RATIONALE FOR REPLACING THE BROKEN SIPHON IN WEST HARBOR POND

The West Harbor Pond Watershed Association (WHPWA), a 501(c)(3) non-profit whose mission is *to protect and preserve West Harbor Pond,* is seeking grant support to replace a broken siphon crossing under State Rte 27, from West Harbor Pond to the inner harbor of Boothbay Harbor. The text and pictures in the accompanying narrative conveys rationale for repairing this passive siphon; it passes beneath a state road, through a state-owned dam with a state-maintained fish ladder. The objectives of this repair include: improvement in water quality, restoration of habitat for fish and aquatic life, enhanced public safety, and provision of a mechanism to deal with the impacts of rising sea levels.

Project Overview

The Association, in cooperation with the local Sewer District, has monitored the Pond's water quality through a testing program established in 2008. During that period, Volunteers have documented the severe and increasing degradation of water quality in West Harbor Pond occurring as a result of the broken siphon. WHP reaches depths of 30', but ***the water below the 12' is toxic to aquatic life***

West Harbor Pond was created in the 1880's when a granite block dam was put across the mouth of Campbell Cove to impound freshwater flowing from Campbell Stream. In damming the Cove, community leaders hoped to develop a commercial ice business that would provide off-season employment for the community's workers and underutilized ships. At the time the dam was built, two siphons were installed to drain the saltwater trapped behind the dam into the inner harbor. When ice production started, one siphon was removed, but the other, with inlet at a depth of 22', was left intact to continue to return to the harbor saltwater that seeped through the dam into the Pond. This system functioned as intended for 130 years, during which time the Pond remained free of saltwater to the depth of the siphon intake.

In 2008, however, after a couple years of gradual decline, the siphon failed entirely, rupturing at a point near the midline of State Route 27. A camera system was inserted into the siphon by Boothbay Harbor Public Works, which revealed the pipe was completely crushed and the broken ends were substantially displaced and misaligned. This situation allows water from the Pond at flood level, and from the sea at extreme high tide, to pass through the break point, and percolate through the inner structure of the dam.

The location of the break is seen in the picture below as a circular blacktop patch just to the right of the shadow cast by a utility pole. This patch is often replaced as water escaping from the pipe break washes out fill and undermines the pavement. The fishway on the left allows passage of alewives, eels and smelt.

Aerial view of south end of WHP showing WHP dam, fishway, and location of break in siphon

It took several years for the negative effects caused by the siphon's failure to be recognized, but today the significant adverse impacts are apparent and well-documented, and include:

- Substantial increase of severely degraded saltwater in the Pond;
- A corresponding reduction in the amount of freshwater in the Pond;
- Increasing water quality problems in a *thinning* freshwater stratum;
- Reduction in capacity of the Pond to buffer runoff from the western Boothbay peninsula;
- Accelerating deterioration of a section of WHP dam adjacent to the broken siphon; and
- Degradation of roadbed and protective structures where Route 27 crosses the WHP dam.

Repair of the broken siphon would provide a mechanism to remedy these problems; problems which have ramifications not only for West Harbor Pond, but for the inner harbor and the Boothbay Harbor community.

Restoring Water Quality in West Harbor Pond:

For 130 years a siphon, draining the lower depths of West Harbor Pond has provided a mechanism for continually returning to the harbor, saltwater infiltrating through the West Harbor Pond dam. Historical DEP data on West Harbor Pond shows that at the 24' depth a significant change in density has existed since collection of water quality information began decades ago; the high conductivity found in water samples collected below that level were indicative of increasing salinity. Twenty-four feet is the depth of the intake pipe opening in the passive siphon. So, as long as it operated properly, the siphon prevented the level of saltwater in the Pond from rising above the siphon's intake. Today, all that has changed.

In the 8 years since the siphon failed, the density interface between fresh and saltwater has risen from the 24' foot recorded in the historical DEP records; to only 12' in depth. The rising level of saltwater has displaced millions of gallons of freshwater and destroyed aquatic habitat of the Pond below the 12' level.

Under different circumstances turnover might mitigate this problem, but in West Harbor Pond, disparity in density between fresh- and saltwater strata prevents this seasonal movement. So, not only is the saltwater layer increasing in volume but, with lack of mixing, the water quality of this lower saltwater layer continues to deteriorate as organic and inorganic materials settle from the upper freshwater layer. Figure A documents the steep decline in dissolved oxygen in the Pond at depths below 12'.

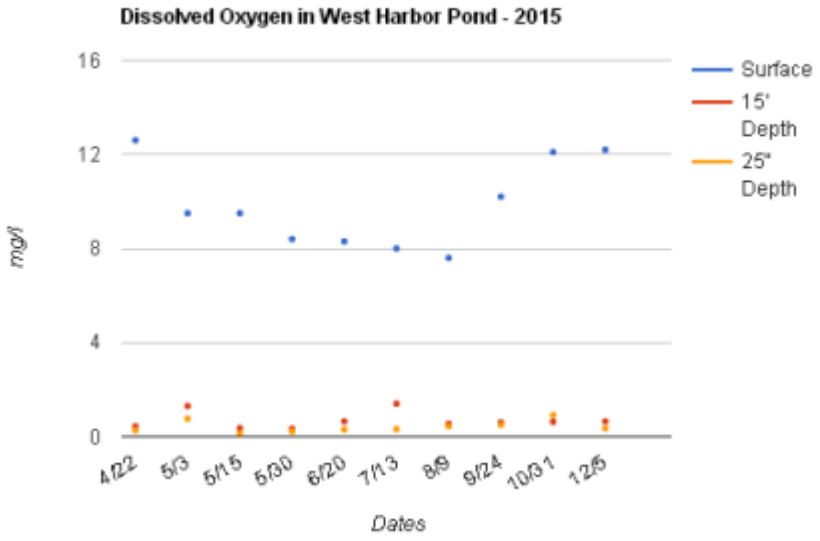


Figure B shows chemical differences between moderate quality freshwater at the Pond's surface and the harsher chemistry below the 12' depth, where water is toxic to aquatic life.

Water Chemistry	Surface	22' Sample Depth
Calcium, total	13.6 mg/L	124 mg/L
Iron, total	0.04 mg	0.07 mg/L
Magnesium, total	36.4 mg/L	404 mg/L
Manganese, total	0.05 mg/L	0.11 mg/L
Sodium, total	291 mg/L	2802 mg/L
Chloride	545 mg/L	9480 mg/L
Alkalinity	15.4 mg CaCO3/L	366 mg CaCO3/L
Ammonia-N	ND mg/L	11.8 mg/L
Nitrate-N	ND mg/L	ND mg/L
TK Nitrogen	<0.05 mg/L	16 mg/L
Phosphorus, total	0.02 mg/L	1.71 mg/L
Phosphorus, dissolved	0.01 mg/L	1.51 mg/L
Sulfate	70.4 mg/L	603 mg/L
Sulfide	<0.01 mg/L	0.5 mg/L
Turbidity	<1.0 NTU	190 NTU

West Harbor Pond Watershed Association volunteers started water quality monitoring in 2008. Locations on the Pond perimeter were established as sampling stations and, for several years, the results of water quality measurements of the surface water showed little reason for concern. In 2013 testing was expanded to include the collection of water quality data throughout the water column. The dissolved oxygen levels, conductivity, and temperatures measured at the lower levels of the Pond were alarming. At the 13' depth, water temperatures changed dramatically, which might be expected; but the nearly

complete lack of oxygen, the overwhelming presence of hydrogen sulfide, and the extremely high conductivity readings of 18,000 microSiemens, below this depth was an unpleasant and troubling surprise. Even more concerning, data in 2014 and 2015, indicated that the depth at which this major change in temperature and water quality occurred, was moving up the water column, to 12' in 2015.

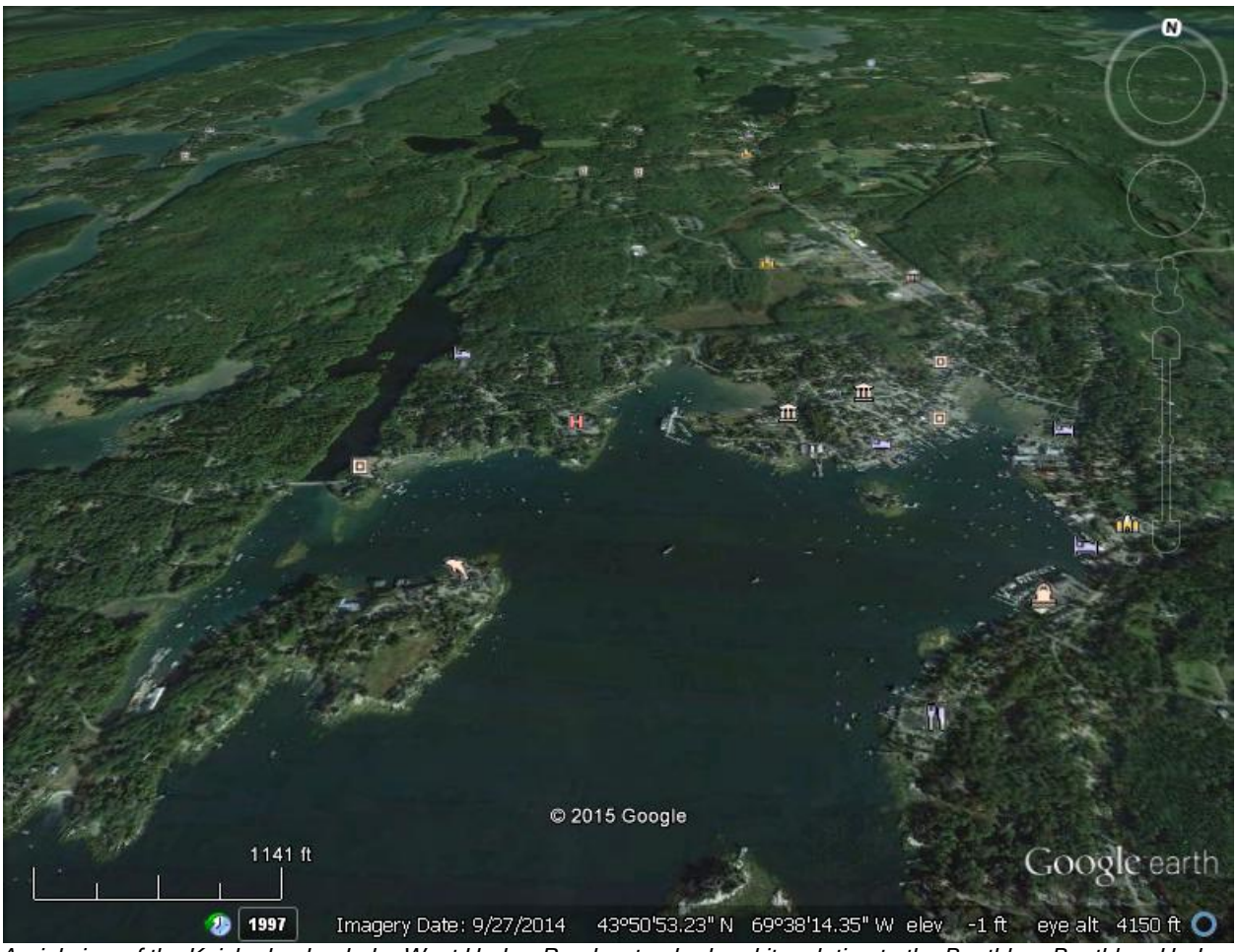
On the advice of Linda Bacon at DEP, WHPWA volunteers extended sampling much later into the year in 2014, started sampling as early as possible in 2015, and continued sampling as late into 2015. This effort demonstrated that there is no seasonal turnover in West Harbor Pond.

In addition to deterioration of the saltwater stratum, there is evidence to suggest the thinning freshwater layer atop the severely degraded saltwater is being progressively degraded as well. Higher conductivity levels – above 3000 microsiemens – are being seen in surface water samples It is likely that as the boundary of degraded saltwater elevates in the water column, it is reaching a level where wind and severe weather can cause some mechanical mixing to occur, in spite of the distinct density differences. As the saltwater layer continues to elevate, it will become more and more susceptible to mechanical mixing during major storm events.

Protecting the Community's Inner Harbor:

Beyond concerns for the water quality of West Harbor Pond itself, failure of the WHP siphon has broader ramifications for the entire Boothbay Harbor community. In 2015, volunteers recorded the highest levels of *E. coli* colonies (nearly 400/100ml) seen since Association members began monitoring in 2008. It's hypothesized that *dilution capacity* of the Pond has been compromised because of the substantial reduction in amount of freshwater. High volumes of runoff from the upland watershed after severe storms simply are not being buffered adequately by the diminished volume of freshwater contained in the Pond.

Seen below, the 1500 acre upland watershed on the western side of the Boothbay Peninsula drains into the three lobes of Knickerbocker Lake, Campbell Stream and into the long, narrow West Harbor Pond. This watershed contributes the largest amount of runoff entering this small protected inner harbor.



Aerial view of the Knickerbocker Lake-West Harbor Pond watershed and its relation to the Boothbay-Boothbay Harbor community and its inner harbor

Before human settlement and commercial development, intermittent inflows of freshwater runoff into the harbor from storms events were not problematic. But with the increase in impermeable surfaces in the harbor's watershed – roads, driveways, parking lots, sidewalks, building roofs and porches – around the inner harbor and throughout this shoreside community, the amount of water laden with both natural and manmade pollutants that pulses into the inner harbor after storms today, is quite significant. For 130 years, West Harbor Pond has played a vital role protecting the community's environment by acting as a settling basin to control and buffer storm water runoff. Indeed, while the ice enterprise that gave impetus to construction of WHP provided employment and business opportunity for only a few years, the real, long-lasting economic benefit provided by the dam and West Harbor Pond – freeboard for long term community growth and development in the inner harbor's watershed – endures to this day.

But as the buffering effectiveness of WHP declines, the threat of problematic runoff reaching the inner harbor increases correspondingly. In short, consequences of the drastic decline in the water quality of WHP are not limited to the Pond itself, but directly affect the whole community.

In recent years poor water quality within local inshore marine waters of the Boothbay Peninsula has become the norm during the warm months of summer. Lowered oxygen levels and high *E. coli* counts caused by runoff and pollution are evidence that water quality in the inner harbor is reaching a tipping point. This circumstance would threaten quality of life in any community, but the threat to Boothbay Harbor is particularly acute because the harbor, a popular destination for tourists and the base of its fishing industry, is the economic engine of Boothbay Harbor.

Without the protective effect of WHP, it's likely the tipping point would have been reached many years ago. Without a functioning siphon, water quality will continue deteriorate in West Harbor Pond and the public benefits of runoff capture, settling, residency time, gradual release into the inner harbor, will be lessened or end altogether.

Restoring Habitat for Fish and other Aquatic Life in the Watershed:

West Harbor Pond is a mile-long manmade impoundment with a maximum depth of 30' and an average depth of 13'. Runs of anadromous species have been sustained for well over a century, initially through a rock-lined sluiceway, and more recently, through an Alaskan-style SteepPass fishway. Runs of American shad and rainbow smelt have been documented in the past, but only runs of alewives and glass eels have been chronicled in recent by the Dept of Marine Resources.The Pond once sustained a population of brown trout and for years received hatchery-reared trout. Today, warming water temperatures in the Pond have led to dominance by large- and small-mouth bass, white perch, and minnows.

The significant increase in volume of anoxic saltwater is reducing freshwater habitat as more pond bottom is overrun by degraded saltwater, and has several negative impacts, including:

1. aquatic vegetation drops to the bottom to decay in an anaerobic environment,

2. dissolved phosphorus accumulates at depth and when released causes algae blooms

3. problematic changes occur in sediments, such as elevation of sulfur compounds

4. submerged structure is no longer available to crayfish, snails, and forage fish

The loss of a sustaining trout population indicated that warming was occurring in the Pond before failure of the siphon, but there is good evidence that warming is now accelerating and becoming pervasive throughout the thinning freshwater layer. The composition of aquatic vegetation is changing with an increase in the prevalence of muskweed along the shoreline and prevalence of native milfoil in shallow water in shallow water coves. Anecdotal reports from fishermen indicate a significant decline in the number of white perch and observation of multiple bacterial lesions on the outside skin of smallmouth bass caught in August and early September. The opportunity for fish to drop into cooler waters in summer months is precluded by the presence of anoxic saltwater below the 12' depth.

The shrinking freshwater habitat in West Harbor Pond has implications for successful passage and/or performance of anadromous species. Three-quarters of a mile above West Harbor Pond, Campbell Stream emerges from Lake Knickerbocker, which is the historical destination for anadromous fish and eels in this watershed. Lake Knickerbocker supports a trout population and provides good habitat for alewife spawning and eel growth. However, if the entire water column in West Harbor Pond becomes degraded, successful seasonal passage up- or downstream will not occur and Knickerbocker will cease to be available for reproduction of anadromous fish and eels.

But West Harbor Pond is not just a *passage* for anadromous species. It's apparent from the large numbers of alewife young-of-the-year found in West Harbor Pond when inflow from Campbell Stream is non-existent that spawning has occurred in the Pond. In addition, fishermen trap adult eels in West Harbor Pond. So the Pond, albeit man-made, provides additional habitat within the local watershed for sustaining historical populations of anadromous species.

SteepPass Fishway for anadromous species at the West Harbor Pond dam

Alewives exiting West Harbor Pond into Campbell Stream heading toward Lake Knickerbocker

Improving Public Safety

Route 27, on top of the West Harbor Pond dam, connects Boothbay Harbor to Southport; it is public infrastructure that is being compromised by the broken siphon. Water exiting the broken siphon pipe courses through inner structure of the dam and serves as lubricant for shifting granite blocks. Large rocks near the siphon are moving outward and falling away from both sides of the dam structure. As the dam subsides and narrows the roadbed of Route 27 is being degraded.

These problems came to light when engineers preparing estimates to repair the siphon pointed out problems related to slumping of the dam structure near the siphon. These marine contractors explained that this damage has likely been caused by water flowing from the broken siphon pipe. Considerable quantities of rock will have to be placed on either side of the siphon to bulwark the dam in this weakened section before excavating and siphon replacement can occur.

Continuing Deterioration of the WHP Dam Caused by the Broken Siphon

On the seaward side at low tide, deterioration of the dam face is obvious as the original wood cribbing is now exposed. Only a few years ago the foot of the siphon pipe was visible at low tide, but rock from the dam face has tumbled down and now obscures this part of the siphon.

Sloughing off seaward face reveals original cribbing - July 2015

Bottom of seaward siphon now fully obscured by fallen rock - July 2015

As the dam has spread and slumped downward, rock has have been moved out from the face; ironically some shifting blocks have wedged behind the siphon pipe on both sides of the dam.

Outward moving rock wedged against lakeside siphon - July 2015

Outward moving rocks wedged against seaward siphon - July 2015

Evidence of outward movement of rock and slow motion collapse is visible all along the seaward dam face, and can be seen in the photographs below, taken in July 2015.The fact that large rocks are not covered with seaweed indicates they tumbled off the dam face recently.

Outward movement of rock visible all along seaward face of dam - July 2015

Rocks recently tumbling away from dam face are obvious due to lack of seaweed growth - July 2015

The Broken Siphon is Creating a Safety Issue

As dam structure shifts, the roadbed of Highway 27 is affected. Erosion of the sides is narrowing the roadbed and undermining edges of the pavement and causing the guardrail stanchions to splay outward. A leaning guardrail can actually help tip a vehicle into WHP or the harbor, instead of containing it.

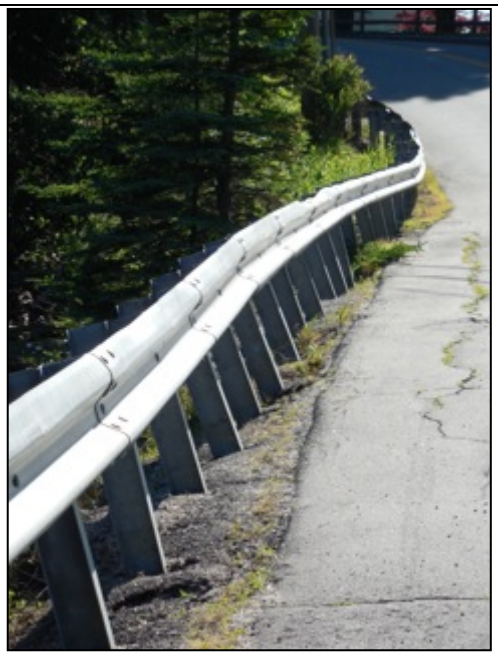
Rock falling away from dam face narrows the roadbed (July 2015)

Erosion along narrowed road bed encroaches under the guard rail to the pavement on the lake side (July 2015)

Erosion encroaches under the guard rail to the edge of the pavement (July 2015)

Once rock face sloughs away, the road bed begins to erode on the seaside (July 2015)

Slumping dam structure cracks pavement and splays guard rail stanchions (July 2015)



Splayed stanchions can tip a fuel truck or school bus INTO the harbor or lake instead of stopping it (July 2015)

Enhancing Opportunity to Address Effects of Warming and Rising Sea Levels

Storms occur less frequently now but are becoming more severe; this impacts capacity of West Harbor Pond to function as an important runoff catchment basin and prevent spikes of pollution in the inner harbor. The Pond provides a basin for slowing, retaining, and diluting runoff from West Boothbay Harbor.

In the past, water levels could be adjusted by using the siphon to lower lake level in preparation for spring runoff and hurricane season. The rationale for water level control certainly includes runoff/pollution control and the possibility of controlling macroalgae growth in the summer; but an important reason recognized in recent years is the need to reduce the pressure of exceedingly high water levels on the dam. In 2011, acknowledging this problem, DOT attempted to reduce incidences and impact of high water in the Pond by cutting a 1' deep channel in the dam threshold of the, rather than repair the siphon. Without a functioning siphon there is no way to lower the water level below the level of the dam threshold.

During and after severe storms, water level in the Pond can rise well above the dam threshold. In many instances there is simply more water entering than can be drained. A functioning siphon allows manipulation of water levels before anticipated seasonal fluctuation and, perhaps major storm events.

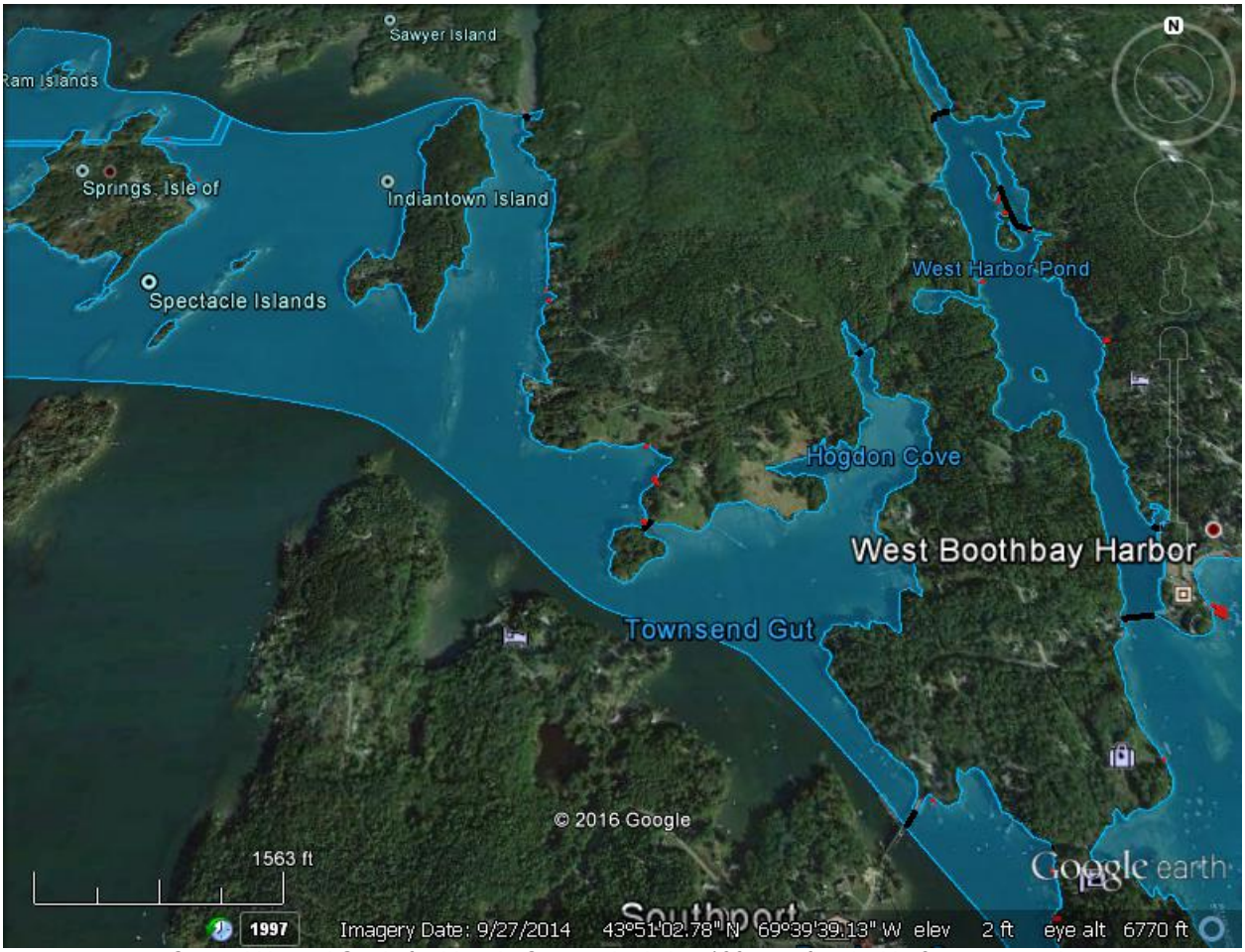
The devastation wrought by Hurricane Sandy a few years ago prompted government officials to authorize Coastal Hazard Studies to be conducted on a county-by-county basis up and down the Atlantic coastline. The underlying rationale was that a rising sea level driven by global warming is putting more shoreline areas and coastal communities at risk during major storm events. The Studies were based on models that incorporated current and projected elevated ocean water levels into damage assessments during major storm events (50- and 100-year storms) and Category I, II, III, IV, V hurricanes. The projected extent of shoreland flooding did not factor in rainfall or wind, therefore, are conservative in estimating impact.

Projections for Boothbay Harbor are included in the Lincoln County Coastal Hazard Study. The four areas identified as vulnerable to significant flooding and damage during major storm events are 1. businesses on the inner harbor shoreline in the commercial district, 2. the sewage treatment plant, 3. Samoset Road, and 4. the West Harbor Pond dam. This risk will only increase as climate warming proceeds.

The black lines on the Hazard Study overlay below show parts of local infrastructure – State route 27, Lakeside Drive, and Wawenock Trail - will be underwater in a 100-year storm event. It's apparent West Boothbay Harbor and Southport, during severe storms, will be cut off entirely from Boothbay Harbor.

In West Harbor Pond, saltwater inundation over the dam will probably remove the density interface separating freshwater from the increasingly large volume of severely degraded saltwater. Release of this anoxic water with harsh chemical constituents into the upper layer of the Pond is likely to kill all the fish and prevent successful migration of anadromous species. Inundation and flooding is also likely to kill shore vegetation and affect the operation/efficiency of nearby septic systems. The resulting poor quality water would flow over the dam threshold into the inner harbor and do so well into the future.

The only remedy for pond restoration in such a saltwater inundation scenario would be reverting to the strategy employed by town leaders 130 years ago, use of a siphon to purge saltwater. But if a functional siphon were in place currently and degraded saltwater was purged from the Pond prior to a major storm event, an increased volume of freshwater in the Pond could provide the opportunity for diluting the inflowing saltwater and serve as a sump for entering saltwater. By removing the threat degraded seawater susceptible to mixing with saltwater breaching the dam in a storm event, it would improve the chances for avoiding a fish kill disaster, and reducing the long-term deleterious effects on the Pond and inner harbor.



Coastal Hazard Study for Lincoln County depicting 100 year flood with .3 meter sea rise

What Would It Cost to Repair the Siphon

Estimates for siphon repair have been received from two marine contractors: Prock Marine in Rockland and Rideout Marine in Boothbay Harbor. The estimates of costs varied somewhat, but there was overlapping opinion on the need for bulwarking the section of the dam adjacent to the broken siphon pipe. Figures shown below are from combining opinions of both contractors.

Engineering plan preparation and permitting	$5,000
Excavation, removal of old siphon, replacement, fill, paving	$20,000
New HDPE siphon pipe components	$10,000
Bulwarking of Dam adjacent to existing siphon	$20,000
Total	**$55,000**

Conclusion

Clearly this is a pond in trouble"……was Dr. John Peckenham' comment last summer after reviewing the water chemistry analysis and water column sampling data from West Harbor Pond; he's Director of the Maine Water Resources Research Inst. and Associate Director of the George J. Mitchell Center, at UMO

West Harbor Pond Watershed Association members realize that with 6000+ ponds, and that-many-or-more streams, there is great need for investment in watersheds across the state. Why should attention and money be directed toward West Harbor Pond, a smallish impoundment in the middle of tourist town, when compared to pristine streams linking Great Ponds in large, undeveloped watersheds? The fact is replacement of the inoperative siphon in WHP is a prudent, long-term investment.

Besides the water quality, fish habitat, anadromous species passage, and obvious public infrastructure implications, there are important imponderables in this project. The West Harbor Watershed Association membership has increased every year since inception in 2008 and now comprises ownership of about 70% of the shoreline. This group has started and maintained a volunteer water quality program and conducts on-the-water aquatic plant identification sessions and invasive species workshops. Its members clear detritus from above the fishway and upstream culverts to facilitate passage of alewives and eels. Last year, it provided most of the volunteer manpower for the survey of Lake Knickerbocker. Finally, it voted unanimously to participate in the Maine Lakes Society LakeSmart Program,

If a way could be found to restore a strong passive siphon, one that might well last, like the original, many, many decades, the cooperating shoreland owners on West Harbor Pond offers a critical mass of volunteer