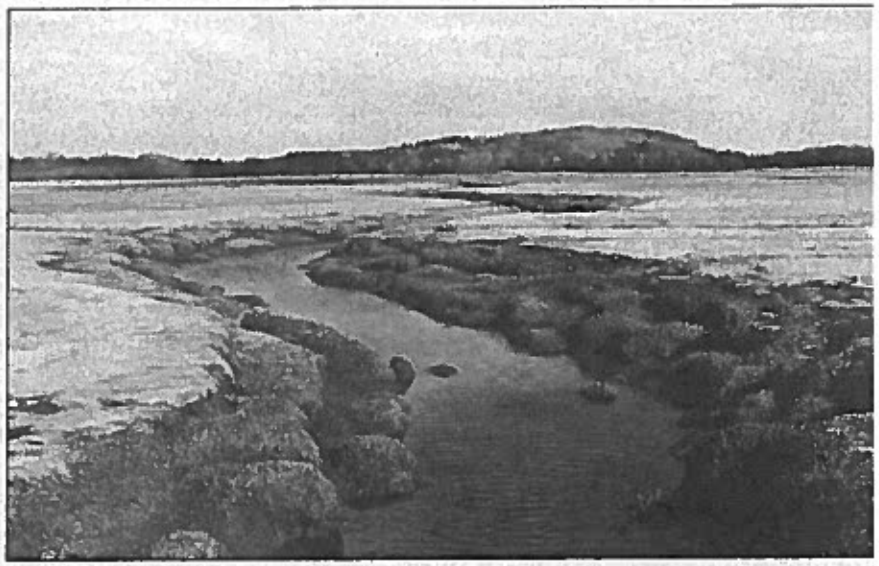
Tidal Crossing Handbook

A Volunteer Guide to Assessing Tidal Restrictions



Timothy A. Purinton and David C. Mountain, Ph.D.

Parker River Clean Water Association

Table of Contents

Acknowledgments

This project would not have been possible without all of the Parker River Clean Water Association's Turn the Tide Volunteers. Likewise, this handbook owes much of its organization and clarity to careful and thoughtful reviews by Barbara Bereman and Becka Roolf. We owe a special thank-you to Christy Foote-Smith of the Massachusetts Wetlands Restoration and Banking Program for sharing her program's data with us and to Michelle Vallencourt who did the lion's share of the work in organizing the Salt Marsh Forum where our work was presented to the public. We would also like to thank our colleagues who carefully reviewed earlier drafts of this handbook: Vicky Boundy, Charles Katuska, and Rob Stevenson.

Funding for the PRCWA tidal restriction study and the production of this handbook was provided by US Environmental Protection Agency through the Eight Towns and the Bay Committee of the Massachusetts Bays Program and through the Gulf of Maine Council for the Marine Environment.

Gulf of Maine
Council on the
Marine Environment

For more information on the Parker River Clean Water Association and the Parker River or to order the Tidal Crossing Inventory and Assessment Report or more copies of this handbook, write:

Parker River Clean Water Association
P.O. Box 823
Byfield, MA 01922 USA

or visit our web site at:
http://engc.bu.edu/~dcm/prcwhome.html

Introduction

The Parker River Clean Water Association (PRCWA) is an independent, non-profit organization dedicated to promoting the restoration and protection of the ecological integrity of the Parker River, Plum Island Sound, their tributary streams, and adjacent lands. The Parker River–Plum Island Sound Basin covers 82 square miles in northeastern Massachusetts and contains extensive salt marshes. A large portion of the marsh area is protected by organizations such as the Parker River National Wildlife Refuge, the Massachusetts Division of Fisheries and Wildlife, the Trustees of Reservations, the Massachusetts Audubon Society, and Essex County Greenbelt.

Unfortunately, some portions of the marsh in the basin are showing signs of degradation such as the presence of invasive plant species or the appearance of upland vegetation. Since these changes are often the result of altered tidal flow, the PRCWA began, in the spring of 1996, to develop a method to assess potential tidal restrictions. In the summer of 1996, the PRCWA received a contract from the Eight Towns and the Bay Committee, the regional governance committee of the Massachusetts Bays Program, to assess over 125 tidal crossings along the coast from the New Hampshire border to Gloucester, Massachusetts. This region includes approximately 40% of all the tidal wetlands in Massachusetts. The results of this study are summarized in The Tidal Crossing Inventory and Assessment Report (PRCWA, 1996). Sites that appeared to be significantly impeding tidal flow were identified and brought to the attention of local municipal officials.

Massachusetts map showing eight towns in the bay study area.

This work led to a subsequent contract with the Gulf of Maine Council on the Marine Environment that funded refinement of the methodology and public outreach activities. As part of the outreach program, the PRCWA worked with the Massachusetts Wetlands Restoration and Banking Program to put on a public forum explaining the value of tidal wetlands and summarizing our findings. The product of this contract is the publication of this handbook, which is designed to disseminate the methodology developed by the PRCWA to other volunteer-based efforts along the coast of the Gulf of Maine and elsewhere.

There is, no doubt, still much room for improvement in our assessment methodology, and we encourage groups that conduct their own tidal restriction studies to give us their comments and suggestions.

References

Parker River Clean Water Association (1996). Tidal Crossings Inventory and Assessment.

To obtain copies contact: The Eight Towns and the Bay Committee, c/o Merrimack Valley Planning Commission, 160 Main St., Haverhill, MA 01830.

Chapter I

The Salt Marsh: A Place to Value and Protect

Why are Salt Marshes Important?

"The peaceful grandeur of a large estuarine salt marsh masks the orgy of biological activity taking place in and around it. It is an eco-truism that this community is one of the most biologically productive on the planet, crucial to the well-being of an astonishing range of organisms, from lowly bacteria and marine fishes to migratory birds and the great hominid ape."

—Leaby et al. (1996)

The productivity of salt marshes and associated mud flats rivals that of the tropical rain forest. The staggering amount of detritus (fragments of material created by disintegration) produced by the marsh grasses is used by a wide spectrum of organisms.

Dead salt-marsh grass is broken down by bacteria and fungi, producing a natural compost that is consumed by a wide range of detritivores (detritus-consuming organisms). Detritivores such as crab larvae provide food for small fish which in turn provide food for larger fish such as striped bass and bluefish. These larger fish are in turn consumed by species such as ospreys and humans.

Salt marshes are home to state and federal rare and endangered wildlife and plant species. In Massachusetts, for example, the threatened bird species include the American bittern, the northern harrier, the peregrine falcon, the shorteared owl, the common tern, and the least tern.

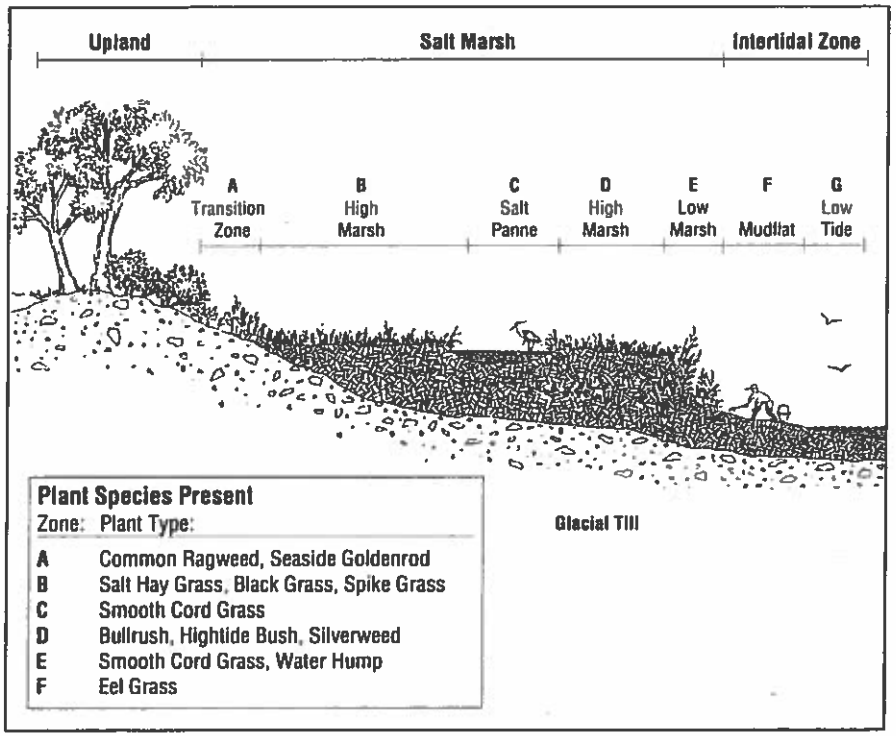


Figure 1. Cross section of a typical Gulf of Maine salt marsh.

The economies of our coastal communities depend in many ways on salt marshes. Salt marshes provide food as well as important spawning and nursery areas for species crucial to the commercial and recreational fish and shellfish industries. An estimated 71% of the dockside value of fish landed in the United States is derived from fish species that depend directly or indirectly on coastal wetlands (US EPA, 1993).

The income generated by bird watchers and ecotourism is crucial to many coastal communities and is growing rapidly. Salt hay production provides additional significant income. Salt marshes also provide coastal flood control, pollution abatement, and an aesthetic appeal that has inspired artists for years.

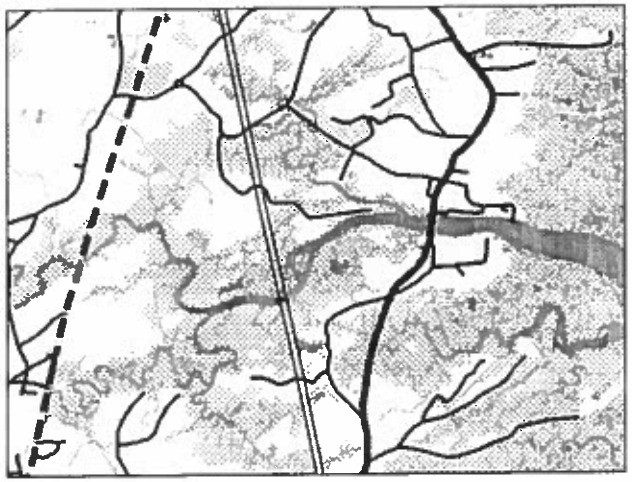
The importance of preserving the ecological integrity of the salt marsh can be measured by the role that marshes play in the global economy. It is estimated that the value of estuaries globally is in the order of $4,000,000,000,000 per year (Costanza et al., 1997). This is estimated by placing a value upon such factors as how estuaries regulate disturbances, cycle nutrients, create biological control, create habitat, produce food and raw materials, and provide recreational and cultural opportunities. Imagine attempting to engineer, from scratch, all the functions of a salt marsh. Nature's services are clearly essential to our health and our planet's well-being.

Figure 2. Salt haystack, circa 1910. Salt hay is still an important crop for many coastal farms (photograph courtesy of Ruth Alexander).

Restricting the Tide: *Roads and Railroads Across the Marsh*

Before European colonization of North America, there were uninterrupted salt marshes all along most suitable areas of coastline. Many Native Americans relied on the marshes and estuaries to provide food, especially where it was difficult to obtain from upland areas. Early settlers depended on the marshes to feed

their cattle and to supplement their diet with wild fish and game, and the coastal rivers and streams were important transportation routes for Native Americans and colonists alike. As the settlements grew, however, roads and railways were built all along the coast to facilitate overland transportation of people and goods. Many of today's roads correspond to these early farm and trade routes. Early settlers generally avoided crossing tidal wetlands, although at times it was necessary to transverse the salt marsh to link nearby portions of upland. Since the advent of the automobile and railroads, however, coastal routes have often been straightened, built on fill deposited in wetlands, and placed where they cut across vast acres of marshland to satisfy the desire for high speed travel.



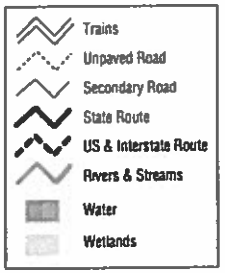


Figure 3. Roads that cross salt marshes can restrict the flow in tidal creeks and rivers.

Where roads and railroads cross tidal creeks, bridges and culverts are often installed to accomodate the flow of water. However, bridges may have an opening which is not wide enough to pass enough tidal water to maintain salt and brackish marshes further upstream (WRBP, 1996). Roads which cross small creeks often have culverts installed to allow passage of tidal waters beneath the roadway. Historically, the

culverts were built like boxes, constructed of large granite slabs. More recently, however, cylindrical corrugated metal culverts have become ubiquitous. In many cases, these culverts are too small to pass sufficient tidal water to maintain the upstream salt-marsh vegetation.

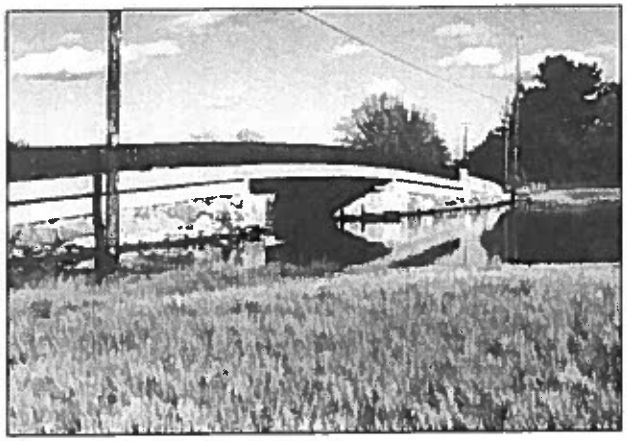


Figure 4. Example of a bridge with a span that is considerably less than the width of the river channel.

A tidal crossing, for purposes of this handbook, is a culvert or bridge that allows tides to flow under a road or railroad. Many crossings skirt the transition zone between salt marsh and upland, and these sites were not defined as tidal crossings. A tidal restriction is a tidal crossing that limits water from freely passing from the upstream to the downstream salt marsh and vice versa. Generally there are two ways in which a crossing becomes restrictive. The first is when the opening is too small and sufficient water can not move through to equalize water levels on both sides of the crossing. The second is if the culvert is positioned too high, reducing tidal range by preventing drainage as the tide drops below the culvert.

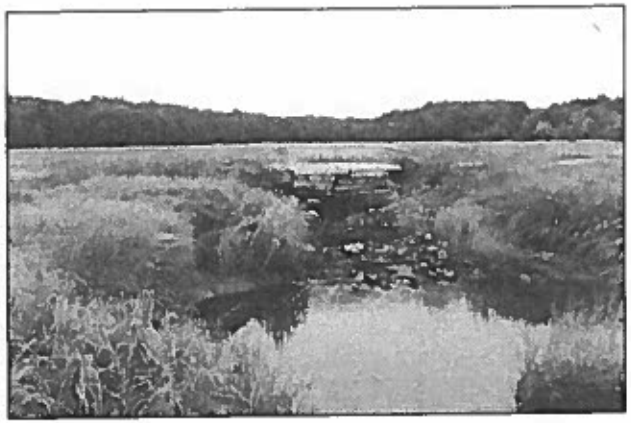


Figure 5. Example of an undersized culvert located well above the low tide level.

In addition to reducing the tidal range, restricted tidal flow and stream blockage caused by poor crossing maintenance can reduce access to tidal marshes by estuarine organisms. Reduced access prevents use of the affected marshes by important bottom-tier food-chain fish species, such as mummichogs (*Fundulus heteroclitus*). Also, culverts that are too long can be a problem for some migratory aquatic species who need light for passage. In addition, the export of organic matter from the salt marshes, a vital life-support function for the detritus-based food web of estuarine and marine environments, is reduced or eliminated where tidal exchange is restricted or cut off by a tide gate, a flapper valve, or a dike.

Ecological Change

"The dangers to salt marshes stem from human activities, not natural processes. Fish and birds have evolved depending on finding marshes all along the coast, wherever they wander. The preservation of a few marshes here and there will not serve for their existence."

—John and Mildred Teal (1969)

The hydrologic changes caused by a restrictive crossing can significantly alter the integrity and productivity of the upstream salt marshes. Poor drainage due to restrictions can reduce root aeration. Flooded, anaerobic soils (soils that have little or no oxygen) may result in stunted plant growth, and in some cases death of vegetation.

A restriction in tidal flow can alter the balance of fresh and salt water, changing a saline environment into a brackish or fresh water one. The "freshening" of salt marshes can cause a major transformation in the vegetation. Salt-marsh grasses and rushes can be displaced by the common reed (*Phragmites australis*) or in some cases by upland species. Common reed often forms a monoculture of tall reeds (up to 12 feet), leading to both lowered plant diversity and a change in vegetative structure (from a low grassy meadow to a tall reedy thicket).

Figure 6. Cedar trees invading a salt marsh due to reduced tidal flow.

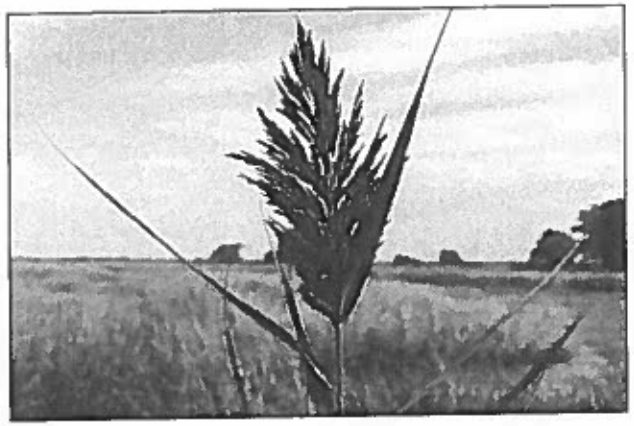


*Figure 7. Common reed (*Phragmites australis*).*

The effect that spreading phragmites has upon salt-marsh wildlife is not well understood and is currently under close scientific scrutiny. It is commonly believed that no species will seek out phragmites over the native salt-marsh habitat and that rare and endangered species do not utilize phragmites in any portion of their life cycle.

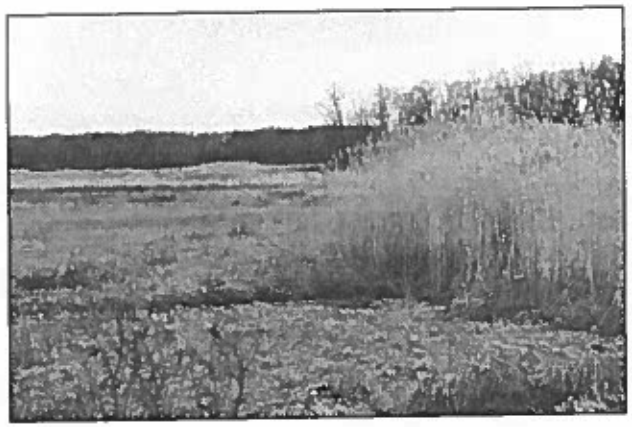


Figure 8. Phragmites invading a salt marsh.

The National Research Council has recently identified habitat modification as one of the major factors threatening the integrity of coastal ecosystems. The impact of human activities on coastal ecosystems has

become a topic of great concern due to the closing of shellfish beds and the decline of our marine fisheries. In Massachusetts alone, it is estimated that 20,000 acres, or 1/3 of the salt marsh, has been lost to human impact between 1945 and the mid 1970s (Leahy et al., 1996).

Get Involved

Preserving the marsh's natural tidal range is the key to maintaining productivity. The cycle of inundation and drainage of the marsh is essential to the vitality of salt-marsh plant species. Unfortunately, in spite of increasing threats to salt marshes and other wetlands, federal and state resource protection agencies across America are cutting back on field assessment projects. If we are to protect our valuable natural resources, citizens' groups and local governments must take the lead through community-based environmental protection and restoration projects. These projects must be based on reliable data and sound methodology. The goal of this handbook is to assist volunteer groups in implementing a field-based methodology for the collection of information on tidal crossings. The methodology should be both exciting and educational, and at the same time produce valid data. The following chapters outline the PRCWA methodology for assessing tidal restrictions and provide a guide on taking action towards improving salt marsh habitat in your area.

References:

US Environmental Protection Agency. ***Wetlands Fact Sheet #4: Economic Benefits of Wetlands.*** *Washington, DC (1993).*

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.B., Sutton, P., and van den Belt, M. ***The Value of the World's Ecosystem Services and Natural Capital.*** *Nature 387:253-260 (1997).*

Leahy, C., Mitchell, J.H., and Conuel, T. ***The Nature of Massachusetts.*** *Addison-Wesley Publishing Company, Inc., Reading, MA (1996).*

Teal, J. and Teal, M. ***Life and Death of the Salt Marsh.*** *Little, Brown and Company, Boston (1969).*

Massachusetts Wetlands Restoration and Banking Program. ***Atlas of Tidally Restricted Marshes: North Shore of Massachusetts.*** *Copies can be obtained from the Executive Office of Environmental Affairs, 100 Cambridge Street - 20th Floor, Boston, MA 02202 (1996).*

Chapter II
Getting Started

Introduction

Once you've decided that you want to get your community involved, it's time to get started educating the public, recruiting volunteers, and doing the assessment. In this chapter we provide an overview of the assessment methodology, explain how to locate and inventory tidal crossings, give suggestions for educating the public about the values of salt marshes and the challenges to their integrity, and provide information on how to recruit volunteers.

Overview of the Methodology

Maximizing efficiency and accuracy can be difficult when assessing an environmental problem, particularly when working with volunteers. These challenges can be overcome by breaking down a larger project into manageable portions. Accordingly, we have broken our evaluation of tidal crossings into three phases, to be overseen by a Tidal Crossing Coordinator.

Phase I consists of locating crossings and performing a preliminary, visual assessment that determines which crossings are potentially restrictive. The goal of Phase I is to inventory the crossings and to identify those that need more quantitative evaluation. This may be done by volunteers or by the coordinator.

Phase II is based on an intensive, day-long monitoring effort. The goal of Phase II is to provide quantitative data on the impact of the crossing on tidal range. Volunteers measure the tides every two hours, at each of several crossings, over a complete tidal cycle

(approximately 12 hours). We billed this intensive effort as "Turn the Tide Day."

Phase III consists of analyzing the data obtained from Phase II and formulating recommendations for changes that can be made to improve tidal flow. The goal of Phase III is to provide information and recommendations to local officials and citizens that will lead to elimination of the identified restrictions.

While you do not need to adhere strictly to the phased approach to assess individual crossings, we believe you will find this structure to be particularly helpful in assessing many sites in a short period of time.

The role of the Tidal Crossing Coordinator is essential in organizing a volunteer effort. This handbook is designed primarily for the Tidal Crossing Coordinator, and it is up to the coordinator to determine the degree of volunteer participation.

Before working with the volunteers, the coordinator should run through the procedures of Phases I and II at several sample sites. This will give the coordinator a sense of what types of situations may arise.

With this experience in mind, consider how committed your volunteers are. Will they want to go out in the field twice—to perform preliminary assessment (Phase I) and again to complete the tidal monitoring (Phase II)? If you are analyzing a small number of sites, you and/or your volunteers could complete both phases for all sites. However, if you have a large number of sites, the visual assessment of Phase I will help you to target sites that are potentially restrictive for monitoring in Phase II. It is not advisable to do both the Phase I and Phase II work on the same day due to time constraints.

If you choose to have volunteers do only Phase II, then the Tidal Crossing Coordinator will need to complete Phase I well before Phase II is scheduled.

Inventory

The first step in implementing a tidal crossing assessment program is to create a list of all tidal crossings in the study area. A good starting point is the USGS topographical maps of the region. A careful examination of roads and railroads will enable you to locate most crossings of tidal rivers and streams. This can be done by first locating the contour that corresponds to the high tide level in your area and then locating all reaches of rivers and streams that are at lower elevations. Wherever these river and stream reaches are crossed by a road or railroad, there is the potential for a tidal restriction. It is important to get out in the field to confirm these locations and look for crossings that are either too new to appear on the maps or too small (such as driveways) to have been included on the maps. You may also find that crossings near the edge of the tidal region may have been misclassified as either tidal or nontidal.

The first step in implementing a tidal crossing assessment program is to create a list of all tidal crossings in the study area.

You will need an easy-to-use referencing system for each site. We used a referencing system that was developed on a town-by-town basis, where each crossing was labeled with an abbreviation for the town and a number for each crossing in the town. For example, N5 represented the fifth crossing studied in the town of Newbury. It is also important to note which water body the road or railroad spans, the street name (indicate town, county or state road), and any distinguishing nearby landmarks. If a large number of sites are to be studied, we recommend that the inventory be put into a computer database for ease of retrieval and sorting.

Public Outreach

There are many ways of educating the public, and specifically your potential volunteers, about the detrimental effects that tidal restrictions have on saltmarshes. One method is to hold a public forum and

invite local ecologists and environmentalists to illustrate the importance of biodiversity and ecological protection. Another is to call a small meeting of your volunteers and demonstrate through slides and open dialogue the concerns and consequences over lack of tidal flow. Painting a broad picture of the concepts and illustrating the pressing threats will build a conceptual foundation that will be reinforced by a field training session.

An outline of an informational session is included below. Slides or overheads work well for illustrating your points, but require some prior preparation. We suggest keeping the concepts simple and stressing points that are easily recognizable in the field. Impressing the point that the salt marsh is a dynamic and mutable ecosystem, under threat of human impacts, is important. Examples of illustrations to use are:

1. Introduction—Photographs of salt marshes
2. Statistics on the productivity of the salt marsh and wildlife uses
3. Aerial photographs or topographic maps illustrating the number of roads that cross the marsh
4. Photographs of typical bridges
5. Photographs of typical culverts
6. Aerial photograph or drawing of a restrictive tidal crossing which illustrates scour pools
7. Photographs of scour pools
8. Photographs of encroaching phragmites
9. Photographs of encroaching upland species
10. Photographs of volunteers working in the salt marsh
11. Conclusion—Photograph of a pristine salt marsh

You can usually capture the essence of these points with a roll of film. We have provided at our web site (http://engc.bu.edu/~dcm/prcwhome.html) photographs which can be downloaded and used for presentations, but local photographs of your area will be more effective.

There are many references at your disposal that can aid in expressing the above points. Here is a short list:

Amos, W.H. and Amos, S.H. ***Atlantic and Gulf Coasts: The Audubon Society Nature Guides.*** *Alfred A. Knopf, New York (1985).*

Chabreck, R.A. ***Coastal Marshes: Ecology and Wildlife Management.*** *University of Minnesota Press, Minneapolis (1988).*

Teal, J. and Teal, M. ***Life and Death of the Salt Marsh.*** *Little, Brown and Company, Boston (1969).*

Recruiting Volunteers

Recruiting volunteers can be a challenging task, especially if the perception within the community is that a problem does not exist. Once some awareness has been raised, we have found that there is a remarkable amount of concern over the health of salt marshes. The spread of invasive phragmites serves as a rallying call for volunteer help. Other issues that motivate people to help out are the need to restore fish migration routes and to preserve ecologically-valuable and aesthetically-unique places.

Utilizing the formal media outlets is a good place to start, but it is good politics to notify the town officials first and to invite their participation. Local newspapers often seek out public interest stories, especially ones that foster a community spirit. Developing a relationship with a regional beat reporter is a good idea, and a story that addresses the threats to salt marshes and incorporates a call for volunteers can be potent.

It is helpful to have the Tidal Crossing Coordinator make a site visit with a reporter before the article is published. An outing provides an excellent photo opportunity and gives the reporter a clear picture of the pertinent problems.

There are many informal networks that can be tapped to recruit volunteers and these should not be ignored. Often they are unique to a community and may include Boy and Girl Scouts, home schooling organizations, sportsmen's associations, The Kiwanis, The Lions Club, Knights of Columbus, Rotarians, parent teacher associations, watershed groups, churches, and large employers. Ways to reach these groups include: going to speak at one of their meetings, asking their newsletter editor to publish a short article in their newsletter, or circulating a flyer to their mailing list.

Chapter III

Phase I: Visual Assessment

Introduction

In Phase I, you will assess restrictions visually, similar to conducting a simple shoreline survey. You will evaluate one biological and two physical indicators, and rank the restriction on a 1-5 scale (5 being most problematic). Phase I has three steps: a field-based training session (if the assessment is to be performed by volunteers), data collection, and data evaluation.

The purpose of the Phase I assessment is not to determine absolutely whether a site is restrictive, but rather to determine whether a site is potentially restrictive. In Phase II, you will determine more accurately how tidal flow is being restricted at a given site.

Getting into the Field

It is best to perform the visual assessment at low tide, when access is easiest and the profile of the stream bank and bed can be most readily seen. The Tidal Crossing Coordinator should use a tide chart to schedule the field work. Remember that high and low tides at specific crossings do not correspond exactly to the high and low tides given on tide charts, which predict tides for a specific coastal point. Generally, the further inland a crossing is, the longer the tide is delayed with respect to the coast. In extreme cases, tides at an inland location can be delayed by as much as 3 hours.

At low tide, problems with culvert placement become immediately obvious, especially if the culvert is too high. If a culvert is placed too high, then water will be trapped on the upstream side as the tide drops below the bottom of the culvert. At high tide, the same site may not seem to be restricting flow, especially when the tide is slack.

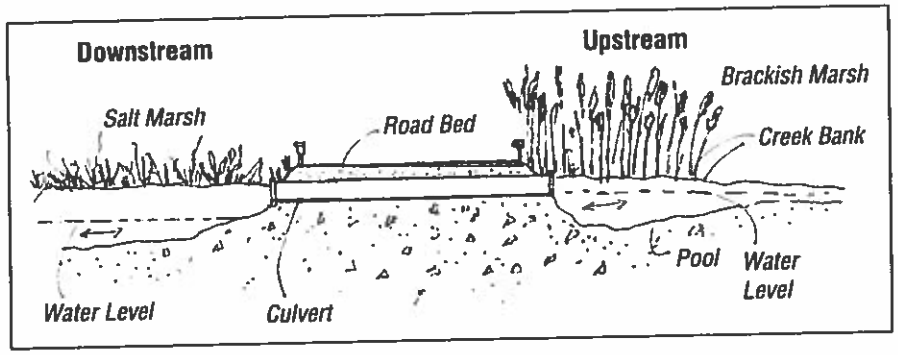


Figure 9. Sketch of a culvert located too high. At low tide water is trapped on the upstream side of the culvert.

The Data to Be Collected

Crossing Ratios: The ideal tidal crossing would be larger than the average width of the stream, to allow for flood tides and storm surges to flood the adjacent marshes. This, unfortunately, is not usually the case. Culverts are often undersized or simply intentionally blocked because of fear of flooding adjacent development.

The crossing ratio is the ratio of stream channel width at the culvert or bridge to the diameter of the culvert or to the width of the bridge opening. You need to estimate the ratio for both upstream and downstream at each crossing. We found that the estimated ratio of stream width to crossing opening width, or where applicable culvert diameter, is an excellent gauge of whether or not a site is actually restricting tidal flow.

Restriction Classification Scheme

Classification	*Channel vs. Culvert / Opening*
1 Upstream / Downstream	River Width < Opening Width
2 Upstream / Downstream	River Width = Opening Width
3 Upstream / Downstream	River Width up to 2 times Opening Width
4 Upstream / Downstream	River Width 2 to 5 times Opening Width
5 Upstream / Downstream	River Width greater than 5 times Opening Width

First, you will need to physically measure the dimensions of the crossing opening at its narrowest point; this procedure is frequently best done at low tide.

Next, you need to determine the river channel width. This can be more challenging, because often a restrictive crossing will have substantially altered the stream banks, especially immediately adjacent to the restriction. You may choose to measure stream width both upstream and downstream of the crossing; be consistent in how far from the crossing you choose to take this measurement. For example, you may always decide to measure your stream width 100' away from the crossing itself.

We used a wheeled distance meter or paced off the high-tide creek widths at the crossing, and compared those measurements, upstream and downstream, to the opening size measured with a tape measure. The data are recorded on a data sheet and the crossing ratio computed.

Bank Erosion: The second physical indicator is bank erosion. If a crossing is restrictive, then water velocity will be increased by passing through the restriction. When this high-velocity flow reenters the natural channel, turbulent eddies result. This increased turbulence can accelerate bank erosion in the immediate vicinity of the restriction. As a result, you may see a scour pool, or wider channel, adjacent to the restriction.

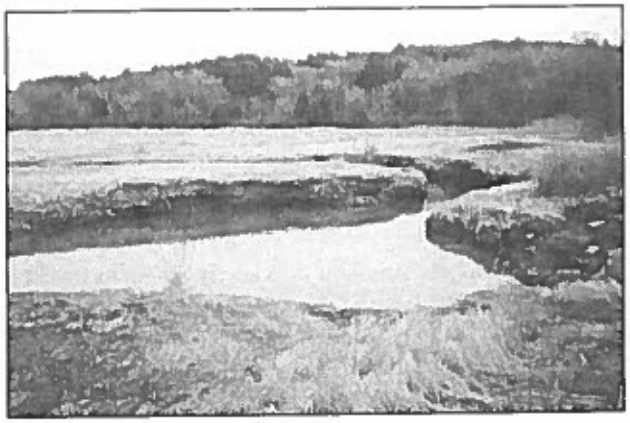


Figure 10. Scour pool resulting from an undersized culvert located just to the right of the pool. The natural width of the creek can be seen where it enters at the upper right part of the pool.

As you visually assess each crossing, characterize the bank erosion and pooling according to the following scheme, and enter the result on the data sheet:

Restriction Classification Scheme

Classification	Evidence of Flow Restriction / Erosion
1 Upstream / Downstream	Unrestricted / No Pooling
2 Upstream / Downstream	Flow Detained / Slight Erosion
3 Upstream / Downstream	Minor Pooling / Erosion Present
4 Upstream / Downstream	Significant Pooling / Significant Erosion Present
5 Upstream / Downstream	Major Pooling / Major Erosion Present

Based on our final results, we found this preliminary bank erosion assessment to be an excellent predictor of whether or not a crossing is actually restrictive.

As with any ranking approach, objectivity is difficult to maintain, especially when first starting. When ranking the degree of bank erosion, the lowest scores should be given to those sites that most closely resemble natural stream conditions. This resemblance can be

determined by studying the surrounding downstream conditions and analyzing similar streams that are not affected by road crossings. As you observe more, you will become familiar with typical conditions. Highly eroded sites will show bank failure or slumping; wide, rounded creek pools; and the buildup of rubble and riprap in the stream bed.

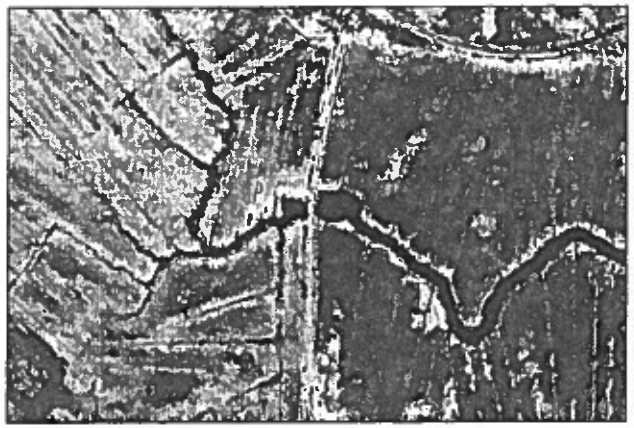


Figure 11. Aerial photo of a tidal creek with scour pools on either side of the crossing.

Vegetation Comparison: When the tidal range is reduced, the upstream habitat may no longer be dominated by salt-marsh grasses, but instead may contain less salt-tolerant species such as common reed (*Phragmites australis*) or freshwater species such as cattails (*Typha sp.*). In extreme cases, the habitat may evolve into shrub or forested swamp, and the former wetland may be invaded by upland species.

Analyzing the differences in vegetation from upstream to downstream can take a trained eye, especially given that the differences may be subtle. Moreover, the differences may not be related to a restriction of salt water.

In assessing our final results from approximately 60 crossings, we found that the Phase I vegetation assessment was the least reliable of the three indica-

tors, and we do not recommend using this criteria unless you and your volunteers are familiar with plant biogeography.

The habitat both upstream and downstream is assessed visually, and any difference in frequency of salt-tolerant and salt-intolerant plant species is recorded on the data sheet using the classification scheme below.

Restriction Classification Scheme

Classification	*Vegetation Comparison*
1	Upstream = Downstream
2	Upstream Slightly Different Than Downstream
3	Upstream Different From Downstream
4	Upstream Much Different Than Downstream
5	Upstream Completely Different Than Downstream

Phase I Data Sheets

Regardless of whether the Phase I assessment will be conducted by the Tidal Crossing Coordinator or by volunteers, you will need data sheets for each site to help standardize your results. You will also want to provide the observers with space to make additional site-specific field notes. You should also provide your observers with a photocopy of a topographic map or other small-scale map, with the crossings to be surveyed identified on it.

A sample data sheet appears in Appendix B and is also available digitally on our web site. Our data sheet fit on an 8 1/2 x 11 piece of paper, copied front and back. Multiple pages have a habit of flying away on the marsh. We also suggest waterproofing your notes;

gallon-size ziplock bags can work well. How ever you decide to format your data sheets, they should ask the observers to provide the following information:

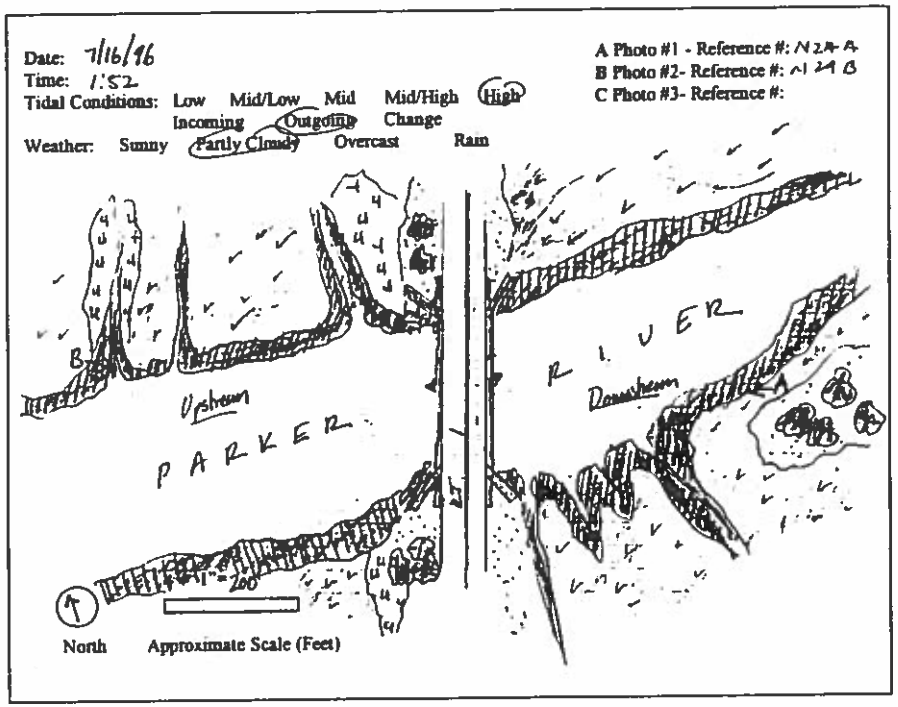
General: Date, time, and observers' names.

Location: Site code (such as N5 for fifth crossing in Newbury), stream or river name (if unnamed, indicate that), town, street name, and references to nearby landmarks.

Stream Flow: Tide level, tide direction, weather, and rainfall.

Sketch: A "bird's eye view" sketch of the site, with notable features labeled, and upstream/downstream flow indicated. Indicate which direction is north, and the approximate scale of the sketch. The sketch should incorporate buildings, vegetation types, and crossing configuration.

Figure 12. Bird's-eye view (plan view) sketch of a tidal crossing.



Photographs: Photos of the crossing from upstream and downstream; indicate where the photo was taken from on the sketch. If you are working with volunteers, you may want to have a supply of recyclable cameras available.

Crossing measurements: Dimensions of crossing opening, width of stream channel (upstream and downstream), width of crossing (middle), width of road (middle), length of crossing, distance from creek bottom to road surface (upstream and downstream).

Crossing characteristics: Type of crossing (culvert, bridge), road surface material, condition of bridge or culvert, condition of road.

General notes: Any other miscellaneous field notes.

For some of these data, you may want to provide the observers with multiple choices to circle. For example, tide level might give a choice of low, mid/low, mid, mid/high, high. Tide direction, weather, crossing type, and road surface all lend themselves to this format.

Some of this information may prove difficult to procure. Usually, scrambling down the bank at low tide and using a carpenter's tape is the best way of getting the opening dimensions. If the assessment must be made during higher tides, observers may use an extension pole with inches marked off to make measurements partly underwater. A wheeled distance measure is good for measuring along a road bed for larger sites, and a weighted tape can be used if you need to estimate large heights.

The information about the crossing condition—both of the bridge or culvert and of the road—can be useful in figuring out which crossings might soon be scheduled for repaving, culvert replacement, bridge repair, or other types of maintenance. Such maintenance can be a window of opportunity for you to

suggest that the crossing opening be widened or lowered to make it less restrictive (see Chapter 5).

The Training Session

Providing a field-based volunteer training session explaining the tidal crossing methodology is the most direct way to demonstrate the issues related to tidal crossing restrictions. As a follow-up to a public forum or an informational meeting, the training session prepares the volunteers to properly conduct tidal measurements and gives a focus to the issues at hand. The success of the training session will dictate the reliability of the tidal data and will ensure a positive experience for the volunteers.

We have found that holding the training session at a road within an area that has more than one crossing is essential. For example, we have held our training sessions at a road with three crossings of varied scale and type in close proximity; one is a bridge, another a large culvert and the third a small culvert. Our training area also includes one site that is clearly restricted and one that shows no sign of restriction. With these three different types of crossings we could properly demonstrate the methodology for measuring crossing ratios, evaluating bank erosion, recording the data on data sheets, and avoiding field work errors. Holding an outdoor training session also creates an informal atmosphere for people to ask questions.

At the first site visited, the Tidal Crossing Coordinator should ask one of the volunteers for assistance and then go through the Phase I evaluation, discussing each step of the evaluation process, explaining what is being done, and asking the volunteers for their opinion on the degree of bank erosion or differences in vegetation (if this latter variable is to be included). For the remaining sites, have your volunteers work in pairs and perform the assessment, then discuss and compare

the results from each of the teams. Emphasize to your volunteers the importance of entering the results on the data sheets as the measurements and observations are being taken. Encourage them to add any notes regarding unusual or interesting conditions at the site.

We recommend teams of two for the field work. Often natural partnerships will form, such as neighbors, couples, or parents and children. Working in pairs minimizes recording errors and increases safety. Other precautions to ensure safety are to wear bright clothing such as blaze orange vests which can be acquired at stores which outfit hunters and to visit the assigned sites beforehand at low tide to examine bank conditions and check out parking. Parking at a site can be difficult, especially at highway sites and bridges. The Tidal Crossing Coordinator should not assign volunteers to busy roads and highways, areas under construction, or areas where safe parking is not available. Remember, also, to always check whether or not a road is public, and if it is not, to seek the landowner's permission to use it.

We recommend teams of two for the field work. Working in pairs minimizes recording errors and increases safety.

Putting the Volunteers to Work

Before sending your volunteers out into the field to gather data, schedule a follow-up meeting. We schedule follow-up meetings so that there are two weekends between the training session and the meeting. This allows your volunteers some flexibility to schedule their data collection around bad weather and family obligations and yet gets them out into the field while the training is still fresh in their minds.

The purpose of the follow-up meeting is for your volunteers to report their findings to the group, for the volunteers to compare experiences, and for the group to identify those sites that will need the Phase II assessment of tidal range.

Identifying Potentially Restricted Sites

Once the visual assessment work has been performed, sites that score a three or above for any of the three categories described above, or crossings that involve a culvert located above the low tide level, should be considered potentially restrictive. These sites should then be evaluated by measuring the tidal range as described in the next chapter.

Chapter IV

Phase II: Measuring the Tides

Introduction

Once it has been determined that a certain site has exceeded one or more of the visual ranking thresholds, a more accurate assessment of the degree of tidal restriction should be performed. This will require measuring the ebb and flow of the tides at a given site. This is the most challenging and time-consuming aspect of assessing a tidal restriction, but provides the most important information and is the most fun.

The approach is to measure the tidal range (the difference in water level between low and high tide) for each side of the crossing. If the upstream and downstream tidal ranges differ, then the crossing is altering tidal flow. For most sites, the water level can be measured simply by using a tape measure. Measurements are taken approximately two hours apart over an entire tidal cycle, and the tidal range for each side of the crossing calculated from the measurements.

Determining Reference Points

At the specified crossing, reference points need to be defined on both the upstream and the downstream side of the bridge or culvert, by the Tidal Crossing Coordinator or by the volunteers. The reference points should be chosen near the middle of the channel, to ensure that your measurements will catch the low water. Reference points should be marked with a small spot of biodegradable paint or colored chalk. It is important to mark the reference point clearly, for each successive measurement should be performed from the exact same point. A weighted tape measure or a

carpenter's tape (for smaller sites) should be used to measure the distance between the water surface and the reference point for both upstream and downstream reference points at each crossing. We recommend using fiberglass tape measures for the larger sites; lead weights can be purchased at local fishing shops.

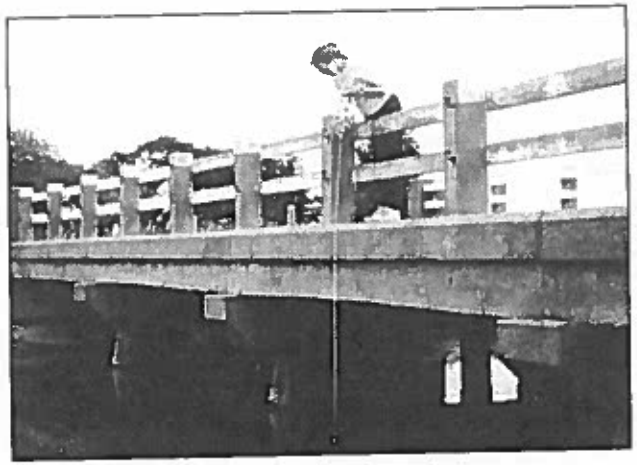


Figure 13. A volunteer measuring the tides using a weighted tape measure.

Volunteers should visit their sites beforehand at high and low tides, if they did not participate in the Phase I assessment, to establish well-placed reference points. Determining reference points can be a tricky endeavor, especially at sites that are highly degraded or do not have a creek overhang from which to easily drop the tape measure. These sites are most often culverts.

Measuring the Tide

The rise and fall of the tide is measured as the distance between the water surface and your reference points. The measurements need only be to the nearest inch, and any extra length on your tape measure due to attaching a weight need not be corrected for so long as the reference point is always out of the water. A total

of 6 measurements timed approximately 2 hours apart need to be collected during one day. Timing your 6 measurements at 2-hour intervals allows you to record an entire tide cycle. It is not important that the measurements are taken exactly 2 hours apart, as 15 or 20 minutes either way will not effect the computation of the tidal range. It is important to note the exact time at which each measurement is taken, however.

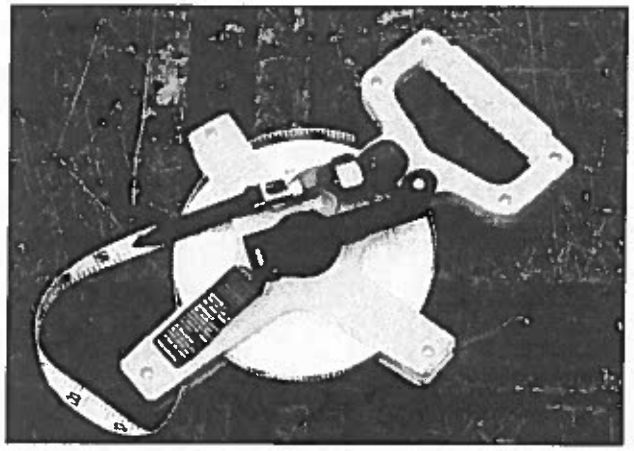


Figure 14. Weighted tape measure.

In some cases, you may find that the stream or river bed is filled with rubble next to the crossing. As the tide goes out, it may be impossible to directly measure the vertical distance between a reference point on the bridge or culvert and the surface of the water in the main part of the channel. In these situations the best solution is to install a temporary staff gauge in the channel to measure water level. Another solution is to use more than one reference point for different stages of the tide, but it is important that the relative height of each reference point be known so that the data can all be referenced to a single reference point for the final analysis. For further discussion of these issues, see Appendix A: Troubleshooting.

Analyzing Your Data

Once the data has been collected, it is entered into a spreadsheet template which computes the peak-to-peak (maximum of the six measurements minus minimum measurement) water-level change for each reference point. This water-level change is the tidal range. The spreadsheet should be set up to compute the tidal range as well as the ratio of the upstream to downstream tidal ranges.

	A	B	C	D	E	F
1		Raw Data			Change	
2	Time	Upstream	Downstream		Upstream	Downstream
3		(in)	(in)		(in)	(in)
4					-B4 +@MEAN(B4..B9)	-C4 +@MEAN(C4..C9)
5					-B5 +@MEAN(B4..B9)	-C5 +@MEAN(C4..C9)
6					-B6 +@MEAN(B4..B9)	-C6 +@MEAN(C4..C9)
7					-B7 +@MEAN(B4..B9)	-C7 +@MEAN(C4..C9)
8					-B8 +@MEAN(B4..B9)	-C8 +@MEAN(C4..C9)
9					-B9 +@MEAN(B4..B9)	-C9 +@MEAN(C4..C9)
10	Tidal Range =	@MAX(B4..B9) - @MIN(B4..B9)	@MAX(B4..B9) - @MIN(B4..B9)			
11	Tidal Range Ratio =	+B10/C10				

Figure 15. Spreadsheet template for tide-level data.

The times and field measurements are inserted in the left three columns. The right two columns compute the tide level with respect to the average level and are used to create a graph of the data. Cells B10 and C10 compute the tidal range for the upstream and downstream data respectively. Cell B11 computes the ratio of the tidal ranges (upstream divided by downstream) and is usually expressed as a percentage.

Examples of our spreadsheet template format can also be downloaded from our web site (http://engc. bu.edu/~dcm/prcwhome.html) in either Quattro Pro or Excel format.

The data can be visualized by graphing both upstream and downstream water-level changes for

each crossing on the same axes. To do this, compute the mean distance to the water surface for both the upstream and downstream data sets, then subtract the mean from each data set, and then plot the resulting values as a function of time of day.

If the crossing creates no restriction, then the upstream and downstream curves should lay over each other and the measured peak-to-peak upstream and downstream level changes will be within 1-2 inches of each other (Figure 16). If there are significant differences between the curves of the upstream and downstream tidal ranges, then the crossing is altering the tidal flow (Figure 17).

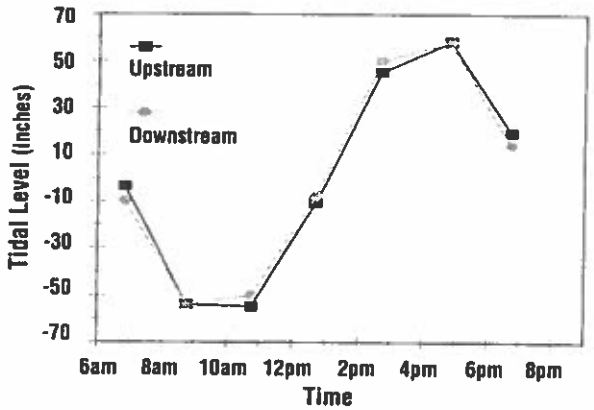


Figure 16. Example tidal data from an unrestricted site. Note that the upstream and downstream curves are almost identical. Tidal level at each time point for the upstream curve is computed as the difference between the measured value and the average value for the upstream data and likewise for the downstream data.

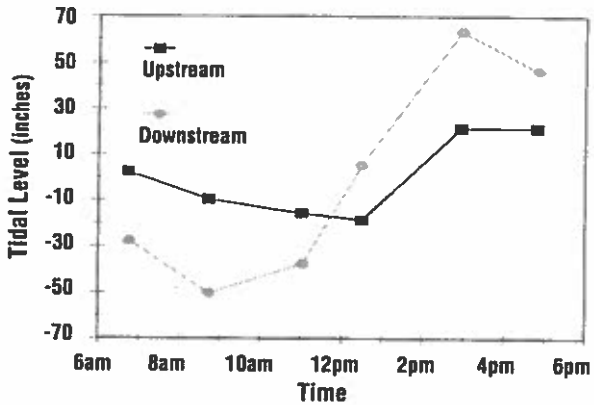


Figure 17. Example tidal data from a restricted site. The large difference between the upstream and downstream curves is the result of a severe restriction due to the collapse of a culvert.

Notice in Figure 17 that the upstream tide cycle is delayed somewhat with respect to the downstream data. This is typical of an extremely restricted site and is due to the fact that the upstream high tide is so much lower than the downstream tide that water is still moving through the restriction to the upstream tide, even when the downstream tide is starting to go out.

We chose to define a crossing as being significantly restricted if the difference between the upstream and downstream tidal range was more than 5 inches. This may or may not mean that the marshes are suffering because of the reduction of tidal flow. To determine the effects on the salt-marsh habitat may take years of research, but it is likely that, if a culvert or bridge is limiting the amount of salt water entering a marsh, marsh productivity will be diminished or the salt-marsh habitat will change to brackish or fresh marsh and in extreme cases upland species may invade the former marsh. Also, the alteration of salt-water flow will increase the chances that invasive species such as phragmites will take hold.

The most common type of restriction in our study area was the case where the culvert was located too high. At these sites, water becomes trapped on the upstream side of the crossing, once the tide drops below the bottom of the culvert. The result is a tidal curve on the upstream side that has a narrow peak at high tide and is flat over much of the rest of the tidal cycle (Figure 18).

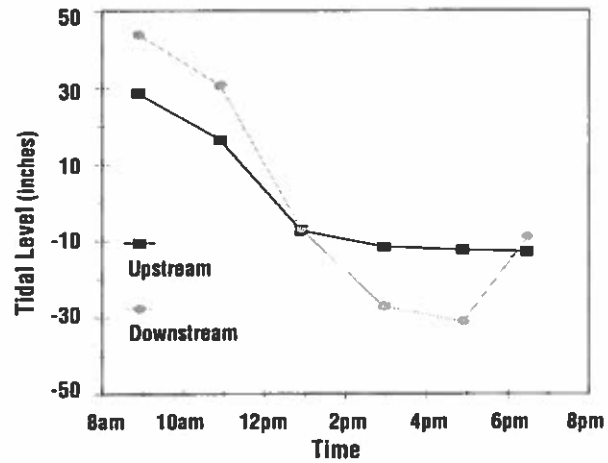


Figure 18. Example tidal data from a site where the culvert was located too high. The upstream curve exhibits little tidal change during the four afternoon data points due to water trapped behind the culvert.

The rise and fall of the tide should progress gradually on both sides of the crossing as shown in Figure 16. If any of the curves have more than one peak or otherwise look irregular, the data should be questioned. The most common error we found was that, on a few occasions, volunteers would switch their upstream and downstream measurements when they recorded them on the data sheets. This error can usually be spotted as irregularity in both curves at the same time point.

Make sure your volunteers know which side of the crossing is upstream. Also emphasize that they should be careful not to reverse their upstream and downstream data.

Figure 19.
A) Example tidal data where the upstream and downstream data for the 4pm measurement have been reversed.
B) The same data plotted correctly.

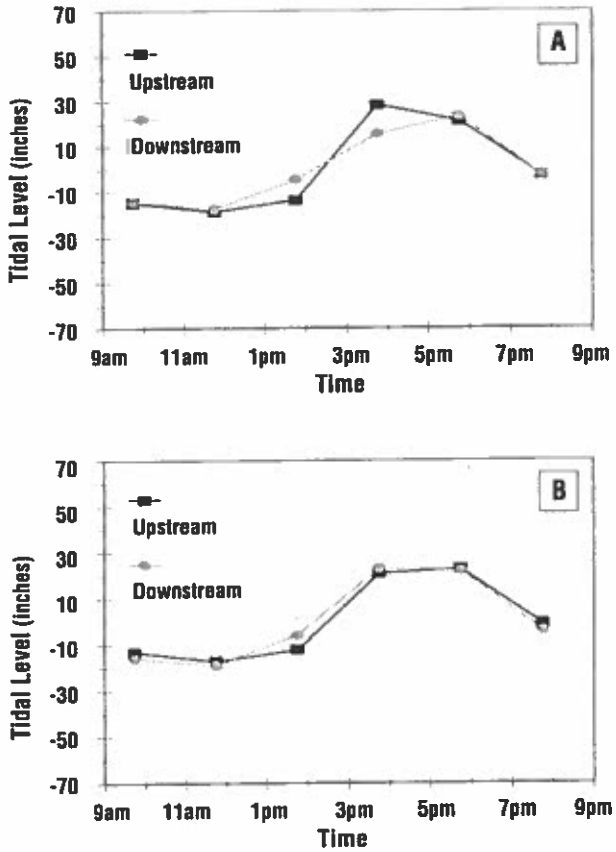


Figure 19a illustrates data from an unrestricted site in which the upstream and downstream data from the fourth measurement were reversed. The result is that the two curves cross over at half-tide but have similar maximum and minimum values. Spotting this type of error takes some practice. A simple way to learn what to look for is to take actual data from unrestricted sites and reverse pairs of data points as was done in Figure 19. As you gain experience with the data, you will become more adept at spotting questionable measurements.

If you have concerns about the quality of the data for any of your sites, you can have a second team of volunteers remeasure the sites in question or have the Tidal Crossing Coordinator repeat the measurements. If there are any questions about the data for a site, the measurements should be repeated.

Volunteer Training

If you are well-prepared for the training session for Phase II, it can be fun. The training should be field-based, and we recommend using the same sites that were used for the Phase I training. The major goal of the training session is to have the volunteers practice water-level measurements at different types of sites before embarking on their own. Above all, emphasize safety during the training session.

When you demonstrate the measurement technique, emphasize to your volunteers that it is critical that they record the exact time for each of their measurements. You can explain to them that the two hour interval between measurements is only approximate. Do emphasize that an early start is important; we don't want volunteers fumbling around in the dark trying to make their measurements.

Create a training pack that can be handed out at the training session. In it there should be a map clearly noting the assigned sites, data sheets for each site (see Appendix B), a resealable bag or small resealable canister of brightly colored paint (or colored chalk), a 1-inch chip brush, a weighted vinyl tape, and a 5-foot wooden 2 x 2" stake, if needed, for measuring underwater reference points. Also within the training pack you could include some sample results, with a graphical presentation of the data, to give the volunteers an understanding of how their data will be used.

At the training session explain to the volunteers what is to be measured—and why—before demonstrating the method. It is important for the volunteers to understand the concept of tidal range and why it is important to the health of the salt-marsh ecosystem. The volunteers must also understand that they must locate their reference points so that they will always be accessible and easy to find, even at high tide. Also explain that reference points do not need to be at the same level on the upstream and downstream sides. Tell your volunteers that they should not attempt to determine the elevation difference between the reference points and adjust their data. The methodology described in this handbook is based solely on tidal range so that measurement of elevation differences and associated errors can be avoided.

The Tidal Crossing Coordinator should demonstrate the measurement technique and discuss potential problems at one or more of the field sites. Don't give the volunteers the actual distance values until after they have performed the measurements on their own. During the training session have each pair of volunteers measure the distance between the reference points and the water surface on the upstream and downstream side of each crossing at the training area. Have the volunteers record the time and distance measurements on data sheets and ask them not to share their results with other teams until the measurements are done. When everyone has completed their measurements, then compare the results and discuss the differences. The coordinator should take care, however, at this stage to make sure that volunteers who may have made mistakes are not criticized, but rather helped to correct their measurement methods.

It is a wise idea to pre-assign sites to your volunteers and designate teams before the training session. Assigning sites to teams can be difficult, and it is advisable to assign a few, closely-situated sites. Site selection

is dependent on site proximity and travel time between sites. As an organizer, you should time the routes between sites to get a sense of how long it will take your volunteers to perform the 6 measurements, spaced at 2-hour intervals, for all of their sites. It should take at most ten minutes to complete the two measurements at each site, and it is best if all the sites assigned to a team can be completed in under an hour. This gives your volunteers about an hour break between measurements to allow for meals and toilet breaks. We suggest assigning the teams sites near their homes because it makes it easier for your volunteers to take advantage of the breaks. We found that, in our area, 3 or 4 sites were about the most that could be easily handled by one team unless the crossings were very close together. If the sites are far apart or require walking some distance from the parking area, this number may need to reduced.

As part of the training session make sure the volunteers know exactly where their sites are and where, at each site, they can safely park.

As part of the training session make sure the volunteers know exactly where their sites are and where, at each site, they can safely park. To have a complete understanding of all the sites, they must be visited beforehand by the Tidal Crossing Coordinator. The coordinator can then warn the volunteers of potential problems that might occur at their sites. For example, the coordinator could warn a volunteer that using the culvert top at a certain crossing will be good for the low tide cycle but will get flooded out at high tide or that a certain reference point will not catch the low tide, so that the volunteer needs to mark the distance from the reference point to the mud flat. Having a good sense of all the sites and tipping your volunteers off to the potential pitfalls will avoid data errors. Remember, too, that your volunteers should check out their sites themselves before tidal measurement day.

Tidal Measurement Day

We have billed this day as Turn the Tide Day. Assigning a name to the measurement day gives it a gravity and importance unto itself, provides a title that attracts press coverage, and can be used in the initial press releases to recruit volunteers.

Scheduling the measurement day is dependent upon a host of factors, some of which are not controllable. The weather and tides should be in cooperation, but only the latter is easily predictable.

A successful measurement day requires that all of the planning work be completed in the training session and any other prior meetings.

Scheduling the measurement day is dependent upon a host of factors, some of which are not controllable. The weather and tides should be in cooperation, but only the latter is easily predictable. We have chosen our tidal measurement days to be on weekends during the summer when there is ample daylight. We generally chose days when high tide occurred during the middle of the day and when the tides were especially high. The rationale for choosing days with large tides is that the important spring tides dictate transition-zone vegetation distribution, and large tides can help emphasize problems and add weight to your data.

We suggest allowing approximately one week between the training session and the measurement day. Volunteers need time to visit their sites before the measurement day and you, the organizer, will need time to set reference points at those troublesome sites. At the same time, it is wise to schedule the tidal measurement day fairly soon after the training session, preferably the weekend after, while the training session is still fresh in the minds of the volunteers.

Conclusion

Insuring accuracy is of paramount importance, and there are a few things that can be done to make sure your data is accurate and reliable. As we all know, some people are more reliable and take more care than others. It is important that the Tidal Crossing Coordinator get to know their volunteers and to try to identify those individuals who might be best assigned to tasks other than quantitative field measurements. We also strongly encourage having volunteers work in pairs. Not only is this good safety practice, but it also reduces the potential for recording and measurement error.

Establishing control sites can add credibility to your data. Control sites are crossings that show absolutely no sign of being restrictive by your visual analysis. Typical examples would be large bridges and culverts with openings that are as large or larger than the creeks or rivers that they service. The lack of restriction should be verified with actual measurements if there is any question.

These control sites can be added to the list of sites assigned to your volunteers. By having your volunteers perform tidal measurements on a site that is known to not be restrictive, you can check the accuracy of your volunteer's measurement techniques. If the plots of upstream and downstream tidal data from the control sites do not seem almost identical, human error is likely the cause. Additional ways of reducing field work errors are addressed in Appendix A.

Chapter V

Phase III: Taking Action

Toward Action

Once the data has been carefully analyzed and the significantly restricted sites have been identified, moving towards the improvement of these sites is the next logical step. Your first step should be to inform local municipal officials about your results. Follow this step by raising public awareness through press releases and public meetings. Identifying a top ten worst sites makes for juicy press material. It is imperative to be able to stand by your data, and to reiterate the strengths and shortfalls of the methodology. Remember, the tidal measurement methodology is a screening tool; the data alone can not address the details of the hydrology at the crossing. A geography professor described our methodology as an excellent "red flag" approach to identifying restricted sites.

As part of your public outreach program, remind everyone that there are other reasons for increasing the size of undersized openings besides improving tidal flow. If an opening is too small, there will be potential problems with the opening restricting rainwater runoff during major storm events. Also, if the opening is too small, the turbulent flow through the opening will lead to bank erosion, which may undermine the road and lead to costly repairs.

Developing detailed recommendations for how to restore a restricted site involves complex engineering decisions. One needs to consider the volume of water that should move under the crossing each tide cycle, the size of the upstream watershed, and the potential flooding of nearby development if tidal flow is restored. If possible find a licensed civil engineer to

help with the details of your recommendations for the most restrictive sites. Enlisting this kind of support certainly adds credibility to your findings.

Notifying Town and State Officials

By far the most influential sector for implementing change are your local appointed and elected officials. The selectmen and women, city councilors, mayors, and county commissioners dictate funding and often, in the smaller communities, run the entire show. You should share your data with local municipal officials before you go to the public with your findings. The support of these officials is crucial if you want your assessment studies to result in action.

You should share your data with local municipal officials before you go to the public with your findings. The support of these officials is crucial if you want your assessment studies to result in action.

Since the form of government and the details of how decisions are made vary from community to community, it is important that you learn how decisions are made in your area. Often, municipal officials other than those mentioned above are more directly involved in decisions that can influence whether a restricted site gets attention or not. Perhaps your best point of initial contact is the local highway department or the department of public works (DPW), because these are the departments that are engaged in road construction and maintenance, including bridge and culvert upgrades. In Massachusetts, each town has a conservation commission that will inevitably be called in to review permits for any major change to a river, stream, or wetlands. In some communities these conservation commissions are quite proactive and can work with other officials within their communities to bring about restoration of degraded or threatened marshes.

In each of the eight towns in our study area, we met with either conservation commission members and/or DPW directors to review our findings. This meant educating them about the basic issues of

phragmites spread and salt marsh productivity. For some towns, field trips were made with these officials, and these trips proved to be the most effective way of illustrating the problems associated with tidal restrictions. Involving local highway superintendents in local environmental issues has many rewards, and often they are grateful to you for acknowledging their services.

Gathering Support

Road work is expensive so you need to develop strong public support for improvements at restricted sites. One way to advance salt-marsh restoration and preservation issues is to rally a common voice among vested parties. Organizations like the Audubon Society, Ducks Unlimited, sportsmen's associations, watershed groups, and neighborhood associations all have a stake in preserving wetlands. These groups often can lobby public opinion through their membership and through local town and city officials. Often these organizations have biologists and wetland scientists among their members and staff who can lend a scientific voice to the pertinent issues.

Road upgrades are usually the time to act on improving tidal flow, for once a road is paved, DPWs and highway and transportation departments are loath to return to disturb newly-laid pavement.

Road upgrades are usually the time to act on improving tidal flow, for once a road is paved, DPWs and highway and transportation departments are loath to return to disturb newly-laid pavement and in some cases can not legally disturb new pavement for a certain time period. You can usually get from municipal officials a schedule of bridges and roads that are to be replaced and maintained. Acting in advance of the construction date is always much better than at the last minute.

Crossings on state roads or railroads may involve some additional players for your awareness-raising and action strategy. State and provincial highway officials usually have staff biologists and engineers to deal with the environmental impacts of their work. Contacting

them and sharing your information will help your cause. Mosquito control officers are important allies, especially if they work with open water marsh management as a method of deterring mosquito hatches. State environmental agencies, the US Army Corps of Engineers, the National Marine Fisheries Service, and the state, provincial and federal Departments of Fish and Wildlife have experience in hydrological and wetlands issues and sometimes can modify construction permits to aid anadromous fish runs and other wildlife.

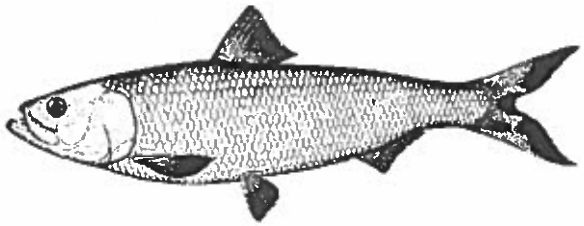


Figure 20. Anadromous fish like this Alewife spend most of their lives at sea, but return to their home streams each spring to spawn. Restricted tidal crossings can interfere with these migrations.

In Massachusetts, we have an active Wetlands Restoration and Banking Program, focused exclusively on wetlands protection and restoration issues. Their staff have been extremely helpful in aiding us at the state level to improve the most restrictive sites in our region. Their expertise and experience with restoration ecology has been valuable, and their interagency networking has done a great deal to advertise the need for better bridges and culverts in our region.

Often these state, provincial and federal groups have interagency meetings, which allow for presentations by outside groups, and these are the perfect forums for illustrating the problems related to tidal crossings.

Potential Pitfalls

Not everyone realizes that they stand to benefit from crossings with improved tidal flow. In areas where there is heavy development at the edge, or on wetland fill, business owners and private residents are concerned with flooding issues. The perception is that blocking the tides—especially the flood and spring tides—will prevent flooded basements, saturated septic systems, and ruined lawns. One disgruntled resident even hounded and practically chased a volunteer off the road where he lived, for fear that improved tidal flow would degrade his already failing septic system.

Figure 21. Danger of flooding upstream development near a restricted tidal crossing may make the site unsuitable for restoration.

In fact, much of the most destructive flooding occurs when stormwater is blocked and cannot escape via water channels. This is certainly exacerbated by a restrictive crossing. A potential solution is the installation of a flapper valve or tide gate. Tide gates, if installed correctly, allow for the normal passage of tides, but during storm tides the gate shuts on the incoming side to reduce flooding damage. Tide gates come in a variety of makes and models, both manual and automatic. We strongly suggest, where applicable, the use of an automatic tide gate, for more often than not, manual tide gates are simply cranked permanently

shut soon after installation. It is a wise idea to notify any abutters of your lobbying efforts and start an open dialogue, for improvement of tidal flow at a single crossing can effect many acres upstream.

Permits

It should be emphasized that further study is often necessary to quantify the engineering aspects of any culvert or bridge improvements that are recommended. Prior to implementation of any recommendations, final engineering documents, including plans and specifications, are required, and permits from the appropriate government agencies will be needed. Please consult your local environmental officials about the applicable wetlands laws.

Follow-up Volunteer Activities

Keeping your volunteers up to date on the follow-up activities is important for affirming their sense of purpose. You should share the data results with your volunteers; this can be done through a newsletter, by posting updates on a web site, or by email. Volunteers may be interested in additional follow-up activities. These may include: completing more tidal measurements, analyzing salinity levels at key crossings over a tide cycle, measuring watershed sizes above restrictive crossings, determining the extent of freshwater input at select crossings, erecting and maintaining permanent staff gauges, and completing a detailed field account of the vegetation types further upstream.

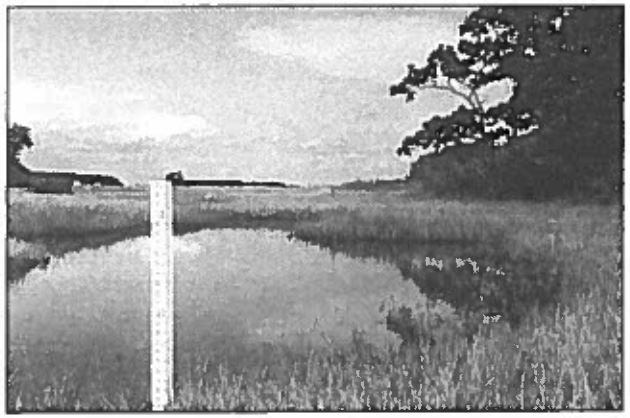


Figure 22. Staff gauge installed for measuring tide levels.

If your assessment and lobbying work results in the successful improvement of a restricted site, it can be especially satifying for you or your volunteers to remeasure the tidal flow at the improved site and to compare the data to the past results. You might also document the change of vegetation caused by the improved tidal flow, and use this documentation in subsequent public outreach – especially if phragmites start to die back or become stunted from the salt-water intrusion.

Figure 23. The Great Marsh near Plum Island circa 1910 (photograph courtesy of Ruth Alexander).

Conclusion

Using volunteers to assess an environmental problem, such as the reduction of tidal flow caused by poorly-designed bridges and culverts, is a time-consuming but vastly rewarding endeavor. The volunteer approach, if properly organized, is a way of getting reliable information at a relatively low cost. The cost is measured in the time of the volunteers and the coordinator, but the payback is in increased public awareness and support for non-restrictive crossings. Many a volunteer that has practiced our methodology has been unable to cross a salt marsh again without wondering if the bridges and culverts that they cross are large enough to maintain the health of the marshes they love.

Glossary

Anadromous:
Fish which migrate up rivers from the sea to breed.

Brackish Marsh:
A wetland that is fed by both fresh water and salt water.

Detritus:
Fragment material produced by weathering and decomposition.

Erosion:
The loss of land associated with weathering.

Estuary:
The mouth of a river where fresh and salt water intermix.

High Marsh:
The higher elevation of the salt marsh which is dominated by short coarse grasses.

Low Marsh:
The lower elevation of the salt marsh which is dominated by the taller smooth grasses.

Phragmites (*Phragmites australis*):
A tall invasive reed that colonizes the edges of salt marshes and can replace low-lying salt-tolerant grass species.

Pooling:
The accumulation of water at an erosion area.

Salt Marsh:
Low-lying wetlands periodically inundated by tides.

Tidal Crossing:
A bridge or culvert that allows tides to flow under a road or embankment.

Tidal Crossing Ratio:
The difference between the width of the crossing opening and the width of the stream channel.

Tidal Range:
The change in tide level between low tide and high tide measured at a given location.

Tidal Range Differential:
The difference between the upstream and downstream tidal ranges.

Tidal Range Ratio:
The ratio between the upstream and downstream tidal ranges.

Tidal Restriction:
Tidal crossing that impedes the ebb and flow of tides.

Upland:
Land where soils are not saturated by water.

Appendix A: Troubleshooting

Potential Problems

The quality of your data depends upon the thoroughness of your preparation and the diligence of your volunteers. Nonetheless, problems will inevitably result and we have included some of the problems that volunteers have experienced—and potential solutions.

Problem:

High tide floods over the reference point.

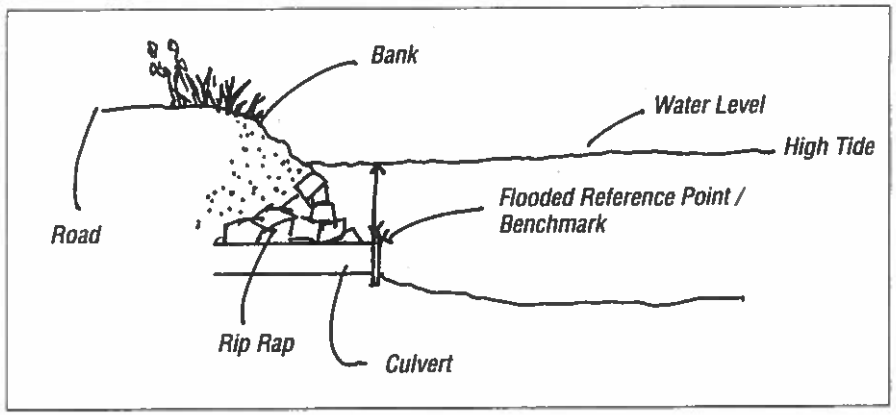


Figure A.1 Example of a flooded reference point.

Solution:

Choose a reference point that will not be covered at high tide. This will require examining the site before the day of measurements. You may use a reference point that gets flooded but be prepared to measure from the submerged reference point up to the water level (this will be a negative measurement). In this case it is helpful to have an easy-to-see paint mark that will be visible underwater. A wooden staff marked in

inches or centimeters or a yardstick is helpful in this case because you can place the staff in the water and an obvious immersion mark will be left when it is pulled from the water. It is important to make sure the staff is exactly perpendicular to the reference point. If you choose this approach, it will be necessary to correct your measurements for any length added to your tape measure by an attached weight. This correction is necessary because tidal range is computed by computing the difference between the maximum and minimum measurements. If all your measurements are with the reference point out of the water, the extra added length on the tape measure will be subtracted out. If, on the other hand, your reference point gets flooded and you use negative numbers as described above, both your positive and negative measurement values will be increased by the added length, and subtracting a negative number is the same as adding a positive number which means the added length will be counted twice and the tidal range over-estimated.

Problem

The bank slopes away from the road and there is no clear overhang from which to set the reference point.

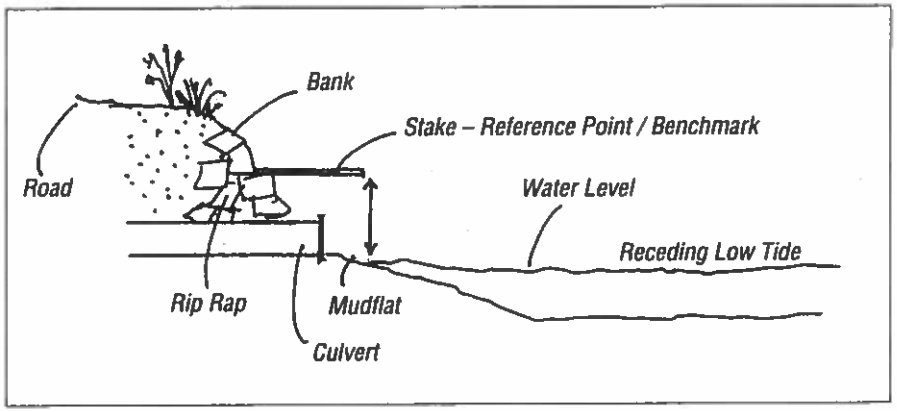


Figure A.2
Using a stake as a reference point for a site with no suitable overhang.

Solution

This is a difficult situation. We recommend solving it by pounding a stake into the bank that will overhang the creek. If this is done, it is imperative that the stake be solidly embedded into the bank so it will not bob with the tides. The end of the stake must be accessible from a stable, preferably dry-at-high-tide, point on the bank. You must also predetermine which point on the stake you will measure from, either the bottom edge or the top edge, and keep it consistent throughout your measurements. Hip-waders are excellent for reaching the end of the stake at high tide conditions, but be aware of your footing. In November, one of our volunteer attempted to reach the end of an overhanging stake at high tide only to find out how cold the Massachusetts waters are during the late fall! For safety's sake, we strongly recommend that these measurements be completed in teams.

Figure A.3
Example of a typical site where a stake is needed for the reference point.

An alternative is to use an in-stream staff gauge for both the upstream and the downstream sides of the crossing. Setting up the staff gauges is time consuming but relatively simple to do. It will require the use of leveling equipment to ensure elevation accuracy; proper engineering so the gauges will be stable under

high tide, low tide, and storm conditions; landowner permission; and the proper permits if applicable. If you go through the trouble of setting up the staff gauges, your accuracy will greatly increase, and the reliability of your data will be high.

Problem

At low tide there is no water directly below my reference point.

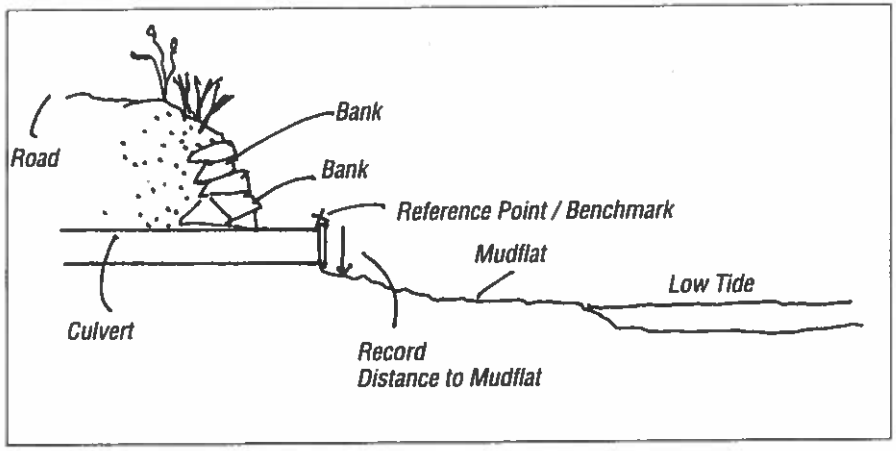


Figure A.4
Example of a site where, at low tide, there is no water near the reference point.

Solution

At low tide many of the crossings will have but a trickle of water, with exposed mud flat. Measuring from the reference point to the mud flat is fine as long as you note that there is no water. One may use a leveled staff to extend further away from the culvert to reach the main channel, but this should only be done if the staff is level and the point you measure from on the staff is at the same elevation as the reference point. A helpful tip for getting those low-tide measurements is to set up a series of reference points below your reference point at known distances. This can allow you to get further out into the channel without struggling with an extended level staff from which you have to

drop your tape. During low tide, at sites that are badly degraded and have riprap strewn about the channel bottom, water may pool and collect above the actual level of the receding tide. In this case, if it is possible, measure to the actual water level, not to the pool level. If this is not possible, then measure to the lowest elevation and note that distance as well as the fact that the tide has receded.

Remember to check out your site both at low tide and at high tide before you do your actual measurements, to pick a stable reference point that will not move when submerged by the tide, and to choose a point in the middle of the channel.

Problem

The reference point on the upstream side is well below the downstream side or vice versa.

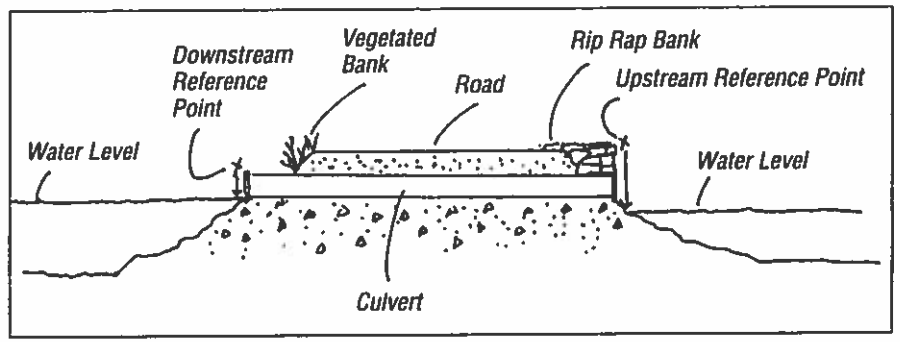


Figure A.5
Example of a site where the reference-point elevations will differ considerably. See the text for an explanation of why this is not a problem.

Solution

It is not important for the two reference points to be at the same elevation, for the total tidal range for each side is the critical factor. Once the tidal measurements are completed, the tidal range for the upstream and the downstream should be compared. If there is a significant difference between the two, then the site is restrictive (more than a few inches). If the tidal ranges are equivalent, then tides are passing freely through the crossing.

Problem

My tape measure blew in the wind.

Solution

The tape should be weighted with a heavy lead sinker before it is given out in the training pack.

Problem

I am not sure if I should measure from the weight or the end of the tape hitting the water.

Solution

It is best to measure where the end of the weight hits the water, and to keep this consistent throughout your measurements. The exception to this rule is when the reference point gets flooded. In this case the water surface is above the reference point, the distance will be recorded as a negative distance and, all of your distances must be measured from the end of the tape, not the end of the weight.

Problem

I dropped and lost the tape measure in the water.

Solution

Ask the volunteers to bring an extra tape in the car on measurement day.

Problem

I could not determine which side of the crossing was the upstream and which was the downstream.

Solution

In the training pack, upstream and the downstream should be clearly delineated on the maps with appropriate landmarks for reference. Volunteers should visit their sites beforehand to determine which sides are which.

Problem

I switched upstream and downstream during the sequence of measurements.

Solution

This is a common error and sometimes can be discovered when the data is graphically presented. A tip for discouraging this confusion is to always do upstream first, then the downstream in your cycle of measurements for each site.

Problem

On high bridges how do you tell when the tape hits the exact level of the water?

Solution

As soon as a ripple of broken water is seen in the water, that is the level at which to make the measurement.

Problem

Due to the turbulent flow under a bridge or coming through a culvert, it was difficult to measure the water level.

Solution

You can estimate the approximate level, or, if the channel is wide enough, the reference point can be set off center of the creek. To determine the right approach, it is important to have the volunteers visit their sites at high and low tide before they actually perform the measurements.

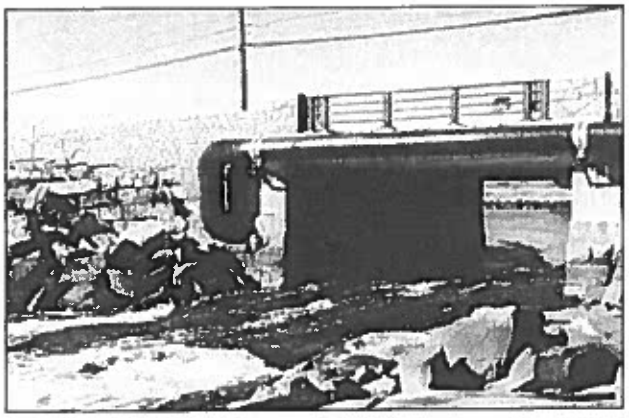


Figure A.6 Turbulent flow under a tidal crossing can make data collection more difficult.

Problem

Some neighbors complained about paint on the bridge.

Solution

In the training pack, include paint that is biodegradable, such as a vegetable dye, or colored chalk. The marks need not be large.

Problem

I could not find the sites.

Solution

In the training pack, the crossing locations should be clearly delineated on the maps with appropriate landmarks for reference. As well, volunteers should visit their sites beforehand to determine the site locations and call the Tidal Crossing Coordinator if they have any questions.

Problem

I could not find a good place for the reference point because the bank was too steep.

Solution

The organizer should pre-establish reference points for difficult sites or not allow volunteers to conduct measurements at tricky crossings. Volunteers should visit their sites beforehand at high and low tides to familiarize themselves with the site and resolve potential problems with the coordinator.

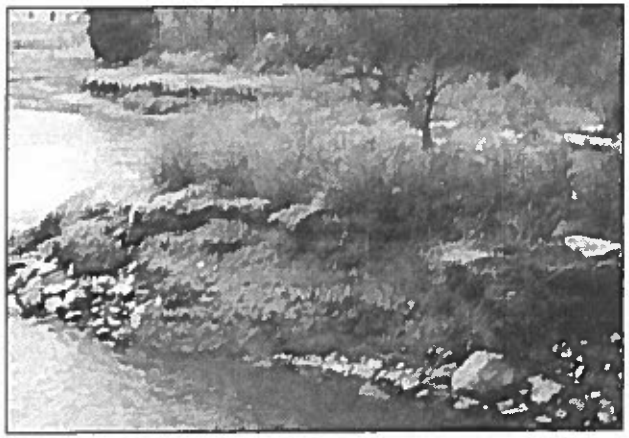


Figure A.7 Steep banks and overhangs can make tidal measurements difficult.

Problem

Reference points are not the same level on the upstream and downstream side.

Solution

This is not a problem as long as the volunteer does not attempt to determine the elevation difference between the reference points and adjust his or her data accordingly.

Problem

Tidewrack covered up the reference point.

Figure A.8 Tidewrack, if not cleared away, can make tidal measurements more difficult.

Solution

Bringing a staff to clear away the tide wrack (the accumulative mass of dead plant stalks) is a good idea, as is using a colorful chalk or paint mark which you can see below the water once the wrack is cleared (be careful because chalk marks can wear away with the tides).

Problem

I stepped on the reference point, and it moved.

Solution

If the reference point was set on loose stone and the stone could not be placed back at its original place, then the data should be discarded.

Problem

There was a high guardrail on the bridge, and I could not reach over to my reference point.

Solution

Sites should be checked for accessibility before they are assigned to volunteers.

Problem

At low tide there was no water so I marked it zero.

Solution

If possible return to the site at low tide and determine the distance to the mudflat, and record the total distance rather than simply recording it as zero.

Problem

I forgot which exact point (top, bottom) on the painted reference point I measured from.

Solution

On the template sheet there is an opportunity to make a map of the site and take notes. This is a good idea if your painted reference point is on a rock where there are two main points from which to measure. As well, keep your reference point markings small and exact.

Problem

The measurements were not on exact two-hour intervals.

Solution

This is not a problem as long as the exact times were noted and not simply rounded off (which some volunteers do). Emphasize exact time in the training.

Problem

I ran out of time; taking 6 measurements is too long.

Solution

If the first measurements are taken at 7am then the volunteers will be finished at 6pm provided that all the sites can be done in one hour. If volunteers start late, then they will finish late. It is important to stress the fact that this is an all-day event, with short breaks throughout.

Problem

I missed a measurement, so went back the next day an hour later to compensate for the tide shift.

Solution

Discard the data.

Problem

I could not measure the upstream and downstream at the exact same time.

Solution

This is not a problem as long as the exact times were noted for the upstream and the downstream.

Problem

A drawbridge was up during a scheduled measurement time.

Solution

The times do not have to be exactly at two-hour intervals, as long as the times are properly marked.

Figure A.9
If your reference point is on a drawbridge and you need to wait for the bridge to be lowered, you can shift your measurement times 10-20 minutes without compromising the results.

Problem

I mixed up centimeters and inches when I did my measurements.

Solution

Some tape measures have inches on one side of the tape and centimeters on the other. It is important to point this out at the training session, and tell the volunteers to mark on their data sheets the units of measure used for every measurement.

Problem

I confused 1/10 of a foot with inches.

Solution

Some tape measures have 1/10 of a foot and inches on either side of the tape; this should be pointed out at the training session.

Problem

I lost the data sheets.

Solution

It is a good idea to collect the data sheets soon after the project is complete to reduce the risk of data getting lost or being eaten by pets.

Problem

I was confused about the purpose of the project.

Solution

Improve your training sessions and pre-training sessions, and share the data results with your volunteers.

Overcoming these problems can be formidable, and we have found that even a thorough explanation of the process will still result in confusion. Often simply analyzing the data once it is in the spreadsheet will highlight field measurement errors, and give you a sense of the reliability of the data. Double-checking the data, by having a different team of volunteers do the same sites at a different time or having the organizer complete the measurements, is an excellent way to see how accurate the tidal data is. There are a few shortcomings associated with volunteer work, but the benefits that result from organizing a volunteer activity far outweigh any problems that may occur.

Appendix B: Sample Data Sheets

Phase I: Tidal Crossing Data Sheet

Location

Map Reference Number	
Water Body / Stream Name	
Town	
Street	
Landmark / Location Description	

Plan View Sketch

Date:
Time:
Tidal Conditions: Low Mid / Low Mid Mid / High High
Incoming Outgoing Change
Weather: Sunny Partly Cloudy Overcast Rain

A Photo #1 – Reference #:
B Photo #2 – Reference #:
C Photo #3 – Reference #:

North

1 inch =

Approximate Scale (Feet)

General Notes:

PHASE I DATA SHEET (continued)

Crossing Information

Type					
Dimensions of Opening (Height, Width, Diameter, Include Sketch if Applicable)					
Upstream Channel Width at Crossing					
Downstream Channel Width at Crossing					
Height of Creek Bottom to Road, Upstream					
Height of Creek Bottom to Road, Downstream					
Length of Crossing					
Crossing Width (In Middle)					
Road Surface Width (In Middle)					
Road Surface Material					
Condition (1-5) of Bridge*	1	2	3	4	5
Condition (1-5) of Road*	1	2	3	4	5
Condition (1-5) of Culvert*	1	2	3	4	5

*1-Excellent 2-Good 3-Fair 4-Poor 5-Need of Immediate Repair (Circle the most appropriate response.)

Restriction Classification Scheme

Classification	***Evidence of Flow Restriction / Erosion***	***Notes***
1 Upstream / Downstream	*Unrestricted / No Pooling*	
2 Upstream / Downstream	*Flow Detained / Slight Erosion*	
3 Upstream / Downstream	*Minor Pooling / Erosion Present*	
4 Upstream / Downstream	*Significant Pooling / Significant Erosion Present*	
5 Upstream / Downstream	*Major Pooling / Major Erosion Present*	
Classification	***Channel vs. Culvert / Opening***	
1 Upstream / Downstream	*River Width < Opening Width*	
2 Upstream / Downstream	*River Width = Opening Width*	
3 Upstream / Downstream	*River Width 1.1 to 2.0x Opening Width*	
4 Upstream / Downstream	*River Width 2.1 to 5.0x Opening Width*	
5 Upstream / Downstream	*River Width 5.1x + Opening Width*	
Classification	***Vegetation Comparison***	
1	*Upstream = Downstream*	
2	*Upstream Slightly Different Than Downstream*	
3	*Upstream Different From Downstream*	
4	*Upstream Much Different Than Downstream*	
5	*Upstream Completely Different Than Downstream*	
Overall Rating =		

General Notes:

Phase II: Water-Level Data Sheet

Date:
Crossing Site: *Street:* *Water Body:* *Landmark:*
Name:
Low Tide: *High Tide:*

Time (Hours: Minutes)	**Height Upstream (Inches)**	**Height Downstream (Inches)**

Sketch of Reference Points in Relation to Site

North

1 inch =

Approximate Scale (Feet)

General Notes: