures represent the total savings after removing leveraged funds.

EXHIBIT ES-2. SUMMARY OF CULVERT REPLACEMENT CASE STUDY FINDINGS

CATEGORY		DINGLE ROAD	HILL STREET	DRIFT ROAD
Background on Project	Culvert Owner	Town of Worthington	Town of Raynham	Town of Westport
	Year of Culvert Upgrade	2008	2010	2012
Costs	Upgrade Cost	$370,000	$440,000	$230,000
	Cost to Owner (percent of total costs)	$56,000 (15%)	$72,000 (17%)	$45,000 (20%)
	Other Funding Sources (percent of total costs)	DER: $61,000 (16%) Other Conservation Partners: $160,000 (42%) Other Sources: $98,000 (26%)	Chapter 90: $340,000 (77%) MORE Grant: $27,000 (6%)	FEMA: $180,000 (80%)
	Long-term Cost Savings Relative to Replacement In-Kind	$180,000	$(41,000)	$520,000
	Owner Savings Relative to Costs of Culvert Repair and Maintenance[1]	$500,000	$220,000 to $320,000	$560,000 to $700,000
Benefits	Social and Economic Benefits	• Removed public safety threat. • Facilitated access to residences for homeowners and safety vehicles. • Avoided cost of repairing damages to Dingle Road and possibly to nearby residential development. • Potential increased property values for four residences due to reduced flood risk. • Increased habitat connectivity for recreationally valuable species, including brook trout.	• Avoided damages to residential properties upstream. • Potential for increased property values of developable land and residential parcels due to reduced flood risk. • Supported construction of large-scale industrial development providing an estimated 300 jobs and $740,000 in local and regional annual tax revenues. • Increased habitat connectivity.	• Avoided costs to the town on the order of tens to hundreds of thousands of dollars for active management of flooded roads for four to ten days per year. • Avoided travel delays for 12,000 to 30,000 travelers annually. • Increased habitat available to and improved habitat conditions for recreationally and commercially valuable species, such as American eel and brook trout.

Notes: Reported costs are adjusted to 2014 dollars using the Engineering News-Record Construction Cost Index and rounded to two significant digits. Present values are calculated over a 30-year time period assuming a 3% discount rate.

1 These figures represent the total savings after removing leveraged funds. Savings at Hill Street and Drift Road are presented as ranges, as the funding sources leveraged at these sites may have been available if the municipalities had decided to replace the culverts in-kind. The upper bound assumes that the municipality would receive no outside funding for replacement in-kind. The lower bound assumes that outside sources would fund the same proportion of the initial replacement in-kind project as they funded the upgrade project.

SECTION 1. INTRODUCTION

1.1 PURPOSE OF REPORT

Dams and culverts exist in abundance across the State of Massachusetts. Many of these structures are in poor condition, having outlived their intended design life. Though culvert replacement and dam removal projects require considerable up-front costs, they also can mitigate flood risks, improve ecosystem function, and relieve long-term financial burdens.

While qualitative information on the consequences of dam removal and culvert upgrade is relatively available, few detailed analyses have attempted to quantify the socioeconomic impacts of these projects. A report from Born et al. (1998) found that while a number of studies investigate the environmental aspects of dam removals, little attention has been paid to the socioeconomic and institutional dimensions associated with the removal of dams despite the importance of those factors in removal decisions.[3] Trout Unlimited (2001) noted that while researching dam removal, "it became decidedly evident that there is very little published research on small dam removal, particularly on its economic ramifications."[4] The Nature Conservancy concludes its report on culvert replacement by noting a similar dearth of detailed economic research, and asserts that "a small and focused set of such analyses would be extremely valuable for highway department managers to understand the full range of societal and environmental costs associated with undersized crossings."[5]

The DER has been proactive in advancing research and education regarding these issues. To gain insight on the socioeconomic implications of its restoration projects, the DER conducted an analysis in 2011 to estimate the regional economic impacts of spending on restoration projects across the Commonwealth. The study found that each $1.0 million dollars spent on its restoration projects (including stream barrier removals, as well as salt marsh restoration) supported 10 to 13 jobs and $1.5 to $1.8 million in regional economic output (2009 dollars).[6] As this study focused on the short-term impacts of spending on these projects (i.e., economic activity precipitated by spending on engineering and construction labor and materials), it represented a first step in understanding how DER's projects affect communities.

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[3] Born, Stephen M. et al, "Socioeconomic and Institutional Dimensions of Dam Removals: The Wisconsin Experience," Environmental Management, Vol. 22, No. 3, pp 359-370.

[4] Trout Unlimited. "Small Dam Removal: A Review of Potential Economic Benefits." October, 2001.

[5] The Nature Conservancy, "An Economic Analysis of Improved Road-Stream Crossings." August, 2013.

[6] Massachusetts Division of Ecological Restoration. "The Economic Impacts of Ecological Restoration in Massachusetts." March 2012.

A handful of studies in other parts of the U.S. have contemplated the long-term benefits associated with dam removal or culvert replacement and upgrade projects. These studies have generally found that these projects are cost effective in the long run, as follows:

Dam Removal

- A 2001 study by Trout Unlimited reviewed costs of dam removals across the country and compared them with the estimated cost of rebuilding or repairing the structures. The authors found that, in most cases, the cost of removing a small dam is less than the cost of rebuilding or repairing it. The study additionally emphasized the long-term economic benefits expected from dam removals, including improved development potential for communities and enhanced conditions for recreation and tourism.[7]
- A study of dam removal projects in Wisconsin estimated that the costs to dam owners of repairing small dams averaged more than three times the cost of removing them. Furthermore, while reviews of the removal projects are mixed within communities, the restored free-flowing river landscapes have created opportunities for recreation in some communities.[8]

Culvert Removal and Upgrade

- A 2013 analysis by The Nature Conservancy focused on New York highlighted that the *initial* costs of removing outdated culvert infrastructure and replacing it with an improved, fish-friendly design may be greater than the initial costs of installing a traditional crossing. The study emphasized, however, that factoring in long-term maintenance and replacement costs of the traditional infrastructure can result in the improved design being the less costly of the two, particularly in light of increasing frequency of intense storms. The improved crossings additionally offer the added benefit of healthier aquatic ecosystems that support recreation and avoid flood-related costs to communities.[9]
- A 2014 study of road-stream crossing infrastructure in Vermont emphasized that relatively modest increases in cost for improved stream crossings yielded substantial societal and economic benefits. In particular, improved stream habitat connectivity and more effective flood resiliency.[10]

Similar to these existing studies, the purpose of our analysis is to improve understanding of the long-term socioeconomic implications of stream barrier removals in

[7] Trout Unlimited. "Small Dam Removal: A Review of Potential Economic Benefits." October, 2001.

[8] Born, Stephen M. et al, "Socioeconomic and Institutional Dimensions of Dam Removals: The Wisconsin Experience," Environmental Management, Vol. 22, No. 3, pp 359-370.

[9] The Nature Conservancy, "An Economic Analysis of Improved Road-Stream Crossings." August, 2013.

[10] Gillespie, Nathaniel et al., February 2014. Flood Effects on Road-Stream Crossing Infrastructure: Economic and Ecological Benefits of Stream Simulation Designs. Fisheries 39(2): 62-76.

Massachusetts.[11] Toward this end, we evaluate six recent stream barrier removal projects in the Commonwealth. To describe how these projects in Massachusetts have affected, and continue to influence, social and economic conditions in communities following their implementation, we evaluate two dimensions of the projects: 1) cost comparisons of implementing the ecological improvements (removing dams and upgrading culverts) versus continuing to repair and maintain existing structures; and 2) evaluating the long term changes in economic activity and the social character of the surrounding communities. This information will provide a strong foundation for DER to communicate the importance of these actions in terms of the ecological, economic, and social benefits they provide.

1.2 INTRODUCTION TO THE ISSUES

DAMS

As of 2011, there were 2,892 known dams in the Commonwealth, of which 1,547 were subject to state regulations. Out of these State-regulated dams, 627 are municipally owned, 676 are privately owned, and 244 are state owned.[12] Most of these are small dams, less than forty feet in height, that were constructed over a century ago to provide hydrokinetic power to textile mills and other light industries. As the textile industry in Massachusetts faded in the second half of the twentieth century and the mills closed, their associated dams no longer served their intended purposes. At this time, many, if not most, of the small dams in Massachusetts serve little purpose other than to maintain their existing impoundments.

Even though they are no longer operating, many of these dams present a threat to human safety. In 2011, the State Auditor's Division of Local Mandates identified 100 municipal dams that were in poor or unsafe structural condition, which presented significant or high hazards to adjacent communities, and were therefore labeled as "critical" for remediation or removal.[13] The State Auditor encouraged the Commonwealth to prioritize addressing issues at these dams, noting that "the goal should be to initiate at least 10 remediation projects per year, because even this ambitious schedule would span 10 years to completion."[14] The State Auditor's report estimated the total cost of removing the 100 critical dams at $60 million.

Thirty-seven of these "critical" dams are classified as "high hazard potential" structures, meaning that dam failure *is likely* to result in loss of life or substantial property damage.

[11] In this document, the term "culvert upgrade" refers to the replacement of a culvert with an improved, stream-friendly structure able to accommodate fish passage and storm water flows.

[12] Auditor of the Commonwealth Division of Local Mandates. "Local Financial Impact Review: Massachusetts Dam Safety Law." January 2011.

[13] Auditor of the Commonwealth Division of Local Mandates. "Local Financial Impact Review: Massachusetts Dam Safety Law." January 2011.

[14] Auditor of the Commonwealth Division of Local Mandates. "Local Financial Impact Review: Massachusetts Dam Safety Law." January 2011.

Sixty-three of these critical dams are designated as "significant hazard potential" structures, meaning that dam failure may result in loss of life or substantial property damage. Even without catastrophic failure, many small dams in Massachusetts have caused adverse economic and environmental impacts. Many dams routinely cause or exacerbate flooding during heavy precipitation events, as they obstruct storm water flows, causing water to back up behind the structure and inundate surrounding properties. In addition to flooding issues, dams fragment and modify aquatic habitat, often serving as barriers to fish passage. Dams also alter natural flow regimes, which produces adverse changes in sedimentation patterns and raises water temperatures. Fish kills in summer months in impounded areas are not uncommon. While people make some use of the altered conditions created by dams, some recreational activities are also directly inhibited by the presence of dams, such as river paddling, or indirectly inhibited, such as some fishing activities.

Despite the negative aspects of keeping a dam in place, many dam owners are hesitant to pursue dam removal. One of the primary hindrances to dam removal is that it requires a one-time financial investment, which must compete with all other demands for public funding or private investment. As stated in the Auditor's report, "one Massachusetts mayor commented that it is very difficult to gain public support to repair a substandard dam while it is still holding; more immediate interests win the competition for limited local revenues."[15] In addition, many communities are accustomed to the presence of dams, and have developed residences, parks, and commercial areas around them. Despite the fact that they typically share little, if any, personal responsibility for maintaining the dam, often the landowners of properties adjacent to impounded waters are vocal opponents of dam removals, fearing that dam removal will eliminate the pond that abuts their property and reduce property value. Some dams may provide recreational opportunities, such as boating or fishing in impounded areas upstream. In addition to recreational benefits, some dams and associated ponds are viewed as historic landmarks in communities.

As previously noted, existing studies find that dam removal is often a less expensive option than repair and continued maintenance of dams in poor condition.[16] This is particularly relevant for Massachusetts, as many dams in the Commonwealth are in poor condition and their owners are facing increased regulatory pressure to repair or remove the structures. Completed removal projects bring a number of long-term community benefits. In many cases, dam removal can provide financial savings to dam owners as they eliminate the need for future expenditures on dam operation, maintenance, and inspection. These costs can accumulate considerably over time, particularly for old dams in poor condition. Dam removals also effectively alleviate the environmental problems outlined above. The restoration of natural flow regimes improves and extends aquatic

[15] Auditor of the Commonwealth Division of Local Mandates. "Local Financial Impact Review: Massachusetts Dam Safety Law." January 2011.

[16] Born, Stephen M. et al, "Socioeconomic and Institutional Dimensions of Dam Removals: The Wisconsin Experience," Environmental Management, Vol. 22, No. 3, pp 359-370; Trout Unlimited. "Small Dam Removal: A Review of Potential Economic Benefits." October, 2001.

wildlife habitat, and can enhance water quality. These ecological improvements can directly benefit local communities by improving access to recreational activities, or even raising property values.[17]

CULVERTS

At least 20,000 road-stream crossings exist in the state of Massachusetts, as estimated by the Critical Linkages Project, managed by UMass Amherst. As a result of their abundant presence across the state, there is limited information regarding their quality and condition. However, the New England Road Stream Crossing Inventory Database provides some high-level information on nearly 5,000 surveyed crossings in Massachusetts. Of the surveyed crossings, 704 were deemed "significant barriers' to the movement of aquatic organisms, and 81 were evaluated as "severe barriers." Many culverts inhibit wildlife passage because they are perched above the streambed. Others are barriers because water depths within the culvert are too low for aquatic organisms to pass through.

Many of these shallow and perched road-stream crossings are also undersized. During heavy storm events, undersized culverts cannot pass the full flow of the river, causing water to back up behind the culvert and often flow over the road. These events gradually erode the culvert, stream bank, and road, and in severe cases can wash out the road entirely. Likely as a consequence, many culverts throughout the state are in poor condition. The New England Road Stream Crossing Inventory Database has identified nearly 900 culverts that are in a condition defined as "poor," "broken," "collapsing," "eroded," or "rusted through."[18]

In 2005, DER released the first edition of the Massachusetts Stream Crossings Handbook[19]. This document outlined many of the issues with traditional stream crossings, and provided standards to guide the construction of crossings that are both ecologically friendly and resilient to storm flows. Following the release of this handbook, the Massachusetts Department of Environmental Protection and the US Army Corps of Engineers required that all new crossings, and all replacement crossings where feasible, observe the standards presented in the handbook.

Replacing culverts to meet stream crossings guidelines may require engineering, design, and permitting that may not be required for an in-kind replacement. For this reason, culvert replacement to meet standards is perceived as being more expensive than replacement in-kind. In-kind replacement is generally faster, and often requires a shorter period of road closure and accompanying inconveniences to local communities. Additionally, many culverts are only replaced after they have been severely damaged by storm events. Such events can leave culverts and roads in a hazardous condition, causing

[17] Trout Unlimited. "Small Dam Removal: A Review of Potential Economic Benefits." October, 2001.

[18] University of Massachusetts Amherst, "New England Road Stream Crossing Inventory Database." Accessed December 15, 2014.

[19] Massachusetts Division of Ecological Restoration, "Massachusetts Stream Crossings Handbook: Second Edition." June 2012.

many communities to seek quick remediation. In many of these cases, it is likely perceived that there is no time to engineer an improved design.

Despite the challenges associated with upgrading undersized culverts, ecologically friendly designs can bring substantial long-term ecological benefits. One field study found that fish abundance and fish species diversity upstream of ecologically-friendly culverts was approximately twice that found upstream of undersized and impassable crossings. (Nislow et al., 2011).[20] Improved culvert designs have also demonstrated a higher tolerance for extreme flooding. A retrospective study in Vermont found that several recently improved culverts survived Tropical Storm Irene undamaged, whereas nearly 1,000 traditional culverts were destroyed or damaged by the storm (Gillespie et al., 2014).[21]

While the economic impacts of improved culvert design are less well-studied, a recent report from The Nature Conservancy details a number of economic benefits, including reduced expenditures on culvert repair and replacement, improved access to river-related recreation, and reduced damages to public and private property resulting from culvert failure. The Nature Conservancy identified one study in Maine which estimated that improved culverts would actually save the State money over a 50-year timeframe, based solely on expected reductions in repair and replacement costs.[22]

1.3 METHODS

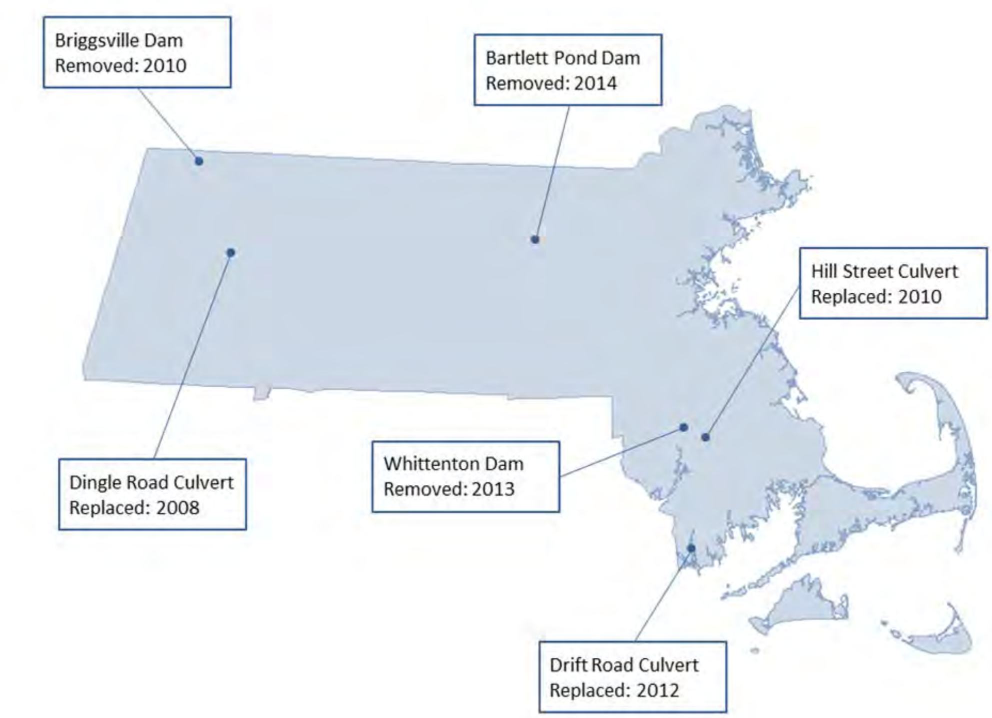
As stated above, we presents data from six recent stream barrier removal projects in Massachusetts to more fully assess the costs and benefits associated with these efforts. Three dam removal sites and three culvert replacement sites were selected as case studies for this analysis. These sites were selected based on availability of data, and diversity of site characteristics, including location, size, and type. As such, these projects are not representative of an “average” dam or culvert site in Massachusetts, but instead are intended to provide a view into the range of costs and benefits that may be associated with stream barrier removal projects, depending on particular site characteristics. Exhibit 1-1 provides an overview map of the selected sites.

[20] Nislow, Keith H., et al. "Variation in local abundance and species richness of stream fishes in relation to dispersal barriers: implications for management and conservation." *Freshwater Biology* 56.10 (2011): 2135-2144.

[21] Gillespie, Nathaniel, et al. "Flood Effects on Road–Stream Crossing Infrastructure: Economic and Ecological Benefits of Stream Simulation Designs." *Fisheries* 39.2 (2014): 62-76.

[22] Long, John. “The Economics of Culvert Replacement: Fish Passage in Eastern Maine.” Natural Resources Conservation Service, Maine. 2010.

EXHIBIT 1-1. SELECTED STREAM BARRIER SITES



For our six case studies, we created a financial and ecosystem service benefits comparison of scenarios with and without project implementation. These scenarios are the backbone of this analysis. To achieve this, we collected and reviewed available cost data for each site, developed engineering estimates of missing data, and conducted interviews with stakeholders familiar with the projects. The results are presented in two parts:

1.4 FINANCIAL COST ANALYSIS

- **Costs of Dam Removal**. Information on the costs of the stream barrier removal projects were drawn from invoices, certificates of payment, construction contracts, dam inspection reports, data tables from DER, and any other sources we could locate.
- **Out of Pocket Costs.** Information on the "out of pocket" costs of removal by dam owners and culvert owners were also collected from these sources.
- **Estimated Costs of Repair and Replacement "in kind."** Alternative estimates of what would have occurred if dams had been repaired or culverts had been replaced "in kind" rather than upgraded were also developed. At the dam sites, estimates of potential repair costs available from feasibility studies and dam inspection reports. The estimates of potential repair costs were not available at

culvert sites; these were estimated by Gomez and Sullivan Engineers based on site visit measurements and professional experience. For all sites, Gomez and Sullivan estimated annual and long-term costs of maintenance based on field measurements and interviews with stakeholders.

- **Comparison of Costs of Repair/Replacement Versus Removal/Upgrade**. The short and long-term financial costs of implementing these projects was then compared to the costs associated with not implementing the projects and maintaining facilities in place.

1.5 SOCIAL AND ECONOMIC BENEFITS ANALYSIS

- In addition to the financial expenditures necessary to implement or not implement these projects, additional categories of potential benefits were investigated, including avoided costs of flood damage and reduced flood risk, increased quality and/or quantity of recreational experiences, improved aesthetic conditions of the landscape, and increased value of commercial fisheries.
- To understand these other categories of potential project impacts, we conducted interviews with town officials, local planners, conservation group members, and any other stakeholders familiar with the projects. Interviews were conducted in-person during site visits and over the phone.
- We reviewed any available flooding records, ecological data, rainfall data, and traffic data.

The following sections detail the findings of our report. The report is organized by Dams (Section 2) and Culverts (Section 3). Each section details the site history, and then presents the costs analysis and the benefits analysis for each site.

SECTION 2. STUDY SITE DAMS: BRIGGSVILLE, BARTLETT, AND WHITTENTON

This section discusses the site histories, costs, and ecological benefits associated with the dams that are the focus of this study.

2.1 SITE HISTORIES

This section presents a short review of major events that lead to the removal of the dams that are the focus of this study.

BRIGGSVILLE DAM, CLARKSBURG

The Briggsville Dam was constructed in Clarksburg, Massachusetts in 1848. The dam was originally built to provide power to neighboring textile mills, though the last mill stopped operating around 1970. For many years, the impoundment behind the dam was used as a recreational pond. However, gradual sediment accumulation eventually inhibited fishing and swimming opportunities. By the time the dam was removed in 2010, sediment levels were so high that there was virtually no impoundment left; the river bed was at the elevation of the dam crest.

In 2006, Cascade School Supplies purchased a building adjacent to the dam. This purchase also granted Cascade ownership of the Briggsville Dam, though the company was unaware of this fact at the time.[23] Cascade only learned that it owned the dam when it received a letter from the Massachusetts Office of Dam Safety, which mandated a dam inspection. In response, Cascade commissioned an engineering report that ultimately revealed the dam to be a significant safety hazard. The Town Administrator at the time noted that the Town had known for years that the poor state of the site needed to be addressed.[24] The engineering report determined that the Briggsville Dam was in poor condition with “significant structural deficiencies.”[25] The report also classified the dam as a Significant Hazard Potential (Class II) dam, indicating that a dam failure event could result in loss of life.[26] As a consequence of these inspection results, the Office of Dam Safety required Cascade to either address the structural deficiencies or remove the dam entirely.

[23] Personal communication with Michael Canales, former Clarksburg Town Administrator, December 9, 2014.

[24] Personal communication with Michael Canales, former Clarksburg Town Administrator, December 9, 2014.

[25] Tighe & Bond, “Hewat Dam Phase I Inspection / Evaluation Report,” 2006.

[26] Tighe & Bond, “Hewat Dam Phase I Inspection / Evaluation Report,” 2006.

BARTLETT POND DAM, LANCASTER

The Bartlett Pond Dam was constructed on Wekepeke Brook in Lancaster in 1814 to provide power to an adjacent chair factory. The factory eventually burned down and was not reconstructed. The dam served no further purpose, and slowly began to fall into disrepair. Eventually, the Town of Lancaster assumed ownership of the dam and incorporated the pond into a conservation area. The conservation area was used for recreational fishing, picnicking, and ice skating.[27] The pond was stocked annually with brook trout, and those not caught would typically die off in the high heat of the summer behind the impoundment.

In recent years, the dam would obstruct water flow and frequently flood the conservation area during heavy precipitation events. Floodwaters would often cause damage to the parking lot and picnic tables, and force a local vendor to close his business for approximately five to seven days every year. During most of these flood events, water would also flow over Route 117 and force one driving lane to close.[28]

In 2008, the Office of Dam Safety issued a notice mandating the inspection of the Bartlett Pond Dam. The Town of Lancaster hired Pare Corporation to conduct this inspection. Pare Corporation found the Bartlett Pond Dam to be in poor condition and classified the structure as a Significant Hazard Potential (Class II) dam, meaning that dam failure could result in loss of life and considerable damage to property or infrastructure. The Route 117 bridge, only 80 feet downstream of the dam, was noted to be at particular risk of significant damage in the result of dam failure.[29]

Following this inspection report, the Office of Dam Safety issued a failure notice to the Town of Lancaster, mandating repair or removal of the dam. Town members were initially divided on the best course of action. Some town members had fond memories of time spent at the pond, and were hesitant to see a change. Others were afraid that removal would turn the conservation area into a "swamp," reducing its value as a recreation area. After multiple public forums, the community determined that dam removal was the best path forward.[30]

WHITTENTON MILL POND DAM, TAUNTON

The Whittenton Mill Pond Dam was constructed in Taunton, Massachusetts in1832 to power a textile mill. Following the mill's closure, the dam fell into disrepair. The dam's poor condition was apparent in 1968, when a large storm breached the structure and produced flooding in parts of downtown Taunton.[31] However, minimal improvements were made to the dam following that event.

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[27] Personal Communication with Tom Christopher, Lancaster Conservation Commission, and Mike Murphy, owner of Murph's Hot Dogs, on December 5, 2014.

[28] Written Communication with Tom Christopher, Lancaster Conservation Commission, on December 18, 2014

[29] Pare Corporation, "Bartlett Pond Dam Phase I Inspection / Evaluation Report," 2009.

[30] Personal Communication with Tom Christopher, Lancaster Conservation Commission, and Mike Murphy, owner of Murph's Hot Dogs, on December 5, 2014

[31] Personal Communication with Richard Ferreira, Director of Emergency Management for Taunton, on December 5, 2014.

Fears of a similar crisis arose in 2005, when heavy precipitation again threatened the integrity of the dam. The Taunton Emergency Management Department evacuated parts of downtown Taunton for a week in response to the threat of dam failure.[32] FEMA, NRCS, the Office of Dam Safety, and others conducted emergency repair operations during the crisis to remove the dam superstructure and shore up the remaining dam structure with riprap and cobbles. State and federal agencies made further efforts to pipe water out of the Whittenton impoundment to alleviate pressure on the dam. While these actions prevented dam failure, the crisis came at a large cost to the government and local business community. This event received national media attention with coverage by Time Magazine, CNN, Fox, and other major news organizations. This event put the situation with outdated and hazardous dams in the spotlight in Massachusetts, and spurred a broad regulatory effort to assess the condition of dams within the state.[33]

After the emergency repairs, the dam owner decided to remove the dam in order to reduce liability and avoid the cost of rebuilding the dam. In 2008, the DER and the Southeastern Regional Planning and Economic Development District hired Inter-Fluve, Inc. to conduct a feasibility study that assessed the costs of dam removal and dam repair. Dam removal was eventually completed in 2013.

2.2 COSTS OF DAM REMOVAL

All three study dams were in poor condition and presented safety hazards that were in violation of State dam safety regulations. State law requires that dams be repaired or removed to meet dam safety standards. Because the three dams were in poor condition, the dam owners faced an immediate decision to repair or remove the dam; the "No Action" alternative was not a feasible alternative at these sites.

This section presents information we collected for each of the study sites of the accrued costs of dam removal at each site. Specifically, we obtained information on the cost of dam removal at each site from a variety of sources, including construction contracts, certificates of payment, and cost tables received directly from DER. For purposes of comparison, we then adjust all costs to 2014 dollars and calculate present values of the costs assuming a three percent discount rate. We assume that, because all dam elements were removed as part of these efforts, no future costs of facility maintenance will occur at these sites over the next 30 years. Exhibits 2-1 through 2-3 present the reported costs of dam removal for our study sites. As shown, removal costs varied from $440,000 at Whittenton Mill Pond Dam to $920,000 at Briggsville Dam.

[32] Personal Communication with Richard Ferreira, Director of Emergency Management for Taunton, on December 5, 2014.

[33] Personal Communication with Richard Ferreira, Director of Emergency Management for Taunton, on December 5, 2014

EXHIBIT 2-1. COSTS OF REMOVAL OF BRIGGSVILLE DAM (30 YEARS)

COST CATEGORY	DESCRIPTION	COSTS (AS QUOTED)	COSTS (PRESENT VALUES)[1]
Engineering	Engineering / Design	$170,000	$210,000
	Engineering Oversight	$46,000	$57,000
	Subtotal	*$220,000*	$270,000
Construction	Implementation	$250,000	$310,000
	Sediment disposal	$110,000	$140,000
	Planting / landscaping	$20,000	$24,000
	Construction materials	$110,000	$130,000
	Planting / landscaping material	$13,000	$16,000
	Subtotal	*$500,000*	$620,000
Permitting	DER Project management / permitting	$22,000	$28,000
	Subtotal	*$22,000*	$28,000
Total[2]		**$740,000**	$920,000

Sources: Costs data provided by DER.

Notes:

1. "As Quoted" costs at each site reflect different dollar years. For comparison purposes, we adjusted all quoted costs to 2014 dollars using the Engineering News-Record Construction Cost Index, and estimated present values of these costs using a 3% discount rate.
2. Estimates are rounded to two significant digits and may therefore not sum to the totals presented.

EXHIBIT 2-2. COSTS OF REMOVAL OF BARTLETT POND DAM (30 YEARS)

COST CATEGORY	DESCRIPTION	COSTS (PRESENT VALUES)
Engineering	Site Recon / Feasibility Report	$3,000
	Phase 2 Inspection / Preliminary Design	$30,000
	Design, Bidding	$79,000
	Subtotal	$110,000
Construction	Construction (Dam Removal and Park Work)	$180,000
	Construction Oversight	$28,000
	Subtotal	$210,000
Permitting	DER in-kind permitting and technical assistance	$10,000
	Subtotal	$10,000
Total[1]		$320,000

Source: Data received directly from DER.

Notes:

1. Estimates are rounded to two significant digits and may therefore not sum to the totals presented.

EXHIBIT 2-3. COSTS OF REMOVAL OF WHITTENTON MILL POND DAM (30 YEARS)

COST CATEGORY	DESCRIPTION	COSTS (AS QUOTED)	COSTS (PRESENT VALUES)[1]
Engineering	Design and Permitting	$100,000	$110,000
	Subtotal	$100,000	$110,000
Construction	Mobilization & Demobilization	$14,000	$15,000
	Erosion and Pollution Control	$11,000	$12,000
	Structure Demolition	$55,000	$58,000
	Earthwork	$80,000	$85,000
	FES-Salvaged Fill	$16,000	$17,000
	Streambed Restoration	$100,000	$110,000
	Construction Oversight	$40,000	$42,000
	Subtotal	$320,000	$330,000
Total[2]		**$420,000**	**$440,000**

Sources: SumCo Eco Contracting, LLC, "Task Order Number 1 Between American Rivers and SumCo Eco-Contracting, LLC," June 2013.

Notes:

1. "As Quoted" costs at each site reflect different dollar years. For comparison purposes, we adjusted all quoted costs to 2014 dollars using the Engineering News-Record Construction Cost Index, and estimated present values of these costs using a 3% discount rate.
2. Estimates are rounded to two significant digits and may therefore not sum to the totals presented.

2.3 "OUT-OF-POCKET" COSTS TO DAM OWNERS

As discussed above, one hindrance to community acceptance of dam removal proposals is the up-front costs of these projects. Due to the ecological health and human safety benefits of these projects, however, multiple public and private programs exist that may provide funding or technical support. Such support is less likely available to dam owners to offset dam repair and maintenance costs. At all three of our study sites, the dam owners/managers were able to leverage considerable outside funding and technical support, in particular from DER, for their removal projects. While the ecological, social, and economic benefits of these projects are realized regardless of the source of funding, the financial and technical resources made available for these projects allows communities to receive these benefits for a lesser cost to the municipalities and private dam owners.

Exhibit 2-4 displays the estimated breakdown of funding sources for each dam removal project. As shown, the amount of leveraged funds ranged from 18 to 99.5 percent of the removal costs:

- At the Briggsville Dam, Cascade School Supplies received funding support from a number of government agencies and conservation groups, including:
    - the USDA Natural Resource Conservation Service;
    - the Massachusetts Division of Ecological Restoration;
    - the U.S. Fish and Wildlife Service;
    - American Rivers; and
    - Trout Unlimited.

  As a result of this funding, Cascade needed to contribute approximately three percent of dam removal costs.[34]
- For the Bartlett Pond Dam removal project, the Town of Lancaster received nearly $60,000 in grants and in-kind technical assistance from DER. The town also received $145,000 in low-interest loans from the Dam and Seawall Repair and Removal Fund. As a result, the town contributed $120,000 of its available funds up front.
- The Whittenton Mill Pond Dam removal project was funded by a broad suite of conservation partners. While we were not able to trace an exact breakdown of funding sources for this project, it appears that the dam owner did contribute any funds to the removal effort.

In contrast to the above, it appears likely that dam owners and municipalities would have been responsible for most, if not all, of costs to repair the dams at these sites.

[34] This number may even be an overestimate, as Pete Cote, president of Cascade School Supplies believes his company paid less than $100,000.

EXHIBIT 2-4. SUMMARY OF DAM REMOVAL COSTS BY FUNDING SOURCE

SITE	REMOVAL COSTS PAID BY DAM OWNER (PERCENT)	REMOVAL FUNDING CONTRUBUTED BY OTHER SOURCES (PERCENT)
BRIGGSVILLE DAM (PRIVATE)	$31,000 (3%)	USDA NRCS: $440,000 (47%) Other Conservation Partners: $320,000 (35%) Other Sources: $130,000 (14%)
BARTLETT POND DAM (MUNICIPAL)	$270,000 (82%)[1]	DER: $60,000 (18%)
WHITTENTON MILL POND DAM (PRIVATE)	$11,000 (in-kind contribution)	NOAA, American Rivers, The Nature Conservancy, Coastal America Foundation: $440,000 (99.5%)

Notes: For comparison purposes, we adjusted all quoted costs to 2014 dollars using the Engineering News-Record Construction Cost Index, and estimated present values of these costs using a 3% discount rate.

[1] The Town of Lancaster also received a $150,000 low interest loan from the Dam and Seawall Repair or Removal Fund. This funded 45 percent of total project costs.

2.4 AN ALTERNATIVE SCENARIO: ESTIMATED COSTS OF DAM REPAIR

While our study focused on sites where dams were removed, we wanted to understand what the costs *would have* been, had the dams been repaired instead of removed. For each site, estimates had been developed as part of feasibility studies and dam inspection reports of the costs of dam repair at each dam site. Consistent with the dam removal costs, we then adjusted these estimates to 2014 dollars and estimated present values assuming a three percent discount rate. In addition to these costs, the decision to keep a dam in place necessitates a number of recurring costs associated with ongoing maintenance as well as periodic safety inspections. Because estimates of expected recurring costs were not available at our study sites, Gomez and Sullivan Engineers developed estimates of these costs. Recurring costs at these sites are expected have included the following:

- **Annual routine maintenance procedures**. such as removing vegetation, clearing debris, and repairing the concrete structure and embankment. Gomez and Sullivan Engineers estimate that these procedures would have cost between $8,000 and $11,000 per year.
- **Periodic maintenance activities**. Every 15 years, long-term maintenance activities such as replacing trash racks and low-level gates, replacing stoplogs used to control flow through the sluiceway.
- **Safety inspections**. Gomez and Sullivan estimate that each inspection would cost approximately $5,000, which is consistent with State Auditor's report estimate of

the average cost of an inspection.[35] These would be required every two to five years.[36]

Emergency Action Plan (EAP). Because Whittenton Dam was classified as a high hazard structure, the dam owner would have been required to develop an EAP. The State Auditor's report estimates that EAPs cost approximately $11,000 to produce.[37] In 2012, Chapter 21 of the Massachusetts General Laws was amended to additionally require EAPs for significant hazard dams (see Section 65). While Bartlett and Briggsville Dams were classified as significant hazards, our counterfactual scenario in this analysis assumes these dams are replaced and maintained over time to avoid a significant hazard designation. Thus costs of an EAP are not included in our analysis. To the extent that these sites would be required to develop in EAP in the counterfactual repair scenario, we underestimate total costs.

Exhibits 2-5 through 2-7 summarize the estimated costs associated with the dam sites over the next 30 years, under a scenario where the dam is maintained and repaired, rather than removed.

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[35] Auditor of the Commonwealth Division of Local Mandates. Local Financial Impact Review: Massachusetts Dam Safety Law. 2011.

[36] Inspections are assumed to be required every five years at the Briggsville Dam and the Bartlett Pond Dam, as they are classified as significant hazard potential dams. Inspections would be required every two years at the Whittenton Dam, as it is classified as a high hazard potential dam.

[37] Auditor of the Commonwealth Division of Local Mandates. Local Financial Impact Review: Massachusetts Dam Safety Law. 2011.

EXHIBIT 2-5. ESTIMATED COSTS OF REPAIR SCENARIO AT BRIGGSVILLE DAM (30 YEARS)

COST CATEGORY	ASSUMPTION	COSTS (PRESENT VALUES)[1]
Estimated Repair Costs	One-time	$910,000
Maintenance Costs	Annual	$11,000
Long-term maintenance[2]	Every 15 years	$8,000
Inspection	Every 5 years	$5,000
Total Costs of Repair Scenario	-	$1,200,000

Sources:

1. Tighe & Bond, "Hewat Dam Phase I Inspection / Evaluation Report," October 2006.
2. Gomez and Sullivan Engineering Estimates
3. Auditor of the Commonwealth Division of Local Mandates. "Local Financial Impact Review: Massachusetts Dam Safety Law." January 2011.

Notes:

1. For comparison purposes, we adjusted all costs to 2014 dollars using the Engineering News-Record Construction Cost Index, and estimated present values of these costs using a 3% discount rate.
2. Gomez and Sullivan predict that Cascade would need to replace the dam's steel trash rack and low-level wooden gate every fifteen years.
3. Estimates are rounded to two significant digits and may therefore not sum to the totals presented.

EXHIBIT 2-6. ESTIMATED COSTS OF REPAIR SCENARIO AT BARTLETT POND DAM (30 YEARS)

COST CATEGORY	ASSUMPTION	COSTS (PRESENT VALUES)[1]
Estimated Repair Costs[2]	One-time	$660,000
Maintenance Costs	Annual	$11,000
Long-term maintenance[3]	Every 15 years	$1,000
Inspection	Every 5 years	$5,000
Total Costs of Repair Scenario	-	$880,000

Sources:

1. Pare Corporation, "Bartlett Pond Dam Phase II Inspection / Evaluation Report," January 2011.
2. Gomez and Sullivan Engineering Estimates
3. Auditor of the Commonwealth Division of Local Mandates. "Local Financial Impact Review: Massachusetts Dam Safety Law." January 2011.

Notes:

1. For comparison purposes, we adjusted all costs to 2014 dollars using the Engineering News-Record Construction Cost Index, and estimated present values of these costs using a 3% discount rate.
2. Estimated repair cost was taken as the average of a low and high estimate.
3. Gomez and Sullivan estimate that the Town of Lancaster would need to replace the wooden stoplogs used to control flow through the sluiceway every fifteen years.
4. Estimates are rounded to two significant digits and may therefore not sum to the totals presented.

EXHIBIT 2-7. ESTIMATED COSTS OF REPAIR SCENARIO AT WHITTENTON DAM (30 YEARS)

COST CATEGORY	ASSUMPTION	COSTS (PRESENT VALUES)[1]
Estimated Repair Costs	One-time	$1,900,000
Maintenance Costs	Annual	$11,000
Long-term maintenance[2]	Every 15 years	$5,000
Inspection	Every 2 years	$5,000
Emergency Action Plan	One-time	$11,000
Total Costs of Repair Scenario	-	$2,200,000

Sources: Gomez and Sullivan Engineering; Auditor of the Commonwealth Division of Local Mandates. "Local Financial Impact Review: Massachusetts Dam Safety Law." January 2011.

Notes:

1. For comparison purposes, we adjusted all costs to 2014 dollars using the Engineering News-Record Construction Cost Index, and estimated present values of these costs using a 3% discount rate.
2. Gomez and Sullivan estimate that the owner would need to replace wooden gates along the wooden walkway structure every fifteen years.
3. Estimates are rounded to two significant digits and may therefore not sum to the totals presented.

2.5 COMPARISON COSTS OF REPAIR VERSUS COSTS OF REMOVAL

Our findings with regards to the costs of dam removal versus dam repair at our study sites are as follows:

1. When the expected future costs associated with owning a dam are considered alongside the initial repair costs, dam removal appear to be considerably less expensive than repair at all of our sites. The total present value of the repair option is nearly twice as large as the actual cost of removal at Bartlett Pond Dam, and nearly four times as large as the actual cost of removal at Whittenton Mill Pond Dam. Even at Briggsville Dam, the total present value of the repair option is nearly $250,000 more than the cost of dam removal.

2. Most of the other funding sources for dam removal projects were non-profit agencies that would be unlikely to provide funds for repair projects. Assuming that owners and municipalities would be responsible for dam repair costs, one can compare the out-of-pocket costs of dam removals to the potential repair costs. Using this method, dam owners would expect to have paid between 70 and 99.5 percent less out of pocket with the dam removal projects than they likely would have had to for the repair costs. These savings ranged from $610,000 to over $2 million dollars over the life of these projects.

3. The financial savings from dam removal had positive impacts for the dam owners and surrounding communities. These avoided costs are large enough to have real consequences for the community. For example, if the town of Lancaster had chosen to repair Bartlett dam, the extra $610,000 would need to be financed through either an increase in taxes or a reduction in public service provision. As a result, the choice of removal over repair avoided the potential for considerable economic burden in the community.

   The other two dam sites were privately owned, so financial savings would likely not have been as broad based. However, in the case of the Briggsville dam, the repair option was so much more expensive than removal that it would likely have forced Cascade School Supplies to go out of business. In this manner, the choice of removal not only saved the firm money, but it preserved jobs and economic activity in the local community.

4. Even without taking recurring maintenance costs into account, all of our sites found that dam removal costs were approximately equal to or lower than repair cost estimates. At both Bartlett Pond Dam and Whittenton Mill Pond Dams, the actual removal cost was significantly lower than the estimated initial repair costs (49 percent and 82 percent, respectively).[38]

[38] At Briggsville Dam, the actual removal cost was essentially equal to the estimated initial repair cost. However, the estimated repair cost did not take into account any expenditure on permitting, and assigned only $38,000 for engineering services. The repair estimates for Bartlett Pond Dam and Whittenton Dam, in contrast, include $110,000 to $165,000 in engineering costs. As a result, it seems possible that the Briggsville Dam repair estimate is understating the true cost of engineering services involved in the repair.

The costs of removal and estimated costs of repair at each site are summarized in Exhibit 2-8.

EXHIBIT 2-8. SUMMARY COMPARISON OF FINANCIAL COSTS OF REMOVAL VERSUS REPAIR AT DAM SITES OVER 30 YEARS (2014 DOLLARS)

SITE	TOTAL COSTS OF DAM REMOVAL (ACTUAL)	OUT-OF-POCKET COSTS TO DAM OWNER (ACTUAL)	ESTIMATED TOTAL COSTS OF REPAIR SCENARIO (30 YEAR PRESENT VALUES)	SAVINGS TO DAM OWNER OF DAM REMOVAL PROJECT (30 YEAR PRESENT VALUES)	PERCENT SAVINGS
BRIGGSVILLE DAM	$920,000	$31,000	$1,200,000	$1,200,000	97 percent
BARTLETT POND DAM	$320,000	$270,000	$880,000	$610,000	70 percent
WHITTENTON MILL POND DAM	$440,000	$11,000	$2,200,000	$2,200,000	99.5 percent

Notes:

1. Expected future costs include regular maintenance, periodic inspections, and occasional replacement of aging dam components. These expected future payments are assumed to occur in all years when no other major work is conducted over a 30-year period.
2. For comparison purposes, we adjusted all quoted costs to 2014 dollars using the Engineering News-Record Construction Cost Index, and estimated present values of these costs using a 3% discount rate.
3. Estimates are rounded to two significant digits and may therefore not sum to the totals presented.

Caveats:

- Because the dam removals were implemented, constructing the counterfactual scenario where dams were repaired, and subsequently required maintenance, required assumptions, as discussed above.
  - **Estimates of repair**. We note that in some cases, the *estimated* dam removal costs were higher than the *actual* costs of removal. To the extent that estimated initial repair costs were similarly overestimated, our use of estimated repair costs could be overstated. However, because repairs at these sites were not implemented, they are uncertain.
  - **Estimates of recurring costs**. As stated above, because maintenance estimates where not developed previously, Gomez and Sullivan estimated these. These estimates were developed as a rough cut, and performed after removal of the initial structures. Again, because repairs at these sites were not implemented, it is not possible to understand what actual recurring costs would have been with certainty.

2.6 SOCIAL AND ECONOMIC BENEFITS OF DAM REMOVAL

As noted above, multiple reasons exist for removing obsolete and failing dam infrastructure. Due to a series of dam failures in the 2000s, the 2011 State Auditor's review and the current call to action to evaluate the status of dams across the Commonwealth focus in particular on safety concerns. Where safety is an issue, benefits to the communities of dam removals are apparent. In such instances, key benefits include reduced risk of loss of life and infrastructure damage associated with flooding.

These benefits of reduced flood risk may be measured in terms of:

1. **Avoided costs of flood events:** These may include avoided costs of infrastructure damages, avoided commuting delays on area roads, and avoided morbidity and mortality from catastrophic events. Flood events in developed areas may also result in a temporary reduction in regional economic activity, as businesses may be forced to close until waters recede and infrastructure is repaired.

2. **People's willingness-to-pay for the reduced risk:** Absent primary research to elicit information on a given population's preference for a particular reduction in flood risk (e.g., through a "stated preference" survey), people's willingness-to-pay may be observed indirectly, for instance, through increased property values. That is, all else equal, people may be more willing to purchase a home or develop a business in an area less at risk of flood damage. Similarly, people are likely willing to pay more for a property that does not include a liability such as a hazardous dam (i.e., property value benefit of reduced liability for private dam owners).

Beyond improving public safety, dam removal initiatives may concentrate on broader ecological health objectives, such as habitat connectivity for fish and wildlife species, healthy functioning wetland habitat, and improved water quality. Such ecological improvements also benefit the underlying social and economic conditions in neighboring communities by promoting valuable ecosystem services.

Ecosystem service benefits of improved habitat and ecological health of river systems include:

1. **Increased quantity or quality of recreational experiences:** Increased habitat connectivity and access to fish spawning areas may benefit recreational fishing and wildlife-viewing activities. Recreational benefits may also accrue up the food chain due to improved habitat conditions for recreationally valuable terrestrial species that rely on the fish and other riverine species as a food source.

2. **Improved aesthetic conditions of the landscape:** At some sites, improved water quality (e.g., increased clarity) and the visual appeal of a free-flowing river landscape may improve aesthetic conditions thereby increasing property values or attracting visitors that stimulate regional economies (e.g., promoting business expansion through trip-related expenditures).

3. **Increased value of commercial fisheries:** Where dam removals open up habitat for commercially valuable wildlife species, the projects may support or increase commercial catch rates. Commercial fishing benefits may also accrue where projects benefit populations of prey species. For example, herring are prey for the commercially valuable cod fishery in Massachusetts. Increased commercial fishing activity may, in turn, have broader regional economic benefits by increasing demand for the goods and services that support fishing operations.

In these ways, the direct benefits of reduced flood risk, together with the ecosystem service benefits of improved ecological health, foster ecologically and economically resilient communities. Exhibit 2-9 highlights the categories of social and economic benefits relevant to our dam removal case studies. The following sections then describe more specifically the nature and potential magnitude of the social and economic benefits of the three projects.

EXHIBIT 2-9. SOCIAL AND ECONOMIC BENEFITS OF THREE DAM REMOVAL PROJECTS

	BENEFITS OF REDUCED FLOOD RISK			BENEFITS OF IMPROVED ECOLOGICAL HEALTH		
CASE STUDY SITE	AVOIDED DAMAGES TO BUILDINGS OR INFRA-STRUCTURE	AVOIDED TRAVEL DELAYS	PROPERTY VALUE MAINTENANCE OR IMPROVEMENT	RECREATION BENEFITS	AESTHETIC BENEFITS	COMMERCIAL FISHING BENFITS
Briggsville	★	☆	★	★	☆	
Bartlett	★	☆	☆	★		
Whittenton	★	★	★	☆		☆

★: The project is likely to have generated this type of benefit.
☆: The project may have generated this type of benefit.

Of note, each of these categories of ecosystem service benefits has the potential to increase regional economic activity (i.e., income and employment). Also, to the extent that the avoided flood risk reduces interruptions in business activity, and/or ecological improvements generate increased visitation to the region, additional spending in area businesses may result. This increased spending has a “ripple effect” in the regional economy, increasing demand for productivity and employment in related economic sectors (also referred to as a “multiplier effect”).

BRIGGSVILLE DAM REMOVAL

A 2011 study by Industrial Economics, Inc. for DER found that the implementation phase of the Briggsville Dam removal project supported 10.5 jobs and $1.5 million in economic output (2009 dollars).[39] This analysis considers the longer term benefits of the project following its completion. The project most immediately benefitted the dam owner. As the dam had not been used for its original purpose as a power source in decades, it primarily presented a substantial nuisance to the owner, causing low levels of flooding in Cascade's building adjacent to the project and in other neighboring buildings during heavy rain events (approximately once every two years).[40] In addition, the removal allowed for the preservation of local jobs, and avoided other infrastructure damages, provided property value benefits, increased recreational fishing, avoided travel delays, and improved aesthetics.

KEY SOCIAL AND ECONOMIC BENEFITS OF BRIGGSVILLE DAM REMOVAL

- $ Avoided flooding of multiple businesses adjacent to dam and downstream residences along one street.
- $ Potential for increased property values due to reduced flood risk.
- $ Potential for increased regional economic activity due to increased opportunity for recreational activities and improved aesthetic appeal.
- Preservation of 150 jobs in the community.
- Improved habitat conditions for brook trout and better access to stream for recreational fishing.

➔ Preservation of Local Jobs

The current President of Cascade noted that, if the company had instead been forced to repair and continually maintain the dam, it would not have been able to leverage the support and funding of public agencies and non-governmental organizations (NGOs), and the cost would have put them out of business. The removal project was therefore instrumental in allowing Cascade to continue operations in Clarksburg, thereby preserving 150 jobs in the community.[41]

➔ Avoided Infrastructure Damages

Since the dam was removed in 2011, the Cascade building and neighboring buildings have not experienced any flooding, even during the unusually heavy rains of Hurricane Irene (determined to reflect a 100-year flood event for this area) later that same year.[42] The dam had also contributed to flooding issues downstream of the structure in 2005 (a flood event comparable to Hurricane Irene), resulting in the need for emergency evacuation of residents of Carson Avenue, a dead end street with approximately ten houses and one multifamily condominium complex. The Town temporarily (for a matter of hours) relocated residents to a nearby senior center for shelter until the flood waters subsided.

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39 "Economic Impacts of Massachusetts Ecological Restoration Projects". Final briefing presentation to the Massachusetts Department of Fish and Game, Division of Ecological Restoration. Industrial Economics, Inc. June 30, 2011

40 Written communication from Peter Cote, President, Cascade School Supplies, Inc., December 18, 2014.

41 Personal communication with Peter Cote, President, Cascade School Supplies, Inc., December 9, 2014.

42 Ibid.

Ultimately, there was limited flood damage to these homes--anecdotal information suggested that some garages took on water. However, the risk of future flooding from particularly heavy rains was real.[43] In fact, one resident is cited as saying that Hurricane Irene resulted in water within six feet (laterally) from his garages on Carson Avenue and that, had the dam been in place at that time, he "... might have lost everything."[44]

The dam removal project included installing proper stormwater drainage, resulting in a reduced risk of flooding for the Carson Avenue residents and avoided cost of emergency response for the town. While estimates of damages from past flooding events are not available to determine the value of these avoided costs (no damage claims were filed or costs documented), at the very least the project removed a nuisance for the building owners and occupants, the nearby residents of Carson Avenue, and the Town of Clarksburg.

While a formal floodplain revision has not been developed following the dam removal, the anecdotal evidence described above supports the finding of reduced flood risk. In addition, a localized flood plain map for the area of the Hoosic River adjacent to Cascade identifies a reduction in the 100-year flood zone (Exhibit 2-10).

EXHIBIT 2-10. HOOSIC RIVER 100-YEAR FLOODPLAIN PRE- AND POST-DAM REMOVAL

Sources:
1. Milone & MacBroom, "Briggsville As-Built: Limits of 100-Year Floodplain," 9/20/2012
2. Map image: Google Earth, 5/10/2014.

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43 Personal communication with Michael Canales, former Clarksburg Town Administrator, December 9, 2014.

44 As quoted in: Murphy, David, P.E., CFM. "Briggsville Dam Removal Flood Mitigation Assessment. October 4, 2012.

➔ Property Value Benefits

There are multiple ways in which the dam removal project may have improved property values in areas near the site. First, the property value of the Cascade parcel, which included the dam itself, is likely significantly improved. Once Cascade realized it owned the dam, it realized that it would not be able to pay to repair and maintain it. The Clarksburg Town Administrator indicated that, if Cascade had to leave due to the potential expense, it would not have been possible to attract buyers for the same reasons.[45] That is, the dam presented a significant liability cost that likely reduced the value of the Cascade property. In theory, the property value effect of a liability such as a dam would reflect the present value of all future costs that would be required in order to remove the liability or mitigate for its potential damages.

MULTIPLE STUDIES FIND THAT MARKET VALUES OF HOMES WITHIN A FLOODPLAIN ARE ON AVERAGE 4% LESS THAN EQUIVALENT HOMES OUTSIDE OF A FLOODPLAIN.

Second, in addition to the direct owner of the dam, economic studies have repeatedly determined that the risk of a property flooding is inversely related to market value of that property. That is, all else equal, a property within a floodplain is likely to have a lower value than a comparable property outside of a floodplain. For example, Bin and Polasky (2004) estimated that market value of homes within a 100-year floodplain were on average 5.7 percent less than market values of homes outside of the floodplain. The authors also found this effect was less marked before a flood event (3.8 percent) and greater (up to 8.3 percent) following a flood event, suggesting recent experience with flooding raises the public's perception about flood risk.[46] Other recent studies identified similar property value effects of location in a floodplain of around four percent.[47]

Even where it is uncertain whether a property falls within a floodplain, or whether a given dam removal results in a property being removed from a floodplain, information regarding recent flooding of a property may have a similar negative effect on property value. Studies indicate that recent flood events or disclosure of recent flooding can increase awareness of flood risk and negatively affect property values.[48] In fact, immediately following a major flood event, property value differentials inside and outside of a flood plain can rise substantially (to between 25 percent and 44 percent) as the flood

[45] Personal communication with Michael Canales, former Clarksburg Town Administrator, December 9, 2014.

[46] Bin, Okmyung and Stephen Polasky. November 2004. Effects of Flood Hazards on Property Values: Evidence Before and After Hurricane Floyd. *Land Economics* 84(4): 490-500.

[47] See, for example: Pope, Jaren C. November 2008. Do Seller Disclosures Effect Property Values? Buyer Information and the Hedonic Model. *Land Economics* 84(4):551-572; and Speyer, Janet Furman and Wade R. Ragas. 1991. Housing Prices and Flood Risk: An Examination Using Spline Regression. *Journal of Real Estate Finance and Economics* 4:395-407.

[48] Pope, Jaren C. November 2008. Do Seller Disclosures Effect Property Values? Buyer Information and the Hedonic Model. *Land Economics* 84(4):551-572

event serves as updated risk information. This greater effect is, however, likely short term (four to nine years according to one study).[49]

The third way in which property values may be increased is due to the change in the landscape to a free-flowing river. One common concern of homeowners of properties adjacent to small dam impoundments is that the removal will negatively affect the values of their homes. On the contrary, recent research in Wisconsin indicates that there is no significant difference in values of shorefront properties on small dam impoundments versus properties on free-flowing rivers (all else equal). Furthermore, for homes within the vicinity of (but not directly on) shorefronts, homes near free-flowing rivers were valued greater than homes near small dam impoundments.[50]

For each of these reasons, the Briggsville dam removal most likely had at least a short term benefit on nearby property values.

➔ **Increased Recreational Fishing**

The Briggsville dam obstructed passage for recreationally valuable fish species in the Hoosic River, in particular fragmenting habitat for Eastern brook trout. A primary concern with respect to the effects of dams on fish populations is passage; however, poorly maintained dams like Briggsville can additionally increase water temperatures (e.g., due to still, stagnant water behind the dam), reduce dissolved oxygen, and concentrate pollutants in a stream, increasing the negative effect on fish.[51] While specific fish counts pre- and post-project are not available, it is likely that, in the long run, the improved habitat conditions and increased connectivity will benefit local brook trout populations.

In addition to the enhanced habitat conditions, the removal project improved access for anglers. Prior to the dam removal, it was difficult to fish both sides of the dam. Anecdotal information suggests that the dam removal resulted in an increase in recreational fishing activity due to the improved access.[52]

The specific increase in recreational fishing activity attributable to the dam removal, and therefore the associated economic value of that activity, are uncertain. Numerous economic impact studies, however, find that in addition to benefitting the individual anglers, recreational fishing activity stimulates regional economies due to anglers' spending on trip-related goods and services.

A 2011 U.S. Fish and Wildlife Service survey found that roughly one third of all freshwater anglers in Massachusetts are targeting trout species. The survey estimated that 294,000 freshwater anglers spent $106 million for fishing trips statewide in 2011,

[49] Ajita, Atreya, Susana Ferreira, and Warren Kriesel. November 2013. Forgetting the Flood? An Analysis of the Flood Risk Discount over Time. *Land Economics* 89(4):577-596.

[50] Provencher, Bill, Helen Sarakinos, and Tanya Meyer. April 2008. Does Small Dam Removal Affect Local Property Values? An Empirical Analysis. Contemporary Economic Policy 26(2):187-197.

[51] Trout Unlimited. "Small Dam Removal: A Review of Potential Economic Benefits." October 2001. Page 3.

[52] Personal communication with Peter Cote, President, Cascade School Supplies, Inc., December 9, 2014.

approximately $360 per angler. Assuming this average applies to the 68,000 freshwater anglers that fish specifically in rivers and streams, river and stream fishing generated approximately $24.5 million in spending in Massachusetts communities in 2011. Trip-related expenditures include food and lodging, transportation, equipment, and "other" trip costs.[53]

The 2011 survey underscores that recreational fishing activity provides economic opportunities to communities. The increased fishing activity in the Hoosic River accordingly can only benefit the local economy, both through direct spending by anglers at regional establishments and indirectly through the multiplier effects on related businesses.

➔ **Avoided Travel Delays**

It is possible that the dam removal also avoided future flooding of road infrastructure. According to observers, the 2005 flood waters were just starting to inundate nearby Route 8. In contrast, following the dam removal, Hurricane Irene flood waters washed out bank repairs along the Route 8 though no road closures were reported.[54] Here again, had the dam been in place during Hurricane Irene, road closures and repairs would may have been a greater risk.

➔ **Aesthetic Benefit**

Due to the lack of maintenance at the dam site, it was increasingly becoming an eye sore on the landscape. The owner of Cascade noted that employees have commented on improved aesthetics of the river near the building.[55] Increased aesthetic appeal of the site may further attract recreators or visitors (e.g., paddlers and anglers) to the area, bolstering the regional economy.

BARTLETT POND DAM REMOVAL

While the dam was only recently removed in 2014, it is notable that a recent heavy rain event of up to four inches did not result in flooding.[56] Although some recreational opportunities were lost at the site (e.g., ice skating), overall the social and economic

KEY SOCIAL AND ECONOMIC BENEFITS OF BARTLETT POND DAM REMOVAL

- $ Avoided costs of repeatedly repairing park infrastructure, including the parking lot.
- $ Avoided travel delays that potentially affected thousands of travelers multiple times per year.
- Created 18 miles of stream habitat for brook trout and other wildlife species, likely benefitting recreational angling at the regional level.
- Potential recreational benefits, including avoided closures of the town conservation area.

[53] U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.

[54] Murphy, David, P.E., CFM. "Briggsville Dam Removal Flood Mitigation Assessment. October 4, 2012.

[55] Personal communication with Peter Cote, President, Cascade School Supplies, Inc., December 9, 2014.

[56] Written communication with Tom Christopher, Lancaster Conservation Commission, on December 18, 2014.

benefits likely accrued, including avoided infrastructure damages and lost revenue for local businesses, avoided travel delays, and recreational opportunities.

➔ **Avoided Infrastructure Damages and Lost Revenue for Local Business**

The most readily observable benefit of the dam removal project is reduced flood risk in the conservation area. While records on flood frequencies are not available for this site, a local business owner (a food vendor) who had worked adjacent to the former impoundment for a decade notes that the dam would overtop and flood the parking lot multiple times a year in the spring. The flooding would preclude use of the conservation area, and damage the parking lot and nearby picnic tables, resulting in costs to the town to repair or replace them.[57] While the flooded area did not overlap building infrastructure, a local food vendor lost approximately five to seven days of business per year due to flooding.[58]

➔ **Avoided Travel Delays**

The flooding of the area behind the dam frequently overlapped one lane of MA Route-117. While this did not result in road closures, the high water did require that traffic cones be placed to block of the lane, and occasionally required that police be present to manage the traffic.[59] The avoided cost to the town of traffic management is therefore a benefit of the removal project.

Because the road was not entirely closed, detours were not required due to the flooding. It is very likely, however, that the one lane closure created a traffic delay nuisance for commuters. Based on recent traffic counts, this section of Route 117 supports about 12,800 vehicle trips per day. Traffic delays until flood waters subsided therefore potentially affected thousands of travelers multiple times per year.[60]

➔ **Recreational Opportunities**

As noted above, a key concern with the dam removal project was the recreational use of the former impoundment for fishing and ice skating, or simply as a feature of the conservation area landscape. While it is true that the free-flowing river landscape does not provide the same recreation activities as did the impoundment, it is not clear that the project necessarily reduced recreational opportunities at the site.

First, recreational fishing is still occurring but is now stream-based, as opposed to pond fishing. Whether the total number of anglers that will visit the site is changed due to the dam removal is uncertain. While the pond had been stocked with brook trout, the poor water quality made it unfavorable habitat. In contrast, natural, free-flowing conditions of the brook created access to 18- miles of new upstream habitat for brook trout and other

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57 Personal communication with John Murphy, local business owner, and Tom Christopher, Lancaster Conservation Commission, on December 5, 2014.

58 Written communication with Tom Christopher, Lancaster Conservation Commission, on December 18, 2014.

59 Written communication with Tom Christopher, Lancaster Conservation Commission, on December 18, 2014.

60 Traffic count on Route 117 near Bartlett. Montachusett Regional Planning Commission. September 2013. "Route 117 Corridor Profile Town of Lancaster, Massachusetts." http://www.mrpc.org/sites/montachusettrpc/files/file/file/final_rt_117_corridor_profile_report.pdf.

native species. Following the removal project, the Massachusetts Department of Fish and Wildlife confirmed that brook trout were found in the newly opened habitat.[61] Increased habitat connectivity and availability indicate that the project may have population-level benefits for brook trout beyond just the conservation area site, potential resulting in recreational fishing benefits in the broader region. As noted above, recreational fishing has the potential to stimulate the regional economy as recreators visit and spend, for example, on food, gas, equipment, at local business.

Second, while some pond-based activities, such as ice skating, are no longer supported at the site, the dam removal changed the landscape of the conservation area so as to increase accessibility for trail-based activities, such as wildlife viewing or dog walking.[62] Here again, whether the overall effect will be to reduce or increase visitation to the conservation area is uncertain. A representative of the Lancaster Conservation Commission notes, however, that he expects the site will become a “premiere stream” over the next three to four years.[63]

WHITTENTON DAM REMOVAL

The Whittenton Dam on the Mill River in Taunton is frequently referenced as a cautionary tale for how poorly maintained dams can be a risk to public safety. Ultimately, the 2005 event at Whittenton Dam generated a statewide call to action to minimize the potential for other outdated dam sites to create a similar threat to public safety and to avoid such costly emergency response and repair situations. One such action was the eventual removal of the Whittenton Dam in 2013. The removal resulted in a reduced risk of flooding, avoided costs of emergency response, increased public safety, property value benefits, and improved habitat conditions for historically valuable fish and wildlife.

KEY SOCIAL AND ECONOMIC BENEFITS OF WHITTENTON DAM REMOVAL

- Removed public safety threat.
- $ Avoided costs of emergency response due to dam failure potential on the order of hundreds of thousands of dollars over the next 30 years.
- $ Avoided costs to regional businesses of closures due to flooding or evacuations.
- $ Potential for increased property values due to reduced flood risk.
- Increased habitat connectivity for native, sensitive species, including herring and American eel.

➔ Avoided Costs of Emergency Response

As noted above, concern for public safety associated with a 2005 storm event resulted in a costly evacuation of downtown Taunton and emergency repair of the dam. The City of Taunton evacuated over 2,000 people for a week, resulting in loss of revenue for area

[61] Massachusetts Executive Office of Energy and Environmental Affairs. Dam and Seawall Repair or Removal Fund Annual Review: Fiscal Year 2014. Project Title: Wekepeke Brook Restoration. August 18, 2014.

[62] Personal communication with John Murphy, local business owner, on December 5, 2014.

[63] Personal communication with Tom Christopher, Lancaster Conservation Commission, on December 5, 2014.

businesses. The best available information suggests the total cost of the emergency response exceeded $1.5 million.[64]

Assuming this cost is representative of what would be required for response activities due to similar, future heavy rain events, the expected value of the emergency response costs over 30 years is at least $600,000 (present value assuming a three percent discount rate).[65] These are avoided costs that would otherwise be borne by taxpayers and local business owners.

MISCONCEPTION	REALITY
Dam removals result in decreased values for properties near the former impoundment.	Studies show that small dam removals do not typically affect property values for shoreline properties and *increase* values of properties near the shoreline.
Dam removals increase flood/safety risk for properties upstream of the dam.	Small dam removals frequently decrease upstream flood risk.

➔ **Public Safety Benefit**

Of course the costs of the worst case scenario of a dam failure without timely emergency response would be expected to be much greater than the avoided costs described above. The costs of a catastrophic flood event in downtown Taunton may have included greater costs of emergency management, damages to building and transportation infrastructure, an increased period of lost revenue for regional businesses, and potentially loss of life.

In addition to the threat of dam failure, local property owners initially expressed concern about the dam removal project, perceiving that the dam protected their properties from flooding. Some owners of property upstream of the site maintained this belief despite the fact that a number of landowners experienced flooding of their yards with heavy rain events.[66]

A 2001 study by Trout Unlimited addresses this issue as a common misconception regarding the purpose of dams. The study describes that, "...(m)ost small dams, particularly those originally designed to power mills, do not provide flood control. In fact, some small dams increase upstream flooding problems because they impede flow, but do not have the capacity to store it."[67] While Whittenton Dam may be more accurately characterized as a medium-sized dam, this statement does reflect the situation upstream of the former dam.

[64] What is included in this cost estimate is uncertain; however, the State Auditor's report suggests this estimate is inclusive of both direct expenditures on emergency response and the lost revenues of local businesses. Auditor of the Commonwealth of Massachusetts. January 2011. "Local Financial Impact Review: Massachusetts Dam Safety Law."

[65] This calculation assumes a 50-year storm event (i.e., a two percent chance of the emergency response in a given year).

[66] Personal communication with Bill Napolitano, Southeastern Regional Planning and Economic Development (SPREDD), December 5, 2014.

[67] Trout Unlimited. "Small Dam Removal: A Review of Potential Economic Benefits." October 2001. Page 6.

➔ Property Value Benefits

As described previously for the Briggsville Dam, the reduced flood risk generated by the Whittenton Dam removal may improve nearby property values. For example, the economics literature identifies a reduced flood risk premium on property values (many studies finding around a four percent reduction in properties located within a flood plain).[68] Furthermore, properties nearby free-flowing rivers have been found to have greater market values than similar properties nearby small dam impoundments, while shorefront properties do not appear to vary depending on a small impoundment or river shore.[69]

The literature on the subject of flood risk effects on property values focuses in particular on residential properties. However, it stands to reason that the sales value for commercial or industrial properties, such as those in downtown Taunton, would benefit from reduced flood risk, as well.

In addition, as with Briggsville Dam, the liability to the dam owner of the on-site safety hazard most likely depressed the property value. Theoretically, the property value would reflect the present value of all future costs of removing the liability or mitigating for its damages. As a result, the dam removal most likely benefitted the dam owner in improving the value of the property.

➔ Improved Habitat Conditions for Historically Valuable Fish and Wildlife

The Whittenton Dam removal was part of a broader river restoration project. The project included removal of a dam downstream of Whittenton in 2012 and installation of fish passage at another dam site upstream of Whittenton in 2013. In addition, one final dam is schedule to be removed in 2015. The downstream dam removal resulted in anadromous herring, eel, and lamprey. The Mill River can likely support an annual run of tens of thousands of river herring once passage is fully restored.[70] Together these projects will restore 29 miles of riverine habitat on the Mill River.[71]

Increased fish and eel populations may improve the quality of regional recreational activities, such as fishing, boating, and wildlife-watching. As herring serve as an important prey species for other wildlife (including fish, birds, mammals and turtles), this benefit is not only directly associated with increased numbers of herring but also healthier populations of other fish and wildlife species within the food web.

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[68] Bin, Okmyung and Stephen Polasky. November 2004. Effects of Flood Hazards on Property Values: Evidence Before and After Hurricane Floyd. Land Economics 84(4): 490-500; Pope, Jaren C. November 2008. Do Seller Disclosures Effect Property Values? Buyer Information and the Hedonic Model. Land Economics 84(4):551-572; and Speyer, Janet Furman and Wade R. Ragas. 1991. Housing Prices and Flood Risk: An Examination Using Spline Regression. Journal of Real Estate Finance and Economics 4:395-407.

[69] Provencher, Bill, Helen Sarakinos, and Tanya Meyer. April 2008. Does Small Dam Removal Affect Local Property Values? An Empirical Analysis. Contemporary Economic Policy 26(2):187-197.

[70] Personal communication between MA Division of Ecological Restoration and MA Division of Marine Fisheries, December 10, 2014.

[71] Graber, Brian. "River Impossible: The Hazard of Whittenton Dam and the Mill River Restoration." February 26, 2013.

The populations of both river herring and American eels have experienced steep declines in recent decades, resulting in recent petitions to list these species under the Federal Endangered Species Act (ESA).[72] The Commonwealth of Massachusetts implemented a moratorium on the harvest of river herring in 2005, and the Atlantic States Marine Fisheries Commission implemented a recreational and commercial fishing moratorium in 2011. The National Marine Fisheries Service (NMFS) identified river herring as a "Species of Concern" in 2006, and though the agency recently decided not to list the species under the ESA, NMFS is planning to implement a coordinated coast-wide river herring conservation effort in collaboration with the Atlantic States Marine Fisheries Commission, to include both monitoring and restoration activities.[73]

River herring constitute one of the oldest fisheries in Massachusetts. Both blueback herring and alewives were harvested commercially in Massachusetts up until the Commonwealth implemented a moratorium on harvest in 2005. Both species of river herring were also harvested recreationally, mainly for bait (i.e., for lobster and striped bass) and personal consumption.[74] Annual commercial landings of river herring in Massachusetts fell dramatically from a peak of about 1.7 million pounds harvested in 1975 to the 89 pounds harvested in 2004. This reduction in catch is due primarily to a coast-wide decline in population resulting from a number of factors including overexploitation, accidental catch while fishing for other species, water quality, and dams.[75]

River herring also play an important ecological role, serving as key species in the dynamics of food chains in freshwater, estuarine, and marine ecosystems. In this way, river restoration projects that improve herring habitat support recreationally and commercially valuable fisheries in Massachusetts, such as largemouth bass, striped bass, and cod.[76]

American eel is also a priority species for the Atlantic States Marine Fisheries Commission, which recently developed an Addendum III to its management plan for American eel to reduce mortality and increase conservation of the species. The species is

[72] Natural Resources Defense Council. 2011. Petition to List Alewife (Alosa pseudoharengus) and Blueback Herring (Alosa aestivalis) as Threatened Species and to Designate Critical Habitat.

[73] National Oceanic and Atmospheric Administration. 2013. Endangered Species Act Listing Determination for Alewife and Blueback Herring. Federal Register 78 (155): 48944-48994.

[74] Atlantic States Marine Fisheries Commission. 2008. Draft Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring for Public Comment (River Herring Management).

[75] Schmidt, R.E., Jessop, B.M., Hightower, J.E. 2003. Status of River Herring Stocks in Large Rivers. American Fisheries Society Symposium 35: 171-182; National Oceanic and Atmospheric Administration. 2013. Endangered Species Act Listing Determination for Alewife and Blueback Herring. Federal Register 78 (155): 48944-48994.

[76] Yako, L.A., Mather, M.E., Juanes, F. 2011. Assessing the Contribution of Anadromous Herring to Largemouth Bass Growth. Transactions of the American Fisheries Society 129(1): 77-88; Natural Resources Defense Council. 2011. Petition to List Alewife (Alosa pseudoharengus) and Blueback Herring (Alosa aestivalis) as Threatened Species and to Designate Critical Habitat; National Oceanic and Atmospheric Administration. 2013. Endangered Species Act Listing Determination for Alewife and Blueback Herring. Federal Register 78 (155): 48944-48994.

also currently under review by the U.S. Fish and Wildlife to determine whether the listing of the species as "threatened" is warranted under the Endangered Species Act.[77]

American eels, which forage in freshwater ponds and rivers but spawn in the Sargasso Sea, also support both recreational and commercial fisheries in the United States. Commercial landings peaked at 3.6 million pounds in 1979, while the value of U.S. commercial American eel landings peaked in 1997 at $6.4 million.[78] In 2009, approximately 728,000 pounds of eels were harvested commercially in the United States with a total value of $1.9 million.[79]

Massachusetts currently supports both recreational and commercial eel fisheries, though the harvest of elvers (the juvenile life stage) is illegal. Though Massachusetts has a relatively small eel harvest, the eel fishery is more economically significant at the regional level. In total, the average annual harvest of yellow eels between 2009 and 2011 in coastal states from Maine to Connecticut was approximately 11,000 pounds. In 2012, 20,764 pounds of elvers were harvested in Maine with a total value of about $39 million, approximately nine percent of the value of Maine's entire commercial fisheries landings in 2012.[80] The difference is due to restrictions in Massachusetts on the harvest of valuable juvenile American eels. To the extent that the population recovers to a sufficient level to lift moratoria, recent experience in Maine indicates that eels could be an even more valuable commercial fishery resource in Massachusetts.

Overall, both river herring and American eel are valuable recreational and commercial fishing resources, both directly and indirectly, to Massachusetts. River restoration projects, such as the Whittenton Dam removal that seek to improve habitat for these species accordingly contribute to the maintenance or improvement of these economic activities.

[77] United States Fish and Wildlife Service. 2011. 90-Day Finding on a Petition to List the American Eel as Threatened. Federal Register 76 (189): 60431-60444.

[78] Atlantic States Marine Fisheries Commission. 2013. Draft Addendum III to the Fishery Management Plan for American Eel for Public Comment; United States Fish and Wildlife Service. 2011. 90-Day Finding on a Petition to List the American Eel as Threatened. Federal Register 76 (189): 60431-60444.

[79] National Oceanic and Atmospheric Administration. 2009. U.S. Commercial Landings – U.S. Domestic Landings, by Species, 2008 and 2009. Accessed on September 13th, 2013 at http://www.st.nmfs.noaa.gov/st1/fus/fus09/02_commercial2009.pdf.

[80] Maine Department of Marine Resources. 2013. Historical Maine Elver Landings. Accessed on September 13th, 2013 at http://www.maine.gov/dmr/commercialfishing/documents/elver.table_000.pdf.

SECTION 3. STUDY SITE CULVERTS: DINGLE ROAD, HILL STREET, AND DRIFT ROAD

This section discusses the site histories, costs, and ecological benefits associated with the culvert replacement projects that are the focus of this study.

3.1 SITE HISTORIES

This section presents a short review of major events that lead to upgrade of the culverts that are the focus of this study.

DINGLE ROAD, WORTHINGTON

The Dingle Road culvert is located in Worthington, Massachusetts, at the crossing of Bronson Brook. Dingle road is a one-lane, unpaved road that serves as the primary access point to three residences. While not a major throughway, the road is a scenic, wooded route that travelers may go out of their way to travel, particular in the autumn.

The original culvert was perched, creating a significant barrier to fish passage. The culvert failed during a major storm in 2003, when debris obstructed flow and caused water to overtop the road. Storm water eroded the road, eventually resulting in a large rift between the road and one side of the culvert. As a result of this damage, Dingle Road was closed for five years. The road closure made access to the three residences difficult, requiring access from an alternate, much steeper side of Dingle Road. The alternative access route was at times impassable during heavy snow or ice. In one case, an emergency vehicle became temporarily stuck attempting to reach a residence. [81]

HILL STREET, RAYNHAM

The Hill Street culvert is located in Raynham, Massachusetts, at the crossing of an unnamed stream. The original culvert was a perched round pipe that was only three feet wide. At the time of its construction, this narrow width was sufficient to accommodate storm water flows. The surrounding landscape at the time was primarily forestland, which could effectively absorb a large amount of precipitation. In recent decades, however, the area upstream of the culvert has seen continual development, which contributed to higher rates of storm runoff. By 2007, the contributing drainage basin for the culvert included parking lots, an industrial park, residential houses, at least six car dealerships, and other impervious surfaces.

These developments have greatly increased the amount of storm water runoff directed to the Hill Street culvert over time. As a result, even relatively minor storm events began to

[81] Personal communication with Amy Singler, American Rivers, December 2014

overwhelm the culvert, producing flooding upgradient of Hill Street.[82] Nearby residences experienced frequent inundation following precipitation events, and large storms occasionally produced flooding all the way back to Route 44. Drainage issues became particularly salient when Electrochem, a high-end battery manufacturer, looked to build a new facility in an industrial park behind the culvert. Pressure from Electrochem and local property owners eventually encouraged the Town to replace the culvert with an improved design.[83]

DRIFT ROAD, WESTPORT MA

The Drift Road culvert is located in Westport, Massachusetts at the crossing of Sam Tripp Brook. Prior to replacement, this crossing consisted of four pipes, two stone and two round two-foot pipes. The pipes were perched, creating a barrier to fish passage. The pipes were too narrow to accommodate the flow of the Sam Tripp Brook during storm events. Even moderate rainfall (one-inch) events would cause the brook to back up behind the culvert and flow over the road, often up to two feet in depth. This resulted in frequent road closures, inconveniencing travelers and placing a burden on the budget of the Westport Highway Department. Flood events also gradually eroded the road, creating a safety hazard for travelers which eventually prompted the replacement project.

3.2 COSTS OF CULVERT UPGRADES

Information on the cost of culvert upgrades at each site was gathered from construction and engineering invoices and from cost tables received directly from DER. All costs were adjusted to 2014 dollars. Irrespective of any maintenance to the roadway over these culverts, the upgraded culverts are likely to require periodic inspection and minor maintenance (e.g. patching of concrete cracks or repair of minor damage to metal parts). However, when compared to the frequent and intensive maintenance that the old culverts required (e.g., including regular clearing of debris), these costs are relatively minor for the larger, newer culverts. Exhibits 3-1 through 3-3 present the actual reported costs of culvert upgrades for our study sites. As shown, costs of the culvert upgrades vary from $230,000 to $440,000.

[82] Personal communication with Bill Napolitano, Southeastern Regional Planning and Economic Development (SPREDD), on December 5, 2014.

[83] Written communication between MA Division of Ecological Restoration and Bill Napolitano, Southeastern Regional Planning and Economic Development (SPREDD), on December 8, 2014.

EXHIBIT 3-1. COSTS OF CULVERT UPGRADE AT DINGLE ROAD

COST CATEGORY	DESCRIPTION	COSTS (AS QUOTED)	COSTS (PRESENT VALUES)[1]
Engineering	Conceptual Designs	$14,000	$20,000
	Habitat Engineering Designs	$47,000	$66,000
	Engineering Plan Revisions for MassHighway	$9,000	$12,000
	Engineering Plan Revisions for MassHighway	$1,000	$2,000
	Guardrail Design	$3,000	$3,500
	Construction Planning/Bid Packets	$13,000	$19,000
	Subtotal:	$88,000	$120,000
Construction	Equipment	$11,000	$15,000
	Construction/Labor	$52,000	$73,000
	Subtotal:	$62,000	$88,000
Materials	Culvert	$53,000	$74,000
	Guard Rail & Concrete	$25,000	$35,000
	Other materials	$38,000	$54,000
	Subtotal:	$116,000	$160,000
Total		$270,000	$370,000

Sources: Data table received from DER.

Notes:

1. For comparison purposes, we adjusted all costs to 2014 dollars using the Engineering News-Record Construction Cost Index, and estimated present values of these costs using a 3% discount rate.
2. Estimates are rounded to two significant digits and may therefore not sum to the totals presented.

EXHIBIT 3-2. ACTUAL COSTS OF CULVERT UPGRADE AT HILL STREET

COST CATEGORY	COSTS (AS QUOTED)	COSTS (PRESENT VALUES)[1]
Engineering & Permitting	$80,000	$100,000
Construction	$270,000	$340,000
Culvert Structure	$54,000	$68,000
Total[2]	$350,000	$440,000

Sources: Chapter 90 Reimbursement Request for the Hill Street Culvert Replacement Project

Notes:

1. For comparison purposes, we adjusted all costs to 2014 dollars using the Engineering News-Record Construction Cost Index, and estimated present values of these costs using a 3% discount rate.
2. Estimates are rounded to two significant digits and may therefore not sum to the totals presented.

EXHIBIT 3-3. ACTUAL COSTS OF CULVERT UPGRADE AT DRIFT ROAD

COST CATEGORY	COSTS (AS QUOTED)	COSTS (PRESENT VALUES)[1]
Engineering & Permitting	$180,000	$200,000
Construction	$20,000	$22,000
Total[2]	$200,000	$230,000

Sources: Written communication between MA Division of Ecological Restoration and the Westport Town Manager on December 4, 2014.

Notes:

1. For comparison purposes, we adjusted all costs to 2014 dollars using the Engineering News-Record Construction Cost Index, and estimated present values of these costs using a 3% discount rate.
2. Estimates are rounded to two significant digits and may therefore not sum to the totals presented.

3.3 "OUT-OF-POCKET" COSTS TO CULVERT OWNERS

Due to the environmental health and safety benefits of the upgrade projects, the owners of all three culvert sites were able to leverage considerable public and private funding, as well as technical support, towards the projects. As a result, the cost borne by the municipalities was only a small portion of total project costs, ranging from 15 to 20 percent of project costs. If the municipalities had pursued replacement in-kind, some of these funding sources would not have been available. While the ecological, social, and economic benefits of these projects are realized regardless of the source of funding, the available financial and technical resources allow communities to benefit from the ecological, social, and economic improvements for a lesser cost to the municipalities.

- To repair the Dingle Road culvert, the Town of Worthington received funding from DER, NOAA, U.S. Fish and Wildlife Service, American Rivers, and other conservation partners. Together these sources contributed over $200,000 towards the project. All of these contributors were primarily interested in the potential ecological benefits of this project. If the Town of Worthington had pursued a traditional, non-ecologically friendly design, none of these funding sources would have been available.
- Similarly, the Hill Street culvert replacement project received at least $27,000 in funding from the Massachusetts Opportunity Relocation and Expansion (MORE) Grant, a program targeted at improving public infrastructure to create private sector jobs. As the original undersized culvert was inhibiting expansion of an industrial park located upstream, this funding would not have been available unless the replacement allowed for improved storm water flows.

Some sources of funding for the culvert projects would likely have been made available regardless of design choice. However, it is possible that outside funding still made the ecologically friendly designs a comparatively more attractive option, as the Town could receive an upgraded design at a considerable discount.

- For example, the Drift Road culvert was significantly damaged by Tropical Storm Irene. As a result, FEMA agreed to provide 80 percent of funding towards a replacement project. It is likely that FEMA funding would have remained available if the Town of Westport had decided to replace the culvert in-kind. However, the availability of FEMA funding provided a greater nominal reduction in the cost of the improved culvert as compared to the traditional design. The Westport Highway Department was thrilled to choose the upgrade, as they would have been unable to afford an improved design without FEMA support.[84]
- The Hill Street culvert replacement project received the majority of its funding from Chapter 90, a statewide program which provides funding for local road repair. Similar to FEMA funding, Chapter 90 funding would support in-kind culvert replacement as well as replacement with an improved design. However, it seems likely that the availability of Chapter 90 funding made the more expensive culvert design more attractive to the Town of Raynham. This would be particularly true if the town did not have any other major repair projects that year, as Chapter 90 funding is made available on an annual basis. In Fiscal Year 2010, the Town of Raynham received $358,035 in Chapter 90 funding, of which $268,880 was allocated to the Hill Street culvert upgrade project.

Exhibit 3-4 provides a summary of the funding sources for all three culvert projects.

[84] Personal Communication with Chris Gonsalves, Director of the Westport Highway Department, on December 5, 2014.

EXHIBIT 3-4. SUMMARY OF CULVERT UPGRADE COSTS BY FUNDING SOURCE (2014 DOLLARS)

SITE	COST TO OWNER	OTHER FUNDING SOURCES
DINGLE ROAD	$56,000 (15%)	DER: $61,000 (16%) Other Conservation Partners: $160,000 (42%) Other Sources: $98,000 (26%)
HILL STREET	$72000 (17%)	Chapter 90: $340,000 (77%) MORE Grant: $27,000 (6%)
DRIFT ROAD	$53,000 (20%)	FEMA: $180,000 (80%)
Notes: For comparison purposes, we adjusted all quoted costs to 2014 dollars using the Engineering News-Record Construction Cost Index, and estimated present values of these costs using a 3% discount rate.		

3.4 AN ALTERNATIVE SCENARIO: ESTIMATED COSTS OF CULVERT REPLACEMENT IN-KIND

Gomez and Sullivan Engineers provided estimates of initial in-kind replacement costs for each site. These estimates were based on observations during site visits, previous engineering measurements at the sites, and prior professional experience.

Additionally, Gomez and Sullivan Engineers estimated the annual cost of maintenance required to address gradual weathering and storm damage at each site. Such maintenance procedures include debris removal, riprap replacement, and minor road repairs. Gomez and Sullivan estimated that these procedures would cost between $9,000 and $24,000 for each culvert. Estimates varied between culverts based on different expected frequencies and impacts of storm events at each site. These estimates reflect the fact that these culverts were severely undersized, and thus were continually susceptible to damage.

In addition to the greater need for annual maintenance, traditional culverts need to be replaced more frequently. Even with regular maintenance, frequent erosion from heavy precipitation events will accumulate until replacement is necessary.[85]

- Gomez and Sullivan estimate that the pipe culverts at Drift Road and Hill Street would need to be fully replaced every 25 years.
- They estimate that the Dingle Road culvert would only need to be replaced in-kind every 50 years, due to the greater resilience of the concrete box culverts at that site. However, Gomez and Sullivan predict that the Dingle Road culvert would still need major repair after 25 years, even though the culvert structure would not need to be replaced.

Exhibits 3-5 through 3-7 presents the engineering estimates of all costs associated with replacement in-kind. As shown, replacement costs in-kind ranged from $120,000 to $170,000, which would have been cheaper than upgrades at all sites. However, after

[85] Gomez and Sullivan Engineers, "MA DER Dam Removal and Culvert Replacement Costs," December 12, 2014.

consideration of the long-term maintenance costs, costs of in-kind replacement are much higher, at $390,000 to $750,000.

EXHIBIT 3-5. ESTIMATED COSTS ASSOCIATED WITH REPLACEMENT IN-KIND SCENARIO AT DINGLE ROAD CULVERT, 2014 DOLLARS

COST CATEGORY	ASSUMPTION	COSTS
Estimated Replacement In-Kind Cost	Every 50 years	$180,000
Maintenance Costs	Annual	$13,000
Long-term maintenance	25 after replacement	$100,000
Total Costs	-	$560,000
Source: Gomez and Sullivan Engineering, 2014. *All values are presented in 2014 dollars.		

EXHIBIT 3-6. ESTIMATED COSTS ASSOCIATED WITH REPLACEMENT IN-KIND SCENARIO AT HILL STREET CULVERT

COST CATEGORY	ASSUMPTION	COSTS
Replacement Cost	Every 25 years	$120,000
Maintenance Costs	Annual	$9,000
Total Costs	-	$390,000
Source: Gomez and Sullivan Engineering, 2014. *All values are presented in 2014 dollars.		

EXHIBIT 3-7. ESTIMATED COSTS ASSOCIATED WITH REPLACEMENT IN-KIND SCENARIO AT DRIFT ROAD CULVERT

COST CATEGORY	ASSUMPTION	COSTS
Replacement Cost	Every 25 years	$170,000
Maintenance Costs	Annual	$24,000
Total Costs	-	$750,000
Source: Gomez and Sullivan Engineering, 2014. *All values are presented in 2014 dollars.		

3.5 COMPARISON OF COSTS REPLACEMENT WITH IMPROVED DESIGN VERSUS REPLACEMENT IN-KIND

Our findings with regards to the costs of upgrading culverts versus replacement in-kind at our study sites are as follows:

- Unlike for the dam sites, the upfront costs of the culvert upgrades were estimated to be greater than the in-kind replacement at each of the three culverts analyzed in this project. This is not surprising, as the larger size and use of higher quality materials with improved designs naturally comes at a cost premium.
    - The greatest expected difference in project costs was at Hill Street, where the culvert upgrade cost more than three times as much as the estimate for replacement in-kind. At the other two sites the discrepancy was less significant.
- However, when the expected future costs associated with maintaining a culvert are considered alongside the initial repair costs, culvert upgrades are less expensive than in-kind replacement at two of our three sites.
    - At two of the culvert sites, Dingle Road and Drift Road, replacement in-kind and the associated maintenance are expected to cost significantly more than replacement with an upgraded design over a 30-year timeframe. At Drift Road, the total cost of replacement is estimated at more than three times the actual cost of replacement with the upgraded design.
    - At the Hill Street culvert, the upgraded design is predicted to cost slightly more than the total cost of replacement in-kind over a 30-year timeframe.
    - While improved culvert designs have a high upfront cost, they significantly reduce long-term maintenance costs. As shown, the costs of maintenance of in-kind replacement projects comprise the majority of expected costs over the next 30 years. This is largely because these projects are all expected to require two full replacements during this time period.
- Outside funding was procured at all of our study sites, significantly reducing costs. When actual out-of-pocket costs to the municipalities are compared against potential costs of replacement and maintenance of in-kind structures, savings are dramatic, showing savings of 75 percent to 94 percent across our study sites.

The costs of culvert upgrades and estimated costs of replacement in-kind are summarized in Exhibit 3-8.

EXHIBIT 3-8. SUMMARY COMPARISON OF FINANCIAL COSTS OF CULVERT UPGRADE VERSUS REPLACEMENT IN-KIND OVER 30 YEARS (2014 DOLLARS)

SITE	TOTAL COSTS OF CULVERT UPGRADE	OUT-OF-POCKET COSTS TO MUNICIPALITY	ESTIMATED COSTS OF REPLACEMENT IN-KIND SCENARIO (30 YEAR PRESENT VALUES)	POTENTIAL SAVINGS TO MUNICIPALITY OF CULVERT UPGRADE PROJECT	PERCENT SAVINGS
DINGLE ROAD	$370,000	$56,000	$560,000	$500,000	89 percent
HILL STREET	$440,000	$72,000	$390,000	$220,000 to $320,000	75 to 82 percent
DRIFT ROAD	$230,000	$45,000	$750,000	$560,000 to $700,000	93 to 94 percent

Notes:

1. Expected future costs include maintenance costs and future replacement in-kind costs. Annual maintenance costs are assumed to occur in all years when no major work is conducted over a 30-year period.
2. Savings at Hill Street and Drift Road are presented as ranges, as the funding sources leveraged at these sites may have been available if the municipalities had decided to replace the culverts in-kind. The upper bound assumes that the municipality would receive no outside funding for replacement in-kind. The lower bound assumes that outside sources would fund the same proportion of the initial replacement in-kind project as they funded the upgrade project.
3. For comparison purposes, we adjusted all quoted costs to 2014 dollars using the Engineering News-Record Construction Cost Index, and estimated present values of these costs using a 3% discount rate.
4. Estimates are rounded to two significant digits and may therefore not sum to the totals presented.

Caveats:

- It is worth noting that Dingle Road was an early culvert upgrade project, completed only a couple years after the release of the Massachusetts Stream Crossings Handbook. As a result, it appears likely that a similar project completed now would be less expensive, as engineering and construction firms, and supporting partners such as DER, are more familiar with how to handle these projects. This is consistent with an interview with Evan Johnson, a selectman in Worthington, who noted that his only complaint about the project was the seemingly excessive expenditures on engineering and design.[86]

[86] Personal Communication with Evan Johnson, Selectman for Town of Worthington, on December 12, 2014.

3.6 SOCIAL AND ECONOMIC BENEFITS OF CULVERT REPLACEMENT

While it is not uncommon for dams that no longer serve their purpose to be neglected and fall in disrepair over decades or even centuries, the project life of a culvert is much shorter, requiring replacement approximately every 25 years. Before some culverts even reach this milestone, however, they may fail and flood adjacent areas. In-kind replacement of culverts, as opposed to upgrades that better accommodate stream flows and wildlife, has been commonplace for two key reasons. First, it is often the less expensive option in the short term, as described in the previous section. Second, culvert replacements may be "battlefield decisions" following failure of the structure, and the urgency of re-construction does not allow sufficient time for proper design.

Outdated culvert infrastructure may affect ecological, social, and economic conditions in a similar manner to dams by increasing flood risk and fragmenting aquatic habitat. During heavy rain events, aging culverts may fail to pass large volumes of stormwater due to either a lack of hydraulic capacity or because debris (e.g., sediment, rocks, or vegetation) blocks passage. This results in flooding of areas upstream of the culvert. Recent research indicates that fish species richness and abundance are reduced by more than half in areas upstream of impassable culverts.[87] In addition, culvert failures may result in a rush of floodwaters, eroding river banks and flooding downstream areas. These issues are of particular concern in light of increasing storm events and flood frequencies due to climate change.[88]

As the key social and economic concerns related to outdated culverts are similar to those related to dams (i.e., flood risk and habitat degradation), the types of benefits most likely to result from a culvert upgrade are likewise similar, including:

1) **Avoided costs of flood events:** Costs of flood events include, for example, infrastructure damages and travel interruptions on area roads. As culverts are developed specifically to provide road crossings over streams, road flooding and closures may be even more common an issue for outdated culverts than for outdated dams.

2) **Property value benefits:** While studies were not identified that assess the property value effects of reduced flood risk specifically due to culvert upgrades, it stands to reason that frequently flooded properties are less attractive to homebuyers than equivalent properties that are less at risk of flooding, regardless of the causative factor of the flooding.

3) **Increased quantity or quality of recreational experiences or commercial fisheries:** As with dams, increased habitat connectivity may improve populations of recreationally (e.g., for fishing or wildlife-viewing) or commercially (fish and shellfish) valuable wildlife species.

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[87] Nislow, K.H., M. Hudy, B.H. Letcher, and E.P. Smith. 2001. Variation in Local Abundance and Species Richness of Stream Fishes in Relation to Dispersal Barriers: Implications for Management and Conservation. Freshwater Biology 56:2135-2144 (as cited in Gillespie, Nathaniel et al., February 2014. Flood Effects on Road-Stream Crossing Infrastructure: Economic and Ecological Benefits of Stream Simulation Designs. Fisheries 39(2): 62-76).

[88] Gillespie, Nathaniel et al., February 2014. Flood Effects on Road-Stream Crossing Infrastructure: Economic and Ecological Benefits of Stream Simulation Designs. Fisheries 39(2): 62-76.

4) **Improved aesthetic conditions of the landscape:** In addition to managing flow, well-planned culvert upgrades better fit the landscape of a site, for example relying on natural bottoms and integrating native vegetation.

Exhibit 3-9 highlights the categories of social and economic benefits relevant to our culvert case studies. The following sections then describe more specifically the nature of the social and economic benefits of the three projects.

EXHIBIT 3-9. SOCIAL AND ECONOMIC BENEFITS OF THREE CULVERT UPGRADE PROJECTS

CASE STUDY SITE	BENEFITS OF REDUCED FLOOD RISK			BENEFITS OF IMPROVED ECOLOGICAL HEALTH	
	AVOIDED DAMAGES TO BUILDINGS AND ROADS	AVOIDED TRAVEL DELAYS OR REDUCED MOBILITY	PROPERTY VALUE MAINTENANCE OR IMPROVEMENT	RECREATION BENEFITS	COMMERCIAL FISHING BENEFITS
Dingle Road	★	★	☆	☆	
Hill Street	★	☆	★	☆	
Drift Road	★	★		☆	☆

★: The culvert upgrade likely generated this type of benefit.
☆: The culvert upgrade may have generated this type of benefit.

DINGLE ROAD CULVERT UPGRADE

The Dingle Road culvert failed in 2003, washing out the one-lane road and complicating access to three residences. The new culvert spans twice the width of the old design, allowing for storm flows to pass underneath Dingle Road and for fish to access upstream habitat. The upgraded culvert performed well during Irene, when many culverts failed. No maintenance to the culvert or road were required despite a difficult storm.[89] In addition to the reduced costs of continual maintenance of site described in the previous section (e.g., for regular debris removal), we emphasize the following benefits of the project.

KEY SOCIAL AND ECONOMIC BENEFITS OF THE DINGLE ROAD CULVERT UPGRADE

- Removed public safety threat.
- Facilitated access to Dingle Road residences for homeowners and safety vehicles.
- $ Avoided cost of repairing damages to Dingle Road (tens of thousands of dollars approximately every 20 years) and possibly to nearby residential development.
- $ Potential for increased property values for four residences due to reduced flood risk.
- Increased habitat connectivity for recreationally valuable species, including brook trout.

➔ **Avoided Damages to Infrastructure and Removed Public Safety Threat**

The 2003 culvert failure resulted in rushing flood waters washing out 100 feet of the road and ripping out bank stabilizations protecting three to four houses downstream.

89 Personal communication with Amy Singler, American Rivers and The Nature Conservancy, on December 10, 2014.

Ultimately, these houses were not inundated, however the flood waters were approaching and anecdotal information suggests they may have flooded a garage and pool.[90]

While the residential properties along Dingle Road did not flood with the 2003 storm event in particular, increasing storm frequencies and intensities, combined with precedence of high flood waters, indicate the potential for damage to residential infrastructure had the culvert not been upgraded to better accommodate stormwater flows.

Repairs to the stretch of unpaved road that washed out during the event were required. Anecdotal information suggests that, since the culvert was constructed in the 1970s, the road had washed out two to three additional times[91] (potentially indicative of 20-year storm events). Cost information on the culvert upgrade indicates that the construction materials required specifically for the road repair element of the 2007 upgrade were approximately $12,500.[92] Labor and design costs are not separated for the road repair project element. It is reasonable to conclude, however, that the costs of road repair with each 20-year storm event amounted to tens of thousands of dollars. These are costs that are avoided due to the upgrade, potentially freeing scarce financial resources to achieve other community projects and programs.

In addition, the rushing waters presented a safety risk and may have harmed people had they been outside near the stream during the event.[93]

➔ **Avoided Travel Delays or Reduced Mobility**

As noted above, there was precedence for significant rain events to wash out a stretch of Dingle Road. While this road is not a thoroughfare for commuters, it was the main access point for three to four residences. The alternative access point required travelling down a steep incline of unpaved road to reach the properties. This created great difficulty with accessing the properties during snow or ice events, generating a real safety hazard by impeding access for safety vehicles. For example, during the five year road closure following the 2003 culvert failure, an ambulance was stuck on the alternative route to these residences.[94] The closure of Dingle Road for five years following the 2003 culvert failure accordingly generated a substantial nuisance for these homeowners.

➔ **Property Value Benefits**

The ability of the upgraded culvert to successfully move stormwater without plugging or failing reduces the risk of flooding to surrounding properties. While the property value benefits of culvert upgrades are not a particular topic of the economics literature, the principles are the same as for dams. That is, people are most likely willing to pay more for homes that are not prone to flooding. Accordingly, as the upgraded culvert continues to successfully function during heavy rain events without flooding, the property values

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90 Personal communication with Carrie Banks, MA Division of Ecological Restoration, on December 10, 2014.

91 Personal communication with Carrie Banks, MA Division of Ecological Restoration, on December 10, 2014.

92 Bronson Brook Cost Breakdown spreadsheet, provided to IEc by MA DER in December 2014.

93 Personal communication with Amy Singler, American Rivers and The Nature Conservancy, on December 10, 2014.

94 Personal communication with Carrie Banks, MA Division of Ecological Restoration, on December 10, 2014.

for the Dingle Road residences may benefit. Furthermore, the reduced potential for flooding of the road used to access the homes may also make these properties more attractive to buyers.

➔ **Recreational Fishing Benefits**

The MA Division of Fisheries and Wildlife stocks brook trout in Bronson Brook downstream of the culvert.[95] The upgraded culvert contains a natural, open bottom, which successfully restored fish passage at the site. To the extent that the improved habitat connectivity increases abundance of recreationally valuable brook trout or other species (see Section 2) upstream, the culvert may result in a better quality recreational fishing experience in the region.

HILL STREET CULVERT UPGRADE

Commercial and residential development in the vicinity of the Hill Street culvert in recent years has resulted in increased impervious surface surrounding the site. The effect of this development has been to increase stormwater loadings to the stream, resulting in flooding upstream of the culvert. Due to increased flood risk to the developed areas and developable land upstream of the culvert, key benefits of the culvert upgrade include avoided damages, improved property values, and expanded regional economic opportunities.

KEY SOCIAL AND ECONOMIC BENEFITS OF THE HILL STREET CULVERT UPGRADE

- $ Avoided damages to residential properties upstream of the culvert.
- $ Potential for increased property values of developable land and residential parcels due to reduced flood risk.
- $ Project supported construction of large-scale industrial development providing an estimated 300 jobs and $740,000 in local and regional annual tax revenues.
- Increased habitat connectivity.

➔ **Avoided Damages to Infrastructure**

Due to the rapid development of the drainage area, the culvert could no longer manage to pass water generated by a two-year flood.[96] As a result, flooding of residences nearby was a chronic problem about which homeowners frequently complained.[97] Following the culvert upgrade in 2010, the culvert has the capacity to move the storm flows, resulting in a reduced risk of flooding to these residential properties. While information is not available regarding the costs of damages or repairs experienced by homeowners, the culvert upgrade reduces the potential for such costs at all, whether financial or nuisance-related.

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[95] Personal communication with Carrie Banks, MA Division of Ecological Restoration, on December 10, 2014.

[96] Weinstein, Susan Parkou. "200 Jobs Lost if Electrochem Walks from Raynham Project." Article printed in Plymouth WickedLocal on August 29, 2007. http://plymouth.wickedlocal.com/article/20070829/NEWS/308299923/?Start=1

[97] Personal communication with Bill Napolitano, Southeastern Regional Planning and Economic Development District, December 5, 2014.

➔ Property Value Benefits

As described in Section 2.6, in addition to avoided damages, reduced flood risk may increase the market value of a property. Studies indicate that homes located within a flood plain may be subject to a four percent decrease in value as compared to homes located outside of a floodplain. The premium associated with the reduced flood risk reflects perceptions of homebuyers with respect to potential flood costs, including both financial costs, such as insurance or damage repair, as well as costs that may not be monetizable, such as loss of irreplaceable memorabilia or the general nuisance factor of temporary displacement and managing the damage.

Quantifying the property value benefits of the reduced flood risk would require information on how many homes may be flooded with a given storm event (this may, for example, be based on historical precedence) and the market values of those parcels. Given the current median home value in Raynham of $304,400,[98] a four percent reduction in property value due to flooding would be on the order of $12,000 per home.

> **THE LIABILITY COST OF THE POOR DRAINAGE AT THE HILL STREET CULVERT DECREASED THE VALUE OF THE SITE AS AN INDUSTRIAL DEVELOPMENT OPTION AND THREATENED TO PRECLUDE OPPORTUNTIES FOR 300 NEW JOBS AND AN ESTIMATED $700,000 ANNUAL TAX REVENUE SOURCE FOR THE REGION.**

Beyond residential development, anecdotal information indicates that frequent flooding of parking lots and other areas may have reduced the land value of parcels planned for commercial or industrial development. For example, citing environmental considerations, including the flooding due to the outdated culvert, Electrochem Commercial Power, threatened to find an alternative site for development of its large-scale industrial facility.[99] In this case, the liability cost to the company of the poor drainage at the culvert decreased the value of the site as an industrial development option.

➔ Increased Regional Economic Opportunities

Following the culvert upgrade and reduced incidences of flooding, Electrochem ultimately constructed an 82,000 square foot facility on 20-acres of land at the site. The facility currently supports 300 jobs and,[100] in 2007, was estimated to provide additional tax revenues to the region of $700,000 annually. Furthermore, Electrochem has indicated the potential for expansion of their facilities at the site, indicating that the foregone regional economic benefit associated with this development may have been even greater.

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[98] Raynham Home Prices and Values. As posted on http://www.zillow.com/raynham-ma/home-values/ as of December 2014.

[99] Weinstein, Susan Parkou. "200 Jobs Lost if Electrochem Walks from Raynham Project." Article printed in Plymouth WickedLocal on August 29, 2007. http://plymouth.wickedlocal.com/article/20070829/NEWS/308299923/?Start=1.

[100] Electrochem facilities description accessed at http://www.electrochemsolutions.com/about/facilities.aspx.

➔ Recreational Benefits

As described for previous sites, the Hill Street culvert upgrade improves fish passage by mimicking more natural conditions with respect to stream flow and substrate. As a result, the project may support quality or quantity of regional recreational fishing opportunities.

DRIFT ROAD CULVERT UPGRADE

As described at the beginning of this section, roads adjacent to the former Drift Road culvert were particularly vulnerable to flooding, becoming inundated with one inch rainfall events (which may occur up to ten times a year in this region). Ultimately the culvert failure resulted in the need to revisit the design to accommodate stormwater.

KEY SOCIAL AND ECONOMIC BENEFITS OF THE DRIFT ROAD CULVERT UPGRADE

- $ Avoided costs to the town on the order of tens to hundreds of thousands of dollars for active management of flooded roads for four to ten days per year.
- $ Avoided travel delays for 12,000 to 30,000 travelers annually.
- Increased habitat available to and improved habitat conditions for recreationally and commercially valuable species, such as American eel and brook trout.

➔ Avoided Cost of Road Closures and Travel Delays

Prior to the culvert upgrade, Drift Road would flood frequently, potentially up to ten times per year and at flood depths up to two feet.[101] Furthermore, the culvert and the embankment above the culvert were collapsing, causing the shoulder of the road to erode and creating a safety hazard for travelers.[102] The road that was subject to flooding four to ten times per year has experienced no flooding in the two years since the culvert upgrade. This reduced flood risk: 1) reduces the direct costs to the town of managing the flood; 2) reduces commute time for travelers; and 3) improves access to homes on Drift Road.

During periods of significant road flooding, the Westport Highway Department would place a road monitor at the site, sometimes overnight. Assuming that a monitor was required four to ten times per year for up to 24 hours each time, the 30-year present value of costs the town avoided in no longer monitoring flooded roads ranges from approximately $60,000 to $150,000.[103] Of note, this includes just the direct labor costs of the monitor and not the potential cost of any associated equipment that may be required.

In addition to the direct costs of monitoring the flooded roads, travel delays for commuters were also an issue of the road closures. Drift Road is lined with residences and experiences traffic primarily for access to those homes. Traffic is particularly great in the summer months. Road closures for approximately two miles of Drift Road due to the

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[101] Personal communication with Chris Gonsalves, Director of the Westport Highway Department, December 5, 2014.

[102] Drift Road Stormwater Mitigation Project Proposal. Provided by MA DER to IEc, December 2014.

[103] This calculation assumes a cost of $30 per hour and a discount rate of three percent over the 30-year timeframe.

culvert flooding generated the need for a detour (up to four miles each way).[104] While precise information regarding how many trips or travelers are affected by the road closures in a given year, available traffic count data for nearby roads indicates trips on the order of 3,000 per day. Assuming road closures of four to ten days per year, this translates to travel delays for 12,000 to 30,000 travelers annually.[105]

➔ **Enhanced Recreational or Commercial Fishing Opportunities**

The upgraded culvert features an open bottom and spans the full width of the Sam Tripp Brook, greatly enhancing fish and wildlife passage. The project provided access for fish to a small upstream pond.[106] A 2010 Biological Survey of Waters conducted by the MA Division of Fisheries and Wildlife indicates that Sam Tripp Brook supports both American eel (a commercially valuable species as described in Section 2.6) and brook trout (a recreationally valuable species as described in Section 2.6).[107] To the extent that the fish passage and water quality benefits generated by the culvert upgrade improve populations for these species, the project promotes both community and regional economic benefits by attracting increasing numbers of recreational anglers.

[104] Personal communication with Chris Gonsalves, Director of the Westport Highway Department, December 5, 2014. Distances estimated using Google Maps.

[105] Vehicle data obtained for nearby roads (including Adamsville Road, Charlotte White Road, and Main Road) from http://www.srpedd.org/manager/external/ckfinder/userfiles/resources/Transportation/Traffic%20Count%20Program/town/Westport.pdf.

[106] Personal communication with Betsy White, Westport River Watershed Alliance, December 5, 2014.

[107] Drift Road Stormwater Mitigation Project Proposal. Provided by MA DER to IEc, December 2014.

APPENDIX A:
ECONOMIC BENEFITS FROM MASSACHUSETTS INVESTMENTS IN GREEN INFRASTRUCTURE

IEc

MEMORANDUM | January 23, 2015

TO Tim Purinton, Hunt Durey, and Nick Wildman, MA Division of Ecological Restoration (DER)

FROM Industrial Economics, Inc.

SUBJECT Task 6: Economic Benefits of Other Green Infrastructure Investments

> "Green infrastructure is our nation's natural life support system – an interconnected network of waterways, wetlands, woodlands, wildlife habitats and other natural areas; greenways, parks and other conservation lands; working farms ranches and forests; and wilderness and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to the health and quality of life for America's communities and people."
>
> - Definition of green infrastructure developed by The Conservation Fund and USDA Forest Service Green

I. INTRODUCTION

Since its inception in 2009, DER has maintained a focus on better understanding and communicating the financial, economic, and social benefits of its restoration projects, including modeling impacts on regional employment and economic output, and conducting cost and benefit case studies. Under Task 6 of the *Economic Analysis of Ecological Restoration* contract, this memorandum broadly describes how different types of green infrastructure (GI) investments across the Commonwealth may result in and social and economic benefits. Specifically, we first identify linkages between the ecological improvements targeted by the green infrastructure investments and their consequent ecosystem service benefits. We then provide information on site-specific factors to consider in determining whether a given green infrastructure project is likely to generate a particular type of ecosystem service benefit. Finally, we provide an overview of analytic methods that may be employed and data that is needed to value these social and economic benefits. This information may assist DER and the MA Office of Energy and Environmental Affairs (EEA) in: 1) evaluating the potential cost-effectiveness of green infrastructure project alternatives; 2) determining what project-specific data may be helpful in evaluating the magnitude of ecosystem service benefits; and 3) scoping future economic analyses of green infrastructure programs and projects.

Green infrastructure approaches rely on conservation, restoration, enhancement, or creation of elements of the natural environment (e.g., forest conservation, wetland restoration, vegetating riparian areas, or planting gardens) to manage environmental degradation. Stormwater management and climate change adaptation are common objectives. Green infrastructure projects are defined by their dual focus on ecological as well as social and economic outcomes. That is, while traditional environmental quality management approaches – i.e., "gray infrastructure" such as wastewater treatment plants – serve a single purpose in mitigating pollution, green infrastructure projects work toward these same environmental goals while contributing to other community quality-of-life objectives, such as creating open space, improving property values, and supporting biodiversity. The USEPA emphasizes that the usefulness of adopting green infrastructure approaches is increasing as water resource management challenges grow with the increased incidences of extreme weather events associated with climate change (USEPA, 2014a).

Past studies of green infrastructure investments have routinely identified cost savings compared to gray infrastructure. Consequently, green infrastructure approaches are pragmatic for governments with limited resources where existing infrastructure is outdated. For example:

- A U.S. Environmental Protection Agency (USEPA) report on 17 green infrastructure stormwater management projects found that in most cases, green infrastructure was cheaper and performed better environmentally than traditional gray infrastructure (USEPA, 2014a).
- A 2010 review of green infrastructure stormwater management case studies (including rain gardens, tree planting, roadside swales, green roofs, wetland restoration, and native vegetation) found that, even absent ancillary social and economic benefits of the green infrastructure projects, these projects are cost-effective simply in terms of their direct cost savings when compared with traditional gray infrastructure. Specifically, the green infrastructure was, on average, approximately 24 percent more cost effective than gray infrastructure over a 30-year period (Jaffe, 2010).
- A frequently cited example of cost savings is the $1.5 billion investment New York City made for watershed protection in the Catskills, thus avoiding $4.0 to $6.0 billion on new water filtration and treatment plants (as cited, e.g., in Benedict and McMahon, 2002).

While the cost savings aspects of green infrastructure projects are well-established, fewer studies have focused on quantifying the numerous ecosystem service benefits they generate. A number of studies emphasize the need for more research focused on quantifying and monetizing social and economic values of these projects (e.g., CNT, 2010). A few studies provide insights into these ecosystem service benefits, for example:[1]

- A Natural Resources Defense Council (NRDC) Report evaluated the economic effects of integrating green infrastructure (including green roofs, tree plantings, rain gardens, and permeable pavement) in commercial and residential developments. The study found that retail centers, office centers, and apartment buildings with the green infrastructure were likely to experience increased retail sales, energy savings, reduced stormwater fees, increased property values, and reduced flood costs. Specifically, the total present value over 40 years of these benefits for both the office center and apartment buildings examples approached $2 million; the total present value of these benefits for the retail center exceeded $24 million (NRDC, 2013).
- An evaluation of a green infrastructure plan (potentially including green roofs, green streets, and engineered wetlands) for New York City estimated that, after a 20-year period, New Yorkers would receive between $139 million and $418 million in reduced energy bills, increased property values, and improved health (NYC DEP, 2010)
- A citywide green infrastructure Plan in Lancaster, Pennsylvania included tree planting, green roofs, bioretention and infiltration practices, permeable pavement, and water harvesting. Based on

[1] While numerous reports and articles exist that evaluate benefits of particular green infrastructure investments, for the purposes of this memorandum we present information on key findings of broader scope studies that focus on green infrastructure in general, or on large-scale green infrastructure plans.

20 demonstration projects, an economic benefits study estimated that, in addition to avoided costs of water quality treatment, the Plan would provide approximately $4.2 million in energy (reduced energy and natural gas usage), air quality (reduced air pollution impacts resulting from pollutant uptake), and climate-related (carbon sequestration) benefits annually. The analysis also noted but did not quantify potential benefits to property values, recreational opportunities, habitat improvement, and education and community cohesion (USEPA, 2014b).

The EEA is currently engaged in a variety of green infrastructure programs and projects across the Commonwealth. As highlighted in its previous analyses, DER has supported multiple dam removal, culvert replacement, wetland restoration, and stream flow management projects. The Office of Coastal Zone Management (CZM) administers the Green Infrastructure for Coastal Resilience Program through which it provides technical and financial resources for coastal resiliency-related green infrastructure projects. In 2014, for example, CZM supported a salt marsh restoration project in Martha's Vineyard involving living shoreline technology. Other projects have included dune restoration and protection (e.g., Breakwater Beach, Brewster and Popponesset Spit and Bay, Mashpee), and stream daylighting (e.g., Back River, Weymouth). As another example, the Department of Conservation and Recreation (DCR) is currently piloting a tree planting program in urban areas focused on lowering wind speeds and reducing summertime air temperature, as well as providing aesthetic benefits. EEA estimates that, in a 15-year timeframe, the benefits of reduced energy costs will justify the tree planting costs (MA EEA, 2014). As the prevalence of green infrastructure projects to manage water resources and climate resiliency grows, EEA requires information to better assess the impacts of these projects on people and communities.

II. LINKING ECOLOGICAL IMPROVEMENTS OF MA GREEN INFRASTRUCTURE PROJECTS WITH POTENTIAL ECONOMIC BENEFITS

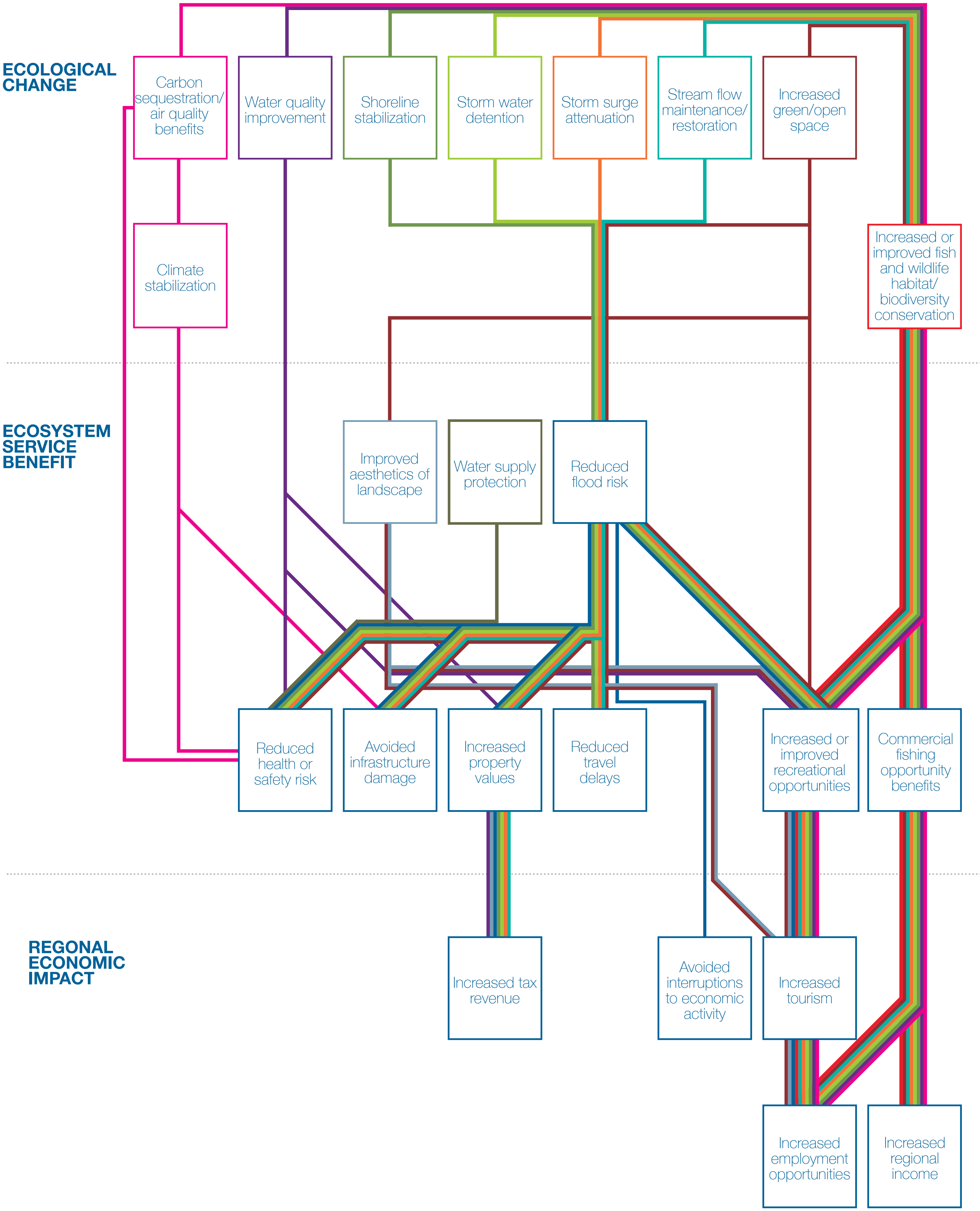
The remainder of this memorandum describes how the primary ecological improvements generated by EEA's green infrastructure projects may improve social and economic conditions in Massachusetts communities. Exhibit A provides a tiered demonstration of the potential benefits of EEA's green infrastructure investments.

- The first tier describes the key categories of direct biophysical or ecological improvements targeted by the green infrastructure projects. These objectives are interrelated with EEA's focus on climate change mitigation and adaptation (e.g., carbon sequestration, shoreline stabilization, storm water management, stream flow), human health (e.g., air and water quality), and improved quality or quantity of fish and wildlife habitat (e.g., stream flow restoration, increased green space/open space).
- The second tier of Exhibit A highlights the key ecosystem service benefits that flow from the ecological changes.
- The third tier shows the connection between the changes in ecosystem services and regional economic impacts. The regional economic impacts reflect changes in market activity. For example, increased open space and improved species populations may attract additional spending on recreation-related goods and services creates business opportunity, which may increase regional income, output, and employment opportunities. In addition, increased values of residential properties may generate additional tax revenue.

The latter two tiers (ecosystem service benefits and regional economic impacts) represent the social and economic benefits that are directly valued by people. Accordingly, analyses that seek to value the benefits of green infrastructure projects focus on the benefits described in these tiers of the flow chart. Of note, an evaluation of the benefits of green infrastructure projects does not necessarily require monetization of these categories. In some cases (e.g., comparing relative benefits of project alternatives), quantified measures of changes, such as numbers of properties expected to benefit or the size of the population benefitting from water security, are meaningful proxies.

Exhibit A also exemplifies that the value to people of different ecological improvements may be realized through similar behavioral changes. For example, nearly all of the ecological changes directly lead to improved species habitat conditions, which can increase participation in recreational (e.g., fishing, wildlife viewing) and commercial (e.g., fishing, aquaculture) activities. In addition, a number of ecological improvements to a property or community (e.g., reduced flood or human health risk, increased green space) may be realized as a premium on property values.

EXHIBIT A. LINKING ECOLOGICAL IMPROVEMENTS WITH ECOSYSTEM SERVICE BENEFITS



III. DATA AND METHODS TO EVALUATE BENEFITS OF GREEN INFRASTRUCTURE PROJECTS

The magnitude of ecosystem service benefits, as well as the data available to measure those benefits, are highly site-specific. While determining the specific value of potential benefits generally requires a project-specific evaluation, project characteristics that are relatively easily to observe may reveal whether or not it is likely to generate a particular type of benefit. It is also possible to generally characterize approaches and data that would be required to evaluate the ecosystem benefits of specific projects. To this end, Exhibit B presents the following:

- the categories ecosystem service benefits associated with EEA green infrastructure project types (developed under Exhibit A);
- the primary site-specific factors that most influence whether a project provides a given category of benefit, as well as the magnitude of those benefits; and
- potential methods and data that would be needed to value these benefits.

This information may be used by EEA in understanding whether the categories of benefit may be relevant to a project and what site-specific characteristics may affect their relative magnitude. For example, the relative public health benefit of water quality improvement projects can be determined considering: (1) the baseline water quality; (2) the particular water pollutants being reduced; (3) the level of pollution reduction; and (2) the size of the population benefitting from the reduction.

As noted above, a variety of project-specific studies have evaluated some categories of benefits of specific green infrastructure projects. Few studies, however, attempted a holistic accounting of benefits of green infrastructure investments, in general. However, of particular relevance, the Center for Neighborhood Technology (CNT) and American Rivers developed a "Guide" to the economic, environmental, and social benefits of green infrastructure (CNT, 2010). The Guide provides qualitative information on the types of benefits expected to be generated by various types of green infrastructure projects, and then presents illustrative examples of benefits calculations for a subset. We will not reiterate all of the examples and example results but note that the descriptions of benefits and valuation methods described are consistent with the information provided in this memorandum.

CNT also developed The National Green Values™ Calculator as a screening tool to assess the costs and benefits of green versus gray infrastructure in managing stormwater. The current version of the tool does not quantify the full suite of benefits expected to result from the project although the developers are looking to expand the tool in this direction. Currently, the benefits evaluated in the tool include: reduced air pollutants, CO2 sequestration, groundwater replenishment, the compensatory value of trees, reduced energy use, and reduced treatment benefits (CNT, 2009).[2]

Exhibit B also provides some examples of valuation methods that may be employed to evaluate benefits of given projects given the required data. Where the ecosystem service benefits are directly revealed in markets (e.g., commercial fishing activity), valuation is straightforward. In such cases, benefits are measured in terms of changes in productivity of the industry (**industry analysis**), and potentially the "multiplier effects" (**regional economic impacts**) in the economy. For non-market ecosystem services, however, economists rely on a variety of approaches to value changes.

[2] Of note, IEc did not independently review the data or methods employed in this model to verify validity. Additional information on the calculator is available at: http://greenvalues.cnt.org/national/calculator.php.

Avoided cost approaches are frequently referenced as a proxy for the value of some services: for example, avoided damages to properties associated with reduced flood risk. Similarly, the avoided costs of increased travel time due to flooded roads may be measured in terms of the value of the additional commuting time required (often measured as a fraction of the wage rate).

With respect to health benefits, **cost of illness approaches** may be used to estimate the economic benefits (avoided costs) of reduced morbidity, for example due to improved air and water quality. The cost of illness approaches may include the direct medical costs associated with an illness, the cost to society resulting from lost earnings, and the value of lost leisure time.

In the case of many ecological improvements, such as reduced flood risk, markets do not exist to provide direct measures of their value to people (i.e., people's "willingness-to-pay" (WTP) for the improvements). In these cases, economists utilize two groups of methods to estimate their value – "revealed preference" methods and "stated preference" methods.

"Revealed preference" methods involve observing choices people make in related markets to infer relative values for environmental attributes. For example, **travel cost models** are often used to estimate recreational use values by examining tradeoffs individuals make between costs of a recreational trip (e.g., fuel, equipment, and time costs) and trip attributes (e.g., water quality at a site). Another revealed preference method, **hedonic models**, relies on statistical analysis to relate the relative contribution of characteristics of a good to its market price. Hedonic studies may be used, for example, to quantify the impact of increased green space on the market value of neighboring residential properties by controlling for other factors (e.g., square footage, population density, or quality of school system) affecting the sales price.

While revealed preference studies can capture how people change behavior with respect to the use of a resource, they cannot capture values that do not necessarily affect people's behavior. For example, an individual may have a positive preference for water quality improvements even outside of his or her ability to drink, fish, swim, or view the water body. He or she may simply have a positive preference for healthy ecosystems or may wish to preserve the ecosystem for future generations ("non-use value"). This individual would therefore benefit from water quality improvements regardless of whether that benefit was observable through, for example, increased recreational activity. In these cases, "stated preference" methods that involve surveying populations to elicit information on relative preferences for a specific commodity or attribute can be used to estimate value.

"Stated preference" methods involve surveying populations to elicit information on relative preferences for the commodity or attribute being valued. These surveys ask respondents a series of hypothetical questions to derive information on WTP for a particular benefit. The surveys may be structured a variety of ways, including direct, open-ended questions focused on an individual's WTP or choice questions designed to gather information on the relative preferences of individual respondents. Stated preference studies are particularly useful in eliciting information on "non-use" values, that is values that individuals hold independent of any planned use of the commodity or attribute of interest. Stated preference studies have, for example, been designed to determine the magnitude of the non-use value from projects generating water quality improvements.

Primary research in the form of stated or revealed preference studies require significant time and effort to collect and evaluate original survey responses or behavioral data (e.g., recreational fishing trip behaviors and costs) from sample populations. It is accordingly common for economic analyses to instead leverage existing research employing, for example, stated preference methods, travel cost models and hedonic analysis to value ecosystem service benefits. The process of applying findings from previous studies to new analyses is called "benefit transfer." Accordingly, the methods described in the last column characterize primary research methods that may be applied to value these benefits, EEA may evaluate benefits of green infrastructure projects by conducting literature reviews of studies that employ these methods, and conducting benefit transfer.

To the extent that the ecosystem service benefits of green infrastructure investment affect markets, (e.g., increased recreators spending on goods and services in the region), economic analysis may also evaluate the regional economic impacts to interrelated economic sectors. Regional economic impact analysis relies on social accounting models, such as IMPLAN, to estimate the multiplier effects to industries that provide goods and services to the directly affected industry (i.e., "indirect and induced effects").[3] That is, increased productivity in the commercial fishing industry also benefits related economic sectors that support aquaculture production, such as fishing equipment, bait, etc.

Considerations in applying various methods to value disparate benefits of green infrastructure projects include avoiding double counting (e.g., by valuing both an intermediate and final benefit separately). For example, valuing carbon sequestration in terms of the avoided social cost of carbon in the atmosphere and avoided climate change-related flood damages may double count benefits as measures of the social cost of carbon frequently internalize costs of climate-related damages. Consequently, care must be taken in determining which benefit values are additive.

In conclusion, existing studies uniformly recognize the broad social and economic benefits provided by green infrastructure investments. Exhibits A and B of this memorandum characterize those benefits most likely to flow from EEA's green infrastructure projects, and demonstrates that a variety of methods and data sources are available that EEA may leverage to evaluate and compare its green infrastructure investments.

[3] IMPLAN is a software model and dataset of The IMPLAN Group. For more information: http://implan.com/.

EXHIBIT B. VALUATION METHODS AND POTENTIAL DATA NEEDS FOR EVALUATING ECOSYSTEM SERVICE BENEFITS OF GREEN INFRASTRUCTURE PROJECTS

ECOSYSTEM SERVICE BENEFIT	RELEVANT PROJECT TYPES	SITE-SPECIFIC FACTORS	VALUATION METHODS AND POTENTIAL DATA NEEDS TO SUPPORT ANALYSIS
Avoided Flood Damages	• Flood Risk Reduction [a]	• Numbers and types of properties subject to flooding • Flood depths associated with particular storm events	**Avoided Cost Approaches:** • Locations and types of development in flood area • Historical flood damage costs (e.g., FEMA or MEMA damage claims) - OR • Flood depths and depth-damage functions (e.g., the U.S. Army Corps of Engineers and FEMA both maintain data on depth-damage relationships)
Health and Safety Risk Reductions	• Flood Risk Reduction [a] • Water Quality Improvement [c] • Urban Landscaping/Tree Planting (i.e., Urban Heat Island Mitigation)	• Exposure pathways to contaminated resource or hazardous site • Size of population exposed	**Costs of Illness Analysis:** • Type of morbidity risk associated with contaminant/hazard • Morbidity rates (i.e., number of affected persons) • Medical expenses for morbidity type • Time losses at work and leisure associated with morbidity type
Property Values	• Flood Risk Reduction [a] • Water Quality Improvement [c] • Urban Park/Green Space Creation • Open Space Preservation • Wetland Restoration • Green Roofs	• Number, type, and baseline value of properties expected to benefit (e.g., the set of properties benefitting depends on the project type, e.g., homes within the vicinity of an improved water body or homes that moved from inside to outside of a floodplain following a project) • Type and magnitude of water quality benefit (water quality-related projects) • Baseline and post-project wetland acres in the region	**Hedonic Analysis:** • Measures of relevant water quality metrics before and after project implementation (for water quality projects) • Proxy for pre- and post-project flood risk • Number of homes experiencing property value benefits (based on geographic location with respect to the project area) • Baseline market values of homes experiencing property value benefits. • Hedonic studies defining the relationship between the particular green infrastructure projects (e.g., green roofs) and values of homes
Reduced Travel Delays	• Flood Risk Reduction [a]	• Miles of road affected • Numbers of trips/commuters (e.g.,	**Time Costs Analysis:** • Number of commuters/trips affected by flooding pre- and post-project • Increased waiting time or increased time associated with alternate route

ECOSYSTEM SERVICE BENEFIT	RELEVANT PROJECT TYPES	SITE-SPECIFIC FACTORS	VALUATION METHODS AND POTENTIAL DATA NEEDS TO SUPPORT ANALYSIS
		daily, seasonally) on the affected roads	• Measure of value of time spent traveling (e.g., the U.S. Department of Transportation provides specific guidance on how to value travel time)
Increased/ Improved Recreational Opportunities	• Habitat Provision/Protection and Biodiversity Conservation (most direct) • All air and water quality projects	• Number of recreators or trips for recreation (historical data) • Baseline and post-project extent of available habitat	**Travel Cost Analysis:** • Baseline extent of available habitat (e.g., stream miles or forest or wetland acres) • Post-project extent of available habitat • Type and magnitude of water quality improvement • Types and levels of recreational use of the water body before and after the project (e.g., trip numbers) • Trip-related expenditures by economic sector **Regional Economic Impact Analysis:** • Trip-related expenditures by economic sector • Number of trips
Increased Commercial Fishing Activities	• Habitat Provision/Protection and Biodiversity Conservation (most direct) • All air and water quality projects	• Statistics on affected fishery (e.g., information on the limiting factor in production, such as population level or regulatory limits)	**Industry Analysis:** • Supply and demand curves for relevant industries • Number of businesses affected • Effect of project on catch levels **Regional Economic Impact Analysis:** • Changes in revenues or costs of production in commercial fishing sector • Input-output model, such as IMPLAN or a regional fisheries-specific model.
Improved Landscape Aesthetics	• Tree Planting • Urban Park/Green Space Creation • Open Space Preservation • Wetland Restoration • Green Roofs	• Number, type, and baseline value of residential properties expected to benefit (e.g., the set of properties benefitting may be a subject of the literature (e.g., homes within one mile)	**Hedonic Analysis:** • Measures of relevant water quality metrics before and after project implementation (for water quality projects). • Proxy for pre- and post-project flood risk. • Number of homes experiencing property value benefits (based on geographic location with respect to the project area). • Baseline market values of homes experiencing property value benefits. • Hedonic studies defining the relationship between the particular green infrastructure projects (e.g., green roofs) and values of homes.
Water Supply Protection	• Floodplain restoration • Open space and forest protection • Riparian buffers • Streamflow restoration	• Extent of service area (population) of the water supply • Availability of substitute sources	**Avoided Costs:** • Costs of accessing substitute water resource (to utilities and resulting effect on average utility bills) • Size of population (e.g., households) affected

ECOSYSTEM SERVICE BENEFIT	RELEVANT PROJECT TYPES	SITE-SPECIFIC FACTORS	VALUATION METHODS AND POTENTIAL DATA NEEDS TO SUPPORT ANALYSIS
Regional Economic Impacts (e.g., employment, income, output, tax revenue)	• All	• Type and level of development attracted to the site (e.g., industrial, commercial, residential) due to the project • Type and level of activity increasing due to the project (e.g., recreation) • Type and level of commercial activity changing (e.g., aquaculture or commercial fishing) **Property Tax Effects:** • Number of properties benefitting	**Regional Economic Modeling:** • Type of development, recreational, or commercial activity occurring post project. • Expenditures on construction associated with a project; or expenditures on recreation-related goods and services; or increased productivity in economic sector • Regional input/output model (e.g., IMPLAN) **Tax Rate Calculations:** • Magnitude of property value benefit (hedonic methods, as noted above) • Relevant regional tax rates

<u>**TABLE NOTES**</u>

[a] **Green infrastructure project types that may result in flood risk reduction include:**

- Dam Removal
- Culvert Replacement (Tidal and Freshwater)
- Saltmarsh Restoration
- Bio-engineered shorelines
- Dune restoration
- Beach Renourishment
- Living Shoreline Creation
- Floodplain Restoration
- Open Space Protection
- Riparian Buffer Restoration
- Wetland Protection/Restoration
- Reforestation

[b] **Green infrastructure project types that aim to or may result in habitat provision and/or protection and biodiversity conservation include:**

- Dam Removal
- Culvert Replacement (Tidal and Freshwater)
- Saltmarsh Restoration
- Bio-engineered shorelines
- Dune restoration
- Beach Renourishment
- Living Shoreline Creation
- Floodplain Restoration
- Stream Daylighting
- Open Space Protection
- Riparian Buffer Restoration
- Wetland Protection/Restoration
- Soil Restoration
- Shellfish Bed/Reef Restoration or Creation

[c] **Green infrastructure project types that aim to or may result in water quality improvements include:**

- Dam Removal
- Culvert Replacement (Tidal and Freshwater)
- Saltmarsh Restoration
- Bio-engineered shorelines
- Dune restoration
- Floodplain Restoration
- Stream Daylighting
- Open Space Protection
- Riparian Buffer Restoration
- Wetland Protection/Restoration
- Reforestation
- Shellfish Bed, Reef Creation
- Seagrass Restoration
- Streamflow Restoration
- Urban Park Creation
- Roof Gardens

ECOSYSTEM SERVICE BENEFIT	RELEVANT PROJECT TYPES	SITE-SPECIFIC FACTORS	VALUATION METHODS AND POTENTIAL DATA NEEDS TO SUPPORT ANALYSIS
	• Urban River Revitalization • Reforestation • Urban Park/Green Space Creation		

IV. REFERENCES

(Benedict and McMahon, 2002) Benedict, Mark A. and Edward T. McMahon. Autumn 2002. Green Infrastructure: Smart Conservation for the 21st Century. *Renewable Resources Journal* 20(3): 12-17.

(CNT, 2009) Center for Neighborhood Technology. June 30, 2009. National Green Values ™ Calculator Methodology. http://greenvalues.cnt.org/national/downloads/methodology.pdf

(CNT, 2010) Center for Neighborhood Technology and American Rivers. 2010. "The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental, and Social Benefits."

(Jaffe, 2010) Jaffe, Martin. December 2010. Reflections on Green Infrastructure Economics. *Environmental Practice* 12(4).

(MA EEA, 2014) Massachusetts Executive Office of Energy and Environmental Affairs. October 2014 Proposal to: Massachusetts Energy Efficiency New Technology Assessment. "Tree Canopy Cover in Residential Areas."

(NRDC, 2013) Natural Resources Defense Council. December 2013. "The Green Edge: How Commercial Property Investments in Green Infrastructure Creates Value." R: 13-11-C.

(NYC DEP, 2010) New York City Department of Environmental Protection. 2010. NYC Green Infrastructure Plan: A Sustainable Strategy for Clean Waterways.

(USEPA, 2014a) U.S. Environmental Protection Agency, Office of Sustainable Communities. October 2014. "Enhancing Sustainable Communities with Green Infrastructure." EPA 100-R-14-006.

(USEPA, 2014b) U.S. Environmental Protection Agency, Green Infrastructure Technical Assistance Program. February 2014. "The Economic Benefits of Green Infrastructure: A Case Study of Lancaster, PA." EPA 800-R-14-007.

APPENDIX B:
MA DER PROJECT TRACKING FOR ECONOMIC BENEFIT

IEc

MEMORANDUM | January 20, 2015

TO Nick Wildman, Hunt Durey, and Tim Purinton, MA Division of Ecological Restoration (DER)

FROM Industrial Economics, Inc.

SUBJECT Task 7: Project Tracking Memo for MA DER

I. INTRODUCTION

DER requires practical, reliable, and traceable performance metrics to monitor progress and support outcome analyses of DER projects. DER also requires a system (currently in development) to collect and track the data needed to support these metrics. In the long run, this will help DER evaluate project outcomes and report the benefits to the public and policymakers.

Under Task 7 of the *Economic Analysis of Ecological Restoration* contract, IEc is advising DER on the selection and use of new performance metrics, and suggesting augmentations to DER's system for tracking project costs and benefits. In fulfillment of Task 7, this memo provides IEc's recommendations in each of these areas: performance metrics (Section 2) and metrics database (Section 3).

II. PERFORMANCE METRICS

Through the end of December 2014, DER tracked two metrics for its projects – i) river miles restored and ii) wetland acres restored – and also tracked DER project spending and co-funding. Going forward, DER would like to develop and track additional performance metrics to better evaluate and communicate project performance. These new metrics should be meaningful, useful, and practical to collect, balancing the need for data with the level of effort required to collect the data. To this end, we recommend that DER adopt a four-step approach for developing new performance metrics. In the rest of this section, we describe the four steps, the rationale for each step, and how the steps fit together. The exhibit at the end of this memo highlights examples of how to apply the four steps for selected project/benefit types.

FOUR-STEP APPROACH FOR DEVELOPING PERFORMANCE METRICS

1. **Develop a project classification framework.** DER is currently developing a framework to classify project sites by impact area (ecosystem type) and intervention (project type); additionally, we suggest that DER include geographic area (e.g., county) as a third category. Once completed, the classification framework will enable DER to better define and segment projects in its tracking system. As discussed in the metrics database section below, the system would assign each project to a particular (predefined) category based on its impact area, intervention type, and geographic area. Clustering projects into unique categories will enable DER to prioritize and track those benefits that are most relevant for each project. In other words, rather than tracking all metrics for every project, DER can focus its attention on the subset of metrics that are most applicable to each project, based on the project category. This system will ensure that DER collects the most important benefits data for each project while minimizing the time and effort spent collecting data for non-essential metrics.

2. **Define the benefits for each project category.** Under Task 6 of this project, IEc is helping DER better understand the types of benefits that may be generated by investments in restoration and green infrastructure projects and methods and data that may support quantification of these benefits. Benefits of the various project types can be mapped to the classification scheme (Step 1) to identify the metrics that may be tracked for each project category. For example, flood risk may be a critical benefit to track for dam removal projects in densely populated areas, but less important for culvert replacements outside of residential or commercial zones. Mapping project benefits (Step 2) to project categories (Step 1) will describe which benefits may be evaluated, and therefore what metrics should be tracked, for each type of project.

3. **Develop SMART metrics for each benefit type**. After defining the project categories (Step 1) and the benefits for each category (Step 2), we recommend that DER develop performance metrics for each benefit. Whereas Step 2 defines the types ecological and economic benefits that DER seeks to achieve (e.g., reduced flood risk), Step 3 will provide operational definitions of each benefit, and specific indicators against which success can be measured. For example, performance metrics for reduced flood risk could include: number of people, homes, or businesses in a flood area; size of the flood area; incidence of floods within a given time period; and/or the probability of a flood occurring within the next three years. While individual metrics will vary across benefit categories, we recommend that, in general, DER follow the principles for "SMART" performance metrics, as shown in Exhibit 1. We anticipate that many of DER's metrics will be quantified but not monetized – e.g., number of houses that benefit from reduced flood risk, but not the monetized avoided flood damages. Monetizing the benefits would require additional analyses beyond routine project tracking; however, the data collected through regular project tracking will provide a solid foundation for conducting more in-depth analyses.

EXHIBIT 1. CHARACTERISTICS OF SMART PERFORMANCE METRICS

Specific: What condition or situation is the project targeting for improvement? How will the project influence the situation?

Measurable: How much influence or change does DER expect to achieve as a result of the project (quantify if possible)? How will DER know when the project achieves its target?

Attainable: How realistic is the target? Is the target likely to be met?

Relevant: How important, timely, and worthwhile is the target?

Time-bound: By what date (or how far in the future) are results expected to occur?

4. **Determine data requirements, availability, and collection strategies.** After determining the performance metrics that DER will track for each benefit category, DER will need to identify: the data required to inform or "populate" each metric; the availability of baseline data (and how to collect it if not already available); and how monitoring data will be collected during and after the project. Baseline and monitoring data are both essential for calculating DER's impact. For example, measuring *changes* in flood risk requires data on the flood zone area or number of people in the flood zone when the project was initiated, and the change in these values over time.

   - **Baseline data:** Best practice indicates that DER should collect baseline data during the project approval stage, prior to implementation. To this end, we recommend that DER require grant applicants to provide baseline data during the application process, as a condition for project funding. While this would entail some additional effort upfront, it would generally be less difficult – and more reliable – than attempting to reconstruct the baseline later on. For projects that are already underway, we recommend that DER assess what baseline data already exist or can easily be obtained. In some cases, DER may need to "backfill" the baseline in order to measure changes for projects that are already in progress. Determinations about how much effort to expend on backfilling baseline data for existing projects can be made on a case-by-case basis (e.g., depending on the project's size and importance).

- **Monitoring data:** DER also needs to collect data on an ongoing basis to measure changes from the baseline. This is necessary (though *not* usually sufficient, given the presence of confounding factors[1]) to show how DER is "moving the needle" relative to selected performance metrics and benefits. To the greatest extent possible, DER should build tracking requirements into grant agreements, and should consider making these data a factor in prioritizing potential projects to support. DER also needs to consider the required tracking frequency (e.g., monthly, quarterly, or yearly), and for how long it will continue to collect data after projects end. For DER-funded projects aiming to realize lasting environmental and economic benefits, we anticipate that post-project tracking (years after projects end) will often be necessary. Depending on the number of years that DER plans to monitor progress after projects close, it should consider the feasibility of withholding final grant payment until grantees submit the more important, required post-project data. DER could also provide incentives for ongoing reporting by providing grantees with benefits information in exchange for data. For example, DER could share its impact methodology and results with grantees that submit post-project tracking data.

- **How much is enough?** Because the data required to support outcome metrics may be difficult and time-consuming to collect, we do *not* recommend tracking all possible outcome data for every project. Instead, we suggest that DER adopt a tiered measurement approach, whereby DER would track basic descriptive information for every project – e.g., intervention time, location, impact area, expected benefits, DER expenditures, and co-funding (Tier 1), and more detailed information for projects meriting an in-depth analysis (Tier 2). Selection criteria for Tier 2 projects could include: project size (expenditures), impact potential, public visibility, and/or learning opportunities. DER could collect primary data and conduct in-depth analyses for Tier 2 projects, while for Tier 1 projects DER could apply "rules of thumb" from the literature. As noted above, the goal is to strike a balance between obtaining useful data and minimizing the time and resources required to collect the data.

USING METRICS DATA TO ANALYZE OUTCOMES

As discussed in the previous section, collecting metrics data is necessary but not sufficient for understanding the outcomes of DER-funded projects. While collecting the data is a critical first step in the process, our experience with other agencies shows that *having* data does not automatically translate to *using* the data appropriately. Before collecting large amounts of data, DER should clarify the data's intended purpose. Thinking through the intended uses of the data upfront will help DER avoid several common pitfalls in the collection and use of metrics data:

[1] Confounding factors are variables outside of DER's direct control that may influence the outcome of DER-funded projects – e.g., changes in technology, the economy, and/or the policy environment. Because confounding factors may reinforce or run counter to DER's project goals, it is important to document these factors (and control for them, to the extent possible) when analyzing DER's impact. As such, a simple "before-and-after" comparison is not usually sufficient to quantify DER's impacts.

- **Pitfall #1: Data is collected but not used.** Mitigation: Clarify internally, and with grantees why DER is collecting data and how it will be used. For example, will the data fulfill DER's reporting requirements and/or support better project management? Will the data be used internally and/or communicated to policymakers and the general public?
- **Pitfall #2: Data quality is too poor to support robust analysis.** Mitigation: Develop standard data collection forms to support clear and consistent tracking. Provide grantees with clear reporting instructions. Review new data submissions to ensure quality, and follow up with grantees in a timely fashion to clarify any data gaps or anomalies.
- **Pitfall #3: Data is not accessible or not analyzable.** Mitigation: Design a metrics system that not only collects data, but has the capacity to export the data and facilitate analysis. We recently worked with a government agency in Massachusetts that is collecting detailed project data, but is unable to get the data out of the system; as such, much of the data collected by this agency is unusable. This pitfall could have been avoided by specifying the data's intended use at the outset, and by designing queries and "canned" reports that export important data fields with the click of a button. Please see our recommendations in the "metrics database" section below for more details.
- **Pitfall #4: Data is used "as is" without analysis or interpretation.** Mitigation: Realize that analyzing project outcomes requires more than simply exporting data from the database. For example, if DER wants to compare project costs across projects or project types, it will need to monetize the benefits in common terms (e.g., adjust the costs to the same dollar year). If the goal is to describe DER's impact on environmental or economic conditions, confounding variables (e.g., general economic trends) should be documented, and controlled for, if possible. Limitations in the analysis or the underlying data should be specified and communicated when sharing the results.
- **Pitfall #5: Analysis of the data is not well-communicated.** Communicating analytical results in a clear and compelling way requires different skills than collecting and analyzing data. We have consulted for many clients who initially believed that their facts and figures would speak for themselves, but later realized that their message was not "landing" with their target audiences. While Task 8 of the current project focuses on effective outreach, here we briefly note a few key factors for effective communication of data. These include: identifying the target audience; understanding the audience's priorities and data-needs; tailoring the description of the data for each audience; and using simple and compelling data visuals. For example, as DER noted at the outset of the project, a detailed report with lots of data and methods discussion may be required for environmental policy analysts, but less effective for communicating DER's economic impact to the Governor's office.

Having described the four steps for developing performance metrics – and common pitfalls to avoid when collecting, using, and reporting the data – the next section provides IEc's recommendations for DER's metrics database.

III. Metrics Database

A well-designed metrics database can be a useful tool for classifying, tracking, analyzing, and reporting on DER-funded projects. Ideally, the database should record all project activities and financial expenditures, both planned and actual.[2] In addition, it should be structured to facilitate analysis on multiple dimensions of performance that are of interest to DER.

DER is in the process of developing a new metrics database in Access. IEc reviewed the database on-site at DER's offices on December 22, 2014. At that time, the database was a work in progress, but already included several tables, forms, and queries. Based on our cursory review, and our understanding of DER's intended use of the database, we offer the following recommendations to augment the database:

- **Use the database to categorize projects and identify relevant benefit categories.** As discussed above in Section 1, we suggest that DER develop a project classification framework (Step 1), and identify the most relevant benefits for each project category (Step 2). DER could use the database to assign projects to the appropriate categories and track the relevant benefits. The database would do this by asking project managers to specify the impact area, intervention, and geographic area for each project. DER may also consider having the project manager specify the targeted benefit of the project so that, in the future, metrics associated with that benefit are prioritized over other, ancillary project benefits. Based on the data provided by the project manager, the database would automatically assign projects to the appropriate category – and managers would only be asked to report the benefits associated with the selected category. This approach would minimize data collection by only requiring relevant benefits data for each project; in addition, automating the process would ensure consistency in how projects are classified.

- **Capture changes in project status and performance while preserving original records.** We understand that a project's status may change over time – e.g., if DER adopts a new type of intervention at the site. In addition, we expect the values for many performance metrics will change during and after the project (e.g., miles of roads subject to flooding). The database should allow DER to create a new record when conditions change, *without* overwriting the previous records. In other words, the tables "behind" the forms in the database should have multiple records for the same project – one record for each point in time (including the date when each record was created). Preserving the original data when conditions change is important for maintaining a "paper trail" on project activities, and is essential for conducting trend analysis.

- **Each project should be assigned a unique identifier.** With project data being recorded in multiple tables – and multiple records per table over time – it is important to be able to find all relevant information for a given project, quickly and reliably. For example, DER should be able to find a project's intervention type, expenditure data, and all relevant metrics data without manually reviewing every table in the database. An easy and reliable method is to assign a unique identifier to each project. Querying on the unique identifier will allow DER to "pull" all relevant information from the database for a particular project.

- **Develop automated queries and reports to facilitate use and identify data issues.** For reporting purposes – and to ensure that DER reviews and uses the data that it collects – consider developing automated queries and reports for key performance and cost metrics. For example, DER could use queries to pull cumulative project-level expenditure data, or to show new expenditures since the last quarter. DER could run these queries on a quarterly or semi-annual basis without considerable time or effort. In addition, DER could develop queries to identify

[2] See the Mekong Wetlands Biodiversity Conservation and Sustainable Use Programme's *Monitoring & Evaluation Systems Manual*, Section 3.3 (April 2005): www.mekongwetlands.org/assets/programme/Systems/M&E%20manual.pdf.

potential issues with the quality or substance of the data. For example, a query could show all projects with expenditures outside of a predefined range of values, alerting project managers to possible data entry errors, and/or unexpectedly high or low expenditures.

- **Align cost variables with IMPLAN sectors to support IMPLAN analysis.** The “Forecasting” table in DER’s new database shows the project cost by phase of work. Ensuring consistency between the data entered in these fields and IMPLAN sectors will support IMPLAN analysis in the future. Exhibit B describes the 440 sectors available in IMPLAN, highlighting those most likely to be relevant to DER projects.

EXHIBIT A. EXAMPLE METRICS, DATA REQUIREMENTS, AND DATA SOURCES FOR SELECTED BENEFIT CATEGORIES

STEP 1	STEP 2	STEP 3	STEP 4	
DER PROJECT CLASSIFICATION	BENEFIT CATEGORIES	POTENTIAL PERFORMANCE METRICS	POTENTIAL DATA SOURCES	COLLECTION FREQUENCY
• Dam Removal • Culvert Replacement (freshwater and tidal) • Saltmarsh Restoration • Tidal flow restoration • Stream flow restoration	Reduced flood damage	• Size (area) of flood zone • No. of buildings/residences in flood zone • No. of persons residing in flood zone • Flood depths (e.g., for two, 20, and 100 year storm events) • Flood frequency rate • Property damage per flood ($) • Miles of road in flood zone • No. of lives lost per flood • No. of injuries per flood	• Flood damage analysis • HEC-HMS hydrologic modeling • MIKE FLOOD hydraulic modeling • GIS floodplain inundation mapping Flood damage analysis • Local GIS residential parcel data • Local GIS land use/land cover data • Town Assessor's property value data	• Before (ideally historic data included) and after project • Follow-up every 3 years
	Improved conditions for recreation / tourism	• No. of visitors • Satisfaction of visitors	• Vehicle counters • Permit or license counts (e.g., fishing) • Field survey of no. of visitors and their satisfaction	• Before (ideally historic data included) and after seasonal estimates • Seasonal estimates annually following project
• Stream flow restoration	Water Supply Protection	• No. of individuals in service area of water supply • Treatment costs ($) • Average water utility rates ($)	• Local utilities	• Before (ideally historic data included) and after seasonal estimates • Seasonal estimates annually following project
• Saltmarsh Restoration	Climate stabilization	• Carbon storage and sequestration rates • Soil depth and biomass levels	• Monitoring data (site-specific or from similar site) • Available scientific literature on average sequestration rates	• Before (ideally historic data included) and after • Annual

Exhibit B. IMPLAN V3 Sectoring Scheme

IMPLAN Sector	IMPLAN Description	2007 NAICS	2002 NAICS	2002 to 2007 NAICS Changes
1	Oilseed farming	11111-2	11111-2	
2	Grain farming	11113-6, 11119	11113-6, 11119	
3	Vegetable and melon farming	1112	1112	
4	Fruit farming	11131-2,111331-4, 111336*, 111339	11131-2,111331-4, 111336*, 111339	
5	Tree nut farming	111335, 111336*	111335, 111336*	
6	Greenhouse, nursery, and floriculture production	1114	1114	
7	Tobacco farming	11191	11191	
8	Cotton farming	11192	11192	
9	Sugarcane and sugar beet farming	11193, 111991	11193, 111991	
10	All other crop farming	11194, 111992, 111998	11194, 111992, 111998	111998* (except algae, seaweed and other plant aquaculture)
11	Cattle ranching and farming	11211, 11213	11211, 11213	
12	Dairy cattle and milk production	11212	11212	
13	Poultry and egg production	1123	1123	
14	Animal production, except cattle and poultry and eggs	1122, 1124-5, 1129	1122, 1124-5, 1129	111998* (algae, seaweed and other plant aquaculture)
15	Forest nurseries, forest products, and timber tracts	1131-2	1131-2	
16	Logging	1133	1133	
17	Fishing	1141	1141	
18	Hunting and trapping	1142	1142	
19	Support activities for agriculture and forestry	115	115	
20	Oil and gas extraction	211	211	
21	Coal mining	2121	2121	
22	Iron ore mining	21221	21221	
23	Copper, nickel, lead, and zinc mining	21223	21223	
24	Gold, silver, and other metal ore mining	21222, 21229	21222, 21229	
25	Stone mining and quarrying	21231	21231	
26	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	21232	21232	
27	Other nonmetallic mineral mining and quarrying	21239	21239	
28	Drilling oil and gas wells	213111	213111	
29	Support activities for oil and gas operations	213112	213112	
30	Support activities for other mining	213113-5	213113-5	
31	Electric power generation, transmission, and distribution	2211	2211	
32	Natural gas distribution	2212	2212	
33	Water, sewage and other systems	2213	2213	
34	Construction of new nonresidential commercial and health care structures	23*	23*	
35	Construction of new nonresidential manufacturing structures	23*	23*	
36	Construction of other new nonresidential structures	23*	23*	
37	Construction of new residential permanent site single- and multi-family structures	23*	23*	
38	Construction of other new residential structures	23*	23*	
39	Maintenance and repair construction of nonresidential maintenance and repair	23*	23*	
40	Maintenance and repair construction of residential structures	23*	23*	
41	Dog and cat food manufacturing	311111	311111	
42	Other animal food manufacturing	311119	311119	
43	Flour milling and malt manufacturing	31121	31121	
44	Wet corn milling	311221	311221	
45	Soybean and other oilseed processing	311222-3	311222-3	
46	Fats and oils refining and blending	311225	311225	
47	Breakfast cereal manufacturing	311230	311230	
48	Sugar cane mills and refining	311311-2	311311-2	
49	Beet sugar manufacturing	311313	311313	
50	Chocolate and confectionery manufacturing from cacao beans	31132	31132	
51	Confectionery manufacturing from purchased chocolate	31133	31133	
52	Nonchocolate confectionery manufacturing	31134	31134	
53	Frozen food manufacturing	31141	31141	
54	Fruit and vegetable canning, pickling, and drying	31142	31142	
55	Fluid milk and butter manufacturing	311511-2	311511-2	
56	Cheese manufacturing	311513	311513	
57	Dry, condensed, and evaporated dairy product manufacturing	311514	311514	
58	Ice cream and frozen dessert manufacturing	311520	311520	
59	Animal (except poultry) slaughtering, rendering, and processing	311611-3	311611-3	
60	Poultry processing	311615	311615	
61	Seafood product preparation and packaging	3117	3117	
62	Bread and bakery product manufacturing	31181	31181	
63	Cookie, cracker, and pasta manufacturing	31182	31182	

IMPLAN Sector	IMPLAN Description	2007 NAICS	2002 NAICS	2002 to 2007 NAICS Changes
64	Tortilla manufacturing	31183	31183	
65	Snack food manufacturing	31191	31191	
66	Coffee and tea manufacturing	31192	31192	
67	Flavoring syrup and concentrate manufacturing	31193	31193	
68	Seasoning and dressing manufacturing	31194	31194	
69	All other food manufacturing	31199	31199	
70	Soft drink and ice manufacturing	31211	31211	
71	Breweries	31212	31212	
72	Wineries	31213	31213	
73	Distilleries	31214	31214	
74	Tobacco product manufacturing	3122	3122	
75	Fiber, yarn, and thread mills	3131	3131	
76	Broadwoven fabric mills	31321	31321	
77	Narrow fabric mills and schiffli machine embroidery	31322	31322	
78	Nonwoven fabric mills	31323	31323	
79	Knit fabric mills	31324	31324	
80	Textile and fabric finishing mills	31331	31331	
81	Fabric coating mills	31332	31332	
82	Carpet and rug mills	31411	31411	
83	Curtain and linen mills	31412	31412	
84	Textile bag and canvas mills	31491	31491	
85	All other textile product mills	31499	31499	*31521 (empbroidery contractors)
86	Apparel knitting mills	31511, 31519	31511, 31519	
87	Cut and sew apparel contractors	31521	31521	*31521 (exc. embroidery contractors)
88	Men's and boys' cut and sew apparel manufacturing	31522	31522	
89	Women's and girls' cut and sew apparel manufacturing	31523	31523	
90	Other cut and sew apparel manufacturing	31529	31529	
91	Apparel accessories and other apparel manufacturing	3159	3159	
92	Leather and hide tanning and finishing	3161	3161	
93	Footwear manufacturing	3162	3162	
94	Other leather and allied product manufacturing	3169	3169	
95	Sawmills and wood preservation	3211	3211	
96	Veneer and plywood manufacturing	321211-2	321211-2	
97	Engineered wood member and truss manufacturing	321213-4	321213-4	
98	Reconstituted wood product manufacturing	321219	321219	
99	Wood windows and doors and millwork	32191	32191	
100	Wood container and pallet manufacturing	32192	32192	
101	Manufactured home (mobile home) manufacturing	321991	321991	
102	Prefabricated wood building manufacturing	321992	321992	
103	All other miscellaneous wood product manufacturing	321999	321999	
104	Pulp mills	32211	32211	
105	Paper mills	32212	32212	
106	Paperboard Mills	32213	32213	
107	Paperboard container manufacturing	32221	32221	
108	Coated and laminated paper, packaging paper and plastics film manufacturing	322221-2	322221-2	
109	All other paper bag and coated and treated paper manufacturing	322223-6	322223-6	
110	Stationery product manufacturing	32223	32223	
111	Sanitary paper product manufacturing	322291	322291	
112	All other converted paper product manufacturing	322299	322299	
113	Printing	32311	32311	
114	Support activities for printing	32312	32312	
115	Petroleum refineries	32411	32411	
116	Asphalt paving mixture and block manufacturing	324121	324121	
117	Asphalt shingle and coating materials manufacturing	324122	324122	
118	Petroleum lubricating oil and grease manufacturing	324191	324191	
119	All other petroleum and coal products manufacturing	324199	324199	
120	Petrochemical manufacturing	32511	32511	
121	Industrial gas manufacturing	32512	32512	
122	Synthetic dye and pigment manufacturing	32513	32513	
123	Alkalies and chlorine manufacturing	325181	325181	
124	Carbon black manufacturing	325182	325182	
125	All other basic inorganic chemical manufacturing	325188	325188	
126	Other basic organic chemical manufacturing	32519	32519	
127	Plastics material and resin manufacturing	325211	325211	
128	Synthetic rubber manufacturing	325212	325212	
129	Artificial and synthetic fibers and filaments manufacturing	32522	32522	
130	Fertilizer manufacturing	325311-4	325311-4	

IMPLAN Sector	IMPLAN Description	2007 NAICS	2002 NAICS	2002 to 2007 NAICS Changes
131	Pesticide and other agricultural chemical manufacturing	325320	325320	
132	Medicinal and botanical manufacturing	325411	325411	
133	Pharmaceutical preparation manufacturing	325412	325412	
134	In-vitro diagnostic substance manufacturing	325413	325413	
135	Biological product (except diagnostic) manufacturing	325414	325414	
136	Paint and coating manufacturing	32551	32551	
137	Adhesive manufacturing	32552	32552	
138	Soap and cleaning compound manufacturing	32561	32561	
139	Toilet preparation manufacturing	32562	32562	
140	Printing ink manufacturing	32591	32591	
141	All other chemical product and preparation manufacturing	32592, 32599	32592, 32599	
142	Plastics packaging materials and unlaminated film and sheet manufacturing	32611	32611	
143	Unlaminated plastics profile shape manufacturing	326121	326121	
144	Plastics pipe and pipe fitting manufacturing	326122	326122	
145	Laminated plastics plate, sheet (except packaging), and shape manufacturing	32613	32613	
146	Polystyrene foam product manufacturing	32614	32614	
147	Urethane and other foam product (except polystyrene) manufacturing	32615	32615	
148	Plastics bottle manufacturing	32616	32616	
149	Other plastics product manufacturing	32619	32619	*32619 (exc. Inflatable plastic boats)
150	Tire manufacturing	32621	32621	
151	Rubber and plastics hoses and belting manufacturing	32622	32622	
152	Other rubber product manufacturing	32629	32629	*32629 (exc. Inflatable rubber boats)
153	Pottery, ceramics, and plumbing fixture manufacturing	32711	32711	
154	Brick, tile, and other structural clay product manufacturing	327121-3	327121-3	
155	Clay and nonclay refractory manufacturing	327124-5	327124-5	
156	Flat glass manufacturing	327211	327211	
157	Other pressed and blown glass and glassware manufacturing	327212	327212	
158	Glass container manufacturing	327213	327213	
159	Glass product manufacturing made of purchased glass	327215	327215	
160	Cement manufacturing	32731	32731	
161	Ready-mix concrete manufacturing	32732	32732	
162	Concrete pipe, brick, and block manufacturing	32733	32733	
163	Other concrete product manufacturing	32739	32739	
164	Lime and gypsum product manufacturing	3274	3274	
165	Abrasive product manufacturing	32791	32791	
166	Cut stone and stone product manufacturing	327991	327991	
167	Ground or treated mineral and earth manufacturing	327992	327992	
168	Mineral wool manufacturing	327993	327993	
169	Miscellaneous nonmetallic mineral products	327999	327999	
170	Iron and steel mills and ferroalloy manufacturing	3311	3311	
171	Steel product manufacturing from purchased steel	33121, 33122	33121, 33122	
172	Alumina refining and primary aluminum production	331311-2	331311-2	
173	Secondary smelting and alloying of aluminum	331314	331314	
174	Aluminum product manufacturing from purchased aluminum	331315, 331316, 331319	331315, 331316, 331319	
175	Primary smelting and refining of copper	331411	331411	
176	Primary smelting and refining of nonferrous metal (except	331419	331419	
177	Copper rolling, drawing, extruding and alloying	33142	33142	
178	Nonferrous metal (except copper and aluminum) rolling,	33149	33149	
179	Ferrous metal foundries	33151	33151	
180	Nonferrous metal foundries	33152	33152	
181	All other forging, stamping, and sintering	332111-2, 332117	332111-2, 332117	
182	Custom roll forming	332114	332114	
183	Crown and closure manufacturing and metal stamping	332115-6	332115-6	
184	Cutlery, utensil, pot, and pan manufacturing	332211, 332214	332211, 332214	
185	Handtool manufacturing	332212-3	332212-3	
186	Plate work and fabricated structural product manufacturing	33231	33231	
187	Ornamental and architectural metal products manufacturing	33232	33232	
188	Power boiler and heat exchanger manufacturing	33241	33241	
189	Metal tank (heavy gauge) manufacturing	33242	33242	

IMPLAN Sector	IMPLAN Description	2007 NAICS	2002 NAICS	2002 to 2007 NAICS Changes
190	Metal can, box, and other metal container (light gauge) manufacturing	33243	33243	
191	Ammunition manufacturing	332992-3	332992-3	
192	Arms, ordnance, and accessories manufacturing	332994-5	332994-5	
193	Hardware manufacturing	3325	3325	
194	Spring and wire product manufacturing	3326	3326	
195	Machine shops	33271	33271	
196	Turned product and screw, nut, and bolt manufacturing	33272	33272	
197	Coating, engraving, heat treating and allied activities	3328	3328	
198	Valve and fittings other than plumbing	332911-2, 332919	332911-2, 332919	
199	Plumbing fixture fitting and trim manufacturing	332913	332913	
200	Ball and roller bearing manufacturing	332991	332991	
201	Fabricated pipe and pipe fitting manufacturing	332996	332996	
202	Other fabricated metal manufacturing	332997-9	332997-9	
203	Farm machinery and equipment manufacturing	333111	333111	
204	Lawn and garden equipment manufacturing	333112	333112	
205	Construction machinery manufacturing	33312	33312	
206	Mining and oil and gas field machinery manufacturing	33313	33313	
207	Other industrial machinery manufacturing	33321, 333291-4, 333298	33321, 333291-4, 333298	*339111 (laboratory distilling equipment)
208	Plastics and rubber industry machinery manufacturing	33322	33322	
209	Semiconductor machinery manufacturing	333295	333295	
210	Vending, commercial, industrial, and office machinery manufacturing	333311-3	333311-3	
211	Optical instrument and lens manufacturing	333314	333314	
212	Photographic and photocopying equipment manufacturing	333315	333315	
213	Other commercial and service industry machinery manufacturing	333319	333319	
214	Air purification and ventilation equipment manufacturing	333411-2	333411-2	
215	Heating equipment (except warm air furnaces) manufacturing	333414	333414	
216	Air conditioning, refrigeration, and warm air heating equipment manufacturing	333415	333415	*339111 (laboratory freezers)
217	Industrial mold manufacturing	333511	333511	
218	Metal cutting and forming machine tool manufacturing	333512-3	333512-3	
219	Special tool, die, jig, and fixture manufacturing	333514	333514	
220	Cutting tool and machine tool accessory manufacturing	333515	333515	
221	Rolling mill and other metalworking machinery manufacturing	333516, 333518	333516, 333518	
222	Turbine and turbine generator set units manufacturing	333611	333611	
223	Speed changer, industrial high-speed drive, and gear manufacturing	333612	333612	
224	Mechanical power transmission equipment manufacturing	333613	333613	
225	Other engine equipment manufacturing	333618	333618	
226	Pump and pumping equipment manufacturing	333911, 333913	333911, 333913	
227	Air and gas compressor manufacturing	333912	333912	
228	Material handling equipment manufacturing	333921-4	333921-4	
229	Power-driven handtool manufacturing	333991	333991	
230	Other general purpose machinery manufacturing	333992, 333997, 333999	333992, 333997, 333999	*339111 (laboratory scales and balances, laboratory centrifuges)
231	Packaging machinery manufacturing	333993	333993	
232	Industrial process furnace and oven manufacturing	333994	333994	*339111 (laboratory furnaces and ovens)
233	Fluid power process machinery	333995-6	333995-6	
234	Electronic computer manufacturing	334111	334111	
235	Computer storage device manufacturing	334112	334112	
236	Computer terminals and other computer peripheral equipment manufacturing	334113, 334119	334113, 334119	
237	Telephone apparatus manufacturing	33421	33421	
238	Broadcast and wireless communications equipment	33422	33422	
239	Other communications equipment manufacturing	33429	33429	
240	Audio and video equipment manufacturing	3343	3343	
241	Electron tube manufacturing	334411	334411	
242	Bare printed circuit board manufacturing	334412	334412	
243	Semiconductor and related device manufacturing	334413	334413	

IMPLAN Sector	IMPLAN Description	2007 NAICS	2002 NAICS	2002 to 2007 NAICS Changes
244	Electronic capacitor, resistor, coil, transformer, and other inductor manufacturing	334414-6	334414-6	
245	Electronic connector manufacturing	334417	334417	
246	Printed circuit assembly (electronic assembly) manufacturing	334418	334418	
247	Other electronic component manufacturing	334419	334419	
248	Electromedical and electrotherapeutic apparatus manufacturing	334510	334510	
249	Search, detection, and navigation instruments manufacturing	334511	334511	
250	Automatic environmental control manufacturing	334512	334512	
251	Industrial process variable instruments manufacturing	334513	334513	
252	Totalizing fluid meters and counting devices manufacturing	334514	334514	
253	Electricity and signal testing instruments manufacturing	334515	334515	
254	Analytical laboratory instrument manufacturing	334516	334516	
255	Irradiation apparatus manufacturing	334517	334517	
256	Watch, clock, and other measuring and controlling device manufacturing	334518-9	334518-9	
257	Software, audio, and video media reproducing	334611-2	334611-2	
258	Magnetic and optical recording media manufacturing	334613	334613	
259	Electric lamp bulb and part manufacturing	33511	33511	
260	Lighting fixture manufacturing	33512	33512	
261	Small electrical appliance manufacturing	33521	33521	
262	Household cooking appliance manufacturing	335221	335221	
263	Household refrigerator and home freezer manufacturing	335222	335222	
264	Household laundry equipment manufacturing	335224	335224	
265	Other major household appliance manufacturing	335228	335228	
266	Power, distribution, and specialty transformer manufacturing	335311	335311	
267	Motor and generator manufacturing	335312	335312	
268	Switchgear and switchboard apparatus manufacturing	335313	335313	
269	Relay and industrial control manufacturing	335314	335314	
270	Storage battery manufacturing	335911	335911	
271	Primary battery manufacturing	335912	335912	
272	Communication and energy wire and cable manufacturing	33592	33592	
273	Wiring device manufacturing	33593	33593	
274	Carbon and graphite product manufacturing	335991	335991	
275	All other miscellaneous electrical equipment and component manufacturing	335999	335999	
276	Automobile manufacturing	336111	336111	
277	Light truck and utility vehicle manufacturing	336112	336112	
278	Heavy duty truck manufacturing	336120	336120	
279	Motor vehicle body manufacturing	336211	336211	
280	Truck trailer manufacturing	336212	336212	
281	Motor home manufacturing	336213	336213	
282	Travel trailer and camper manufacturing	336214	336214	
283	Motor vehicle parts manufacturing	3363	3363	
284	Aircraft manufacturing	336411	336411	
285	Aircraft engine and engine parts manufacturing	336412	336412	
286	Other aircraft parts and auxiliary equipment manufacturing	336413	336413	
287	Guided missile and space vehicle manufacturing	336414	336414	
288	Propulsion units and parts for space vehicles and guided missiles	336415, 336419	336415, 336419	
289	Railroad rolling stock manufacturing	3365	3365	
290	Ship building and repairing	336611	336611	
291	Boat building	336612	336612	
292	Motorcycle, bicycle, and parts manufacturing	336991	336991	
293	Military armored vehicle, tank, and tank component manufacturing	336992	336992	
294	All other transportation equipment manufacturing	336999	336999	
295	Wood kitchen cabinet and countertop manufacturing	33711	33711	
296	Upholstered household furniture manufacturing	337121	337121	
297	Nonupholstered wood household furniture manufacturing	337122	337122	
298	Metal and other household furniture manufacturing	337124-5, 337129	337124-5, 337129	
299	Institutional furniture manufacturing	337127	337127	
300	Office furniture manufacturing	337211, 337214	337211, 337214	

IMPLAN Sector	IMPLAN Description	2007 NAICS	2002 NAICS	2002 to 2007 NAICS Changes
301	Custom architectural woodwork and millwork manufacturing	337212	337212	
302	Showcase, partition, shelving, and locker manufacturing	337215	337215	
303	Mattress manufacturing	33791	33791	
304	Blind and shade manufacturing	33792	33792	
305	Surgical and medical instrument manufacturing	339112	339112	
306	Surgical appliance and supplies manufacturing	339113	339113	
307	Dental equipment and supplies manufacturing	339114	339114	
308	Ophthalmic goods manufacturing	339115	339115	
309	Dental laboratories	339116	339116	
310	Jewelry and silverware manufacturing	33991	33991	
311	Sporting and athletic goods manufacturing	33992	33992	
312	Doll, toy, and game manufacturing	33993	33993	
313	Office supplies (except paper) manufacturing	33994	33994	
314	Sign manufacturing	33995	33995	
315	Gasket, packing, and sealing device manufacturing	339991	339991	
316	Musical instrument manufacturing	339992	339992	
317	All other miscellaneous manufacturing	339993, 339995, 339999	339993, 339995, 339999	
318	Broom, brush, and mop manufacturing	339994	339994	
319	Wholesale trade	42	42	
320	Retail - Motor vehicle and parts	441	441	
321	Retail - Furniture and home furnishings	442	442	
322	Retail - Electronics and appliances	443	443	
323	Retail - Building material and garden supply	444	444	
324	Retail - Food and beverage	445	445	
325	Retail - Health and personal care	446	446	
326	Retail - Gasoline stations	447	447	
327	Retail - Clothing and clothing accessories	448	448	
328	Retail - Sporting goods, hobby, book and music	451	451	
329	Retail - General merchandise	452	452	
330	Retail - Miscellaneous	453	453	
331	Retail - Nonstore	454	454	
332	Air transportation	481	481	
333	Rail transportation	482	482	
334	Water transportation	483	483	
335	Truck transportation	484	484	
336	Transit and ground passenger transportation	485	485	
337	Pipeline transportation	486	486	
338	Scenic and sightseeing transportation and support activities for transportation	487, 488	487, 488	
339	Couriers and messengers	492	492	
340	Warehousing and storage	493	493	
341	Newspaper publishers	51111	51111	
342	Periodical publishers	51112	51112	
343	Book publishers	51113	51113	
344	Directory, mailing list, and other publishers	51114, 51119	51114, 51119	
345	Software publishers	51121	51121	
346	Motion picture and video industries	5121	5121	
347	Sound recording industries	5122	5122	
348	Radio and television broadcasting	5151	5151	
349	Cable and other subscription programming	5152	5152	
350	Internet publishing and broadcasting	51913	516	Is now 51913 (includes 2002:518112)
351	Telecommunications	517	517	Now includes 5181 (broadband ISP; telephone ISP)
352	Data processing, hosting, and related services	518	5182	Now 518 as 5181 was defined away
353	Other information services	51911-2, 51919	519	Is now 51911-2 as 51913 was created out of 516
354	Monetary authorities and depository credit intermediation	521, 5221	521, 5221	
355	Nondepository credit intermediation and related activities	5222-3	5222-3	
356	Securities, commodity contracts, investments, and related activities	523	523	
357	Insurance carriers	5241	5241	
358	Insurance agencies, brokerages, and related activities	5242	5242	
359	Funds, trusts, and other financial vehicles	525	525	52599 Other financial vehicles (52593 defined away)
360	Real estate	531	531	(Includes 52593)
361	Imputed rental value for owner-occupied dwellings	n.a.	n.a.	
362	Automotive equipment rental and leasing	5321	5321	
363	General and consumer goods rental except video tapes and discs	53221-2, 53229, 5323	53221-2, 53229, 5323	

IMPLAN Sector	IMPLAN Description	2007 NAICS	2002 NAICS	2002 to 2007 NAICS Changes
364	Video tape and disc rental	53223	53223	
365	Commercial and industrial machinery and equipment rental and leasing	5324	5324	
366	Lessors of nonfinancial intangible assets	533	533	
367	Legal services	5411	5411	
368	Accounting, tax preparation, bookkeeping, and payroll services	5412	5412	
369	Architectural, engineering, and related services	5413	5413	
370	Specialized design services	5414	5414	
371	Custom computer programming services	541511	541511	
372	Computer systems design services	541512	541512	
373	Other computer related services, including facilities management	541513, 541519	541513, 541519	
374	Management, scientific, and technical consulting services	54161, 561312*	54161	Is now 54161, 5613*
375	Environmental and other technical consulting services	54162, 54169	54162, 54169	
376	Scientific research and development services	5417	5417	
377	Advertising and related services	5418	5418	
378	Photographic services	54192	54192	
379	Veterinary services	54194	54194	
380	All other miscellaneous professional, scientific, and technical services	54191, 54193, 54199	54191, 54193, 54199	
381	Management of companies and enterprises	55	55	
382	Employment services	5613 (except part 561312*)	5613	part of 561312 moved to 374
383	Travel arrangement and reservation services	5615	5615	
384	Office administrative services	5611	5611	
385	Facilities support services	5612	5612	
386	Business support services	5614	5614	
387	Investigation and security services	5616	5616	
388	Services to buildings and dwellings	5617	5617	
389	Other support services	5619	5619	
390	Waste management and remediation services	562	562	
391	Elementary and secondary schools	6111	6111	
392	Junior colleges, colleges, universities, and professional schools	6112-3	6112-3	
393	Other educational services	6114-7	6114-7	
394	Offices of physicians, dentists, and other health practitioners	6211-3	6211-3	
395	Home health care services	6216	6216	
396	Medical and diagnostic labs and outpatient and other ambulatory care services	6214-5, 6219	6214-5, 6219	
397	Hospitals	622	622	
398	Nursing and residential care facilities	623	623	
399	Child day care services	6244	6244	
400	Individual and family services	6241	6241	
401	Community food, housing, and other relief services,	6242-3	6242-3	
402	Performing arts companies	7111	7111	
403	Spectator sports	7112	7112	
404	Promoters of performing arts and sports and agents for public figures	7113-4	7113-4	
405	Independent artists, writers, and performers	7115	7115	
406	Museums, historical sites, zoos, and parks	712	712	
407	Fitness and recreational sports centers	71394	71394	
408	Bowling centers	71395	71395	
409	Amusement parks, arcades, and gambling industries	7131-2	7131-2	
410	Other amusement and recreation industries	71391-3, 71399	71391-3, 71399	
411	Hotels and motels, including casino hotels	72111-2	72111-2	
412	Other accommodations	72119, 7212-3	72119, 7212-3	
413	Food services and drinking places	722	722	
414	Automotive repair and maintenance, except car washes	81111-2, 811191, 811198	81111-2, 811191, 811198	
415	Car washes	811192	811192	
416	Electronic and precision equipment repair and maintenance	8112	8112	
417	Commercial and industrial machinery and equipment repair and maintenance	8113	8113	
418	Personal and household goods repair and maintenance	8114	8114	
419	Personal care services	8121	8121	
420	Death care services	8122	8122	
421	Dry-cleaning and laundry services	8123	8123	
422	Other personal services	8129	8129	
423	Religious organizations	8131	8131	
424	Grantmaking, giving, and social advocacy organizations	8132, 8133	8132, 8133	

IMPLAN Sector	IMPLAN Description	2007 NAICS	2002 NAICS	2002 to 2007 NAICS Changes
425	Civic, social, professional, and similar organizations	8134, 8139	8134, 8139	
426	Private households	814	814	
427	Postal service	491	491	
428	Federal electric utilities	n.a.	n.a.	
429	Other Federal Government enterprises	n.a.	n.a.	
430	State and local government passenger transit	n.a.	n.a.	
431	State and local government electric utilities	n.a.	n.a.	
432	Other state and local government enterprises	n.a.	n.a.	
433	*Not an industry (Used and secondhand goods)	n.a.	n.a.	
434	*Not an industry (Scrap)	n.a.	n.a.	
435	*Not an industry (Rest of the world adjustment)	n.a.	n.a.	
436	*Not an industry (Noncomparable imports)	n.a.	n.a.	
437	Employment and payroll for SL Government Non-Education	n.a.	n.a.	
438	Employment and payroll for SL Government Education	n.a.	n.a.	
439	Employment and payroll for Federal Non-Military	n.a.	n.a.	
440	Employment and payroll for Federal Military	n.a.	n.a.	