SEASONAL SWIM DOCK ALTERNATIVES ANALYSIS

Connecticut River at Dartmouth College

MMI #4459-01

January 21, 2011

Background

On June 23, 2010, the Dartmouth College student swim dock area located on the Connecticut River was closed due to concerns for swimmer safety. The site-specific conditions of concern include excessively deep water (18 to 25 feet), a rapid drop in depth moving away from the riverbank, high turbidity leading to low visibility (one to two feet), varying flow velocity due to changes in hydroelectric operations at Wilder Dam and storm events, and submerged debris. All of these factors reduce swimming safety and complicate lifeguard rescue should it be needed.

In an effort to reopen the swim docks, college administration has requested that an alternatives analysis be performed to evaluate ways to reduce risks working toward the ultimate goal of reopening a safer swim dock in summer 2011. Alternatives to be explored include:

1. Restore swimming at the existing swim dock location with the same dock configuration
2. Restore swimming at the existing swimming location with new dock configurations
3. Restore swimming at another location on the Connecticut River frontage
4. Move swimming to another location near the campus

College students are eager to reopen the swim docks. A recent document entitled *Student Swim Dock Report* issued by the Dartmouth Swim Dock Committee and Student Assembly offers some good information on swimming safety in natural bodies of water and provides some useful general guidelines to reduce the risk of swimming. Recommendations include:

1. "Ensure that everyone swims in the same place;
2. Ensure swimming is supervised;
3. Ensure easy access in and out of the water;
4. Make sure people know how to swim; and
5. Ensure that people are not under the influence of alcohol."

The *Student Swim Dock Report* recommends a rectangular swim dock with an inner swim area.

A college staff working group is currently developing a new operational management framework for a future swim dock that will include specific guidelines for access to the docks, lifeguard staffing and expectations, monitoring, and criteria for closing the docks. The recommendations of the working group will also be informed by the findings of this alternatives analysis.

The Connecticut River

The Connecticut River (total watershed area ~ 11,250 square miles) is New England's largest river (length ~ 400 miles), draining portions of New Hampshire, Vermont, Massachusetts, Connecticut, and Quebec. The U.S. Environmental Protection Agency (US EPA) has designated the Connecticut River an American Heritage River for its importance as a natural and cultural resource. Countless studies and texts document the many habitats for species and ecosystem services for humans provided by the Connecticut River, as well as it being a river that generally shaped civilization in the eastern United States (e.g., Allis, 1939; Bell, 1985).

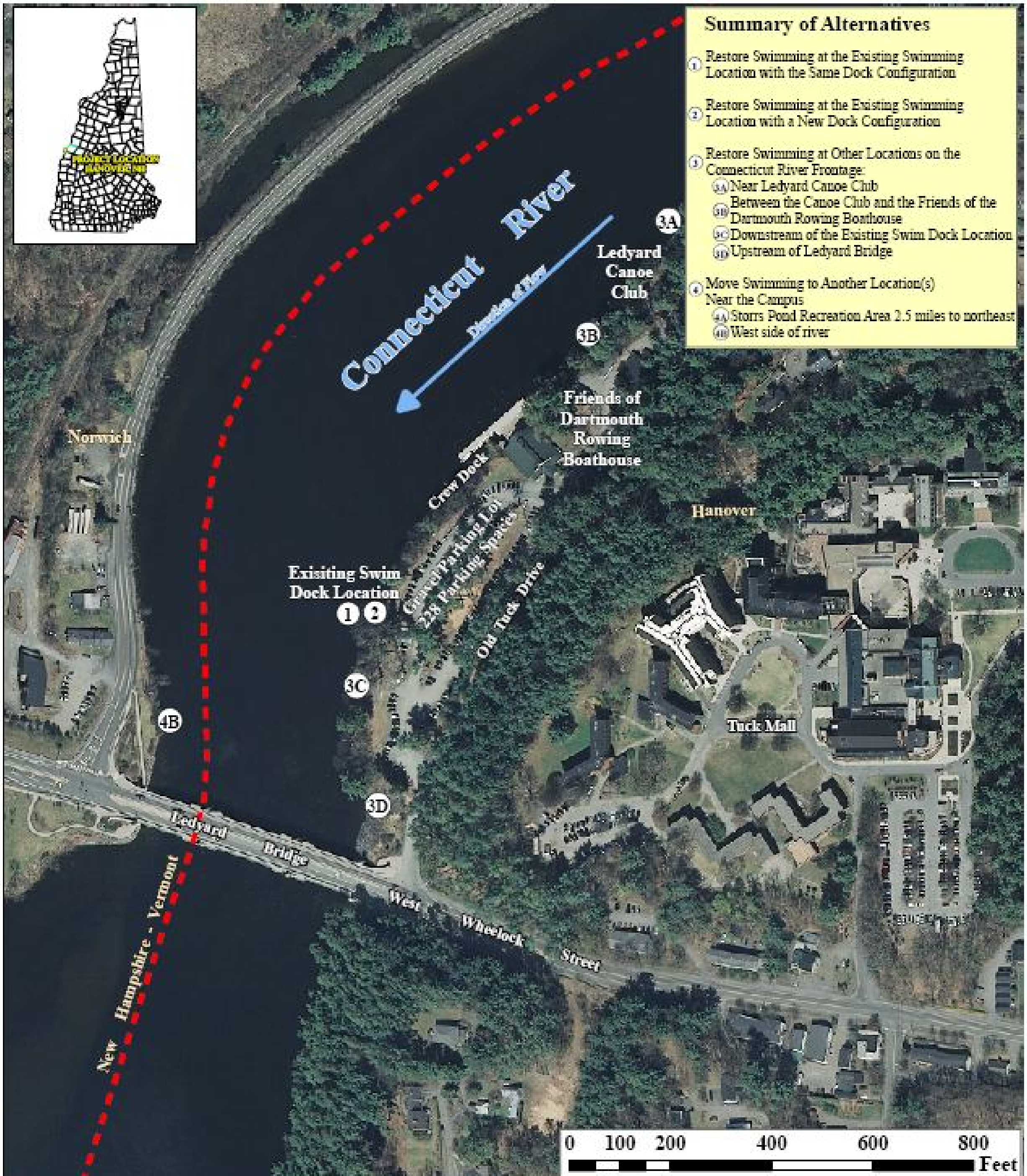
The Connecticut River originates from the fourth Connecticut Lake in New Hampshire and rapidly grows from a mountain stream to a large river that is typically wide and deep. The upper river is largely regulated, consisting of water storage reservoirs that supply hydroelectric dams further downstream. The lower 60 miles of the river is tidal between Long Island Sound and Windsor Locks, Connecticut. The size of the river channel is often increased from the numerous dams that impound water. The U.S Fish and Wildlife Service estimates that there are more than 1,000 dams in the Connecticut River watershed. A portion of dams are on the main stem river (13 on the upper Connecticut River) primarily for hydroelectric power generation and flood control.

The Connecticut River moves a large amount of water, sediment, and debris from the highlands in New Hampshire and Vermont to the coastal lowlands in Connecticut. Typical flow rates at the river outlet are 20,000 cubic feet per second (cfs). The Connecticut River is known to carry large loads of silt throughout its entire course, leading to high turbidity levels. The silt eventually deposits in Long Island Sound.

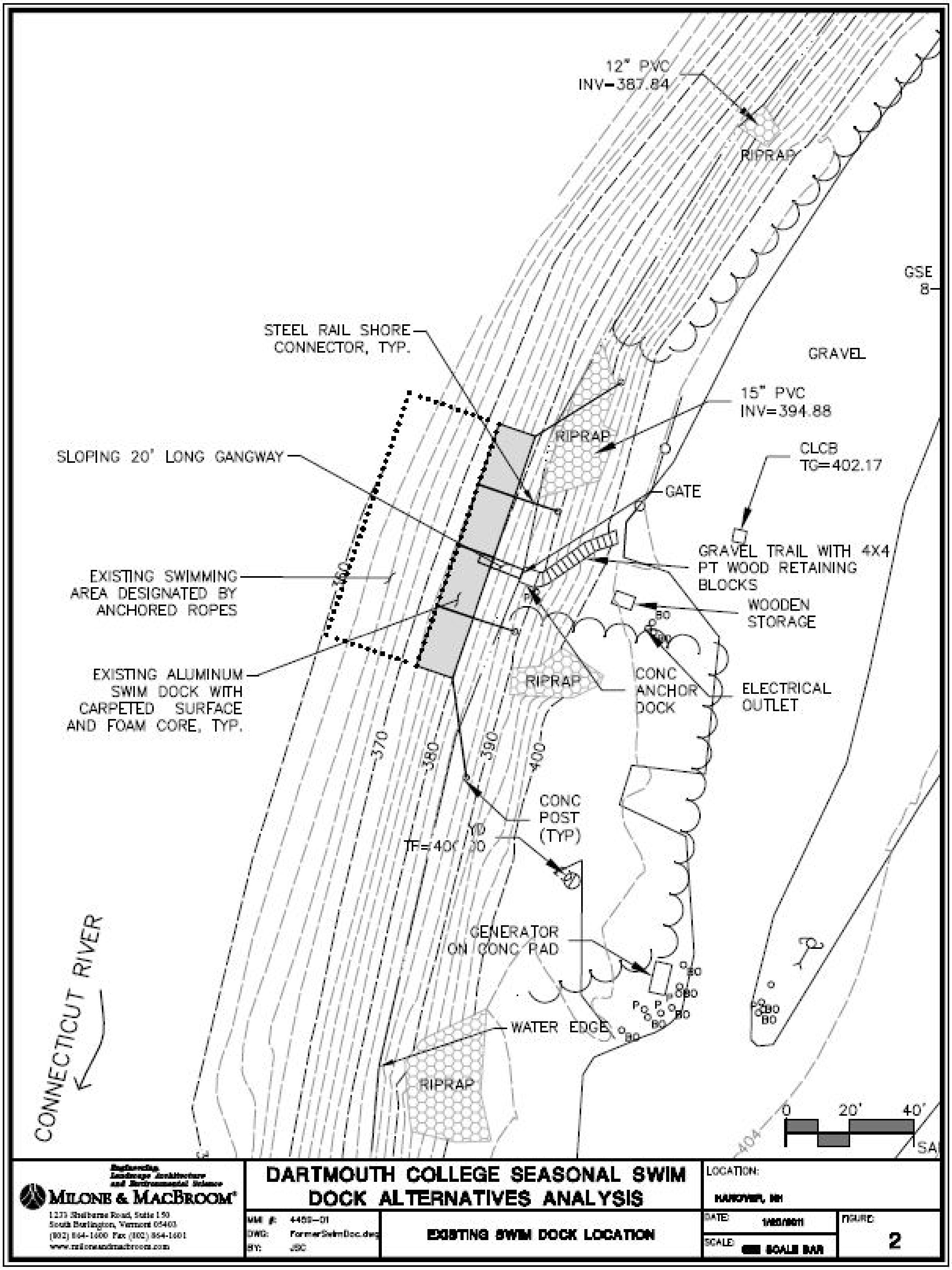
The Connecticut River forms the boundary between Vermont and New Hampshire. In the Upper Valley Region (Piermont to Lebanon), the boundary is located at the low water line on the western (Vermont) side of the river (1933) and, thus, New Hampshire owns most of the river. When the river is impounded by a dam, the boundary is located further away from the western bank and typically at a historic low water line when the river is flowing free.

The Existing Swim Dock

The existing Dartmouth College swimming dock is located adjacent to the east shore of the Connecticut River upstream of the Ledyard Bridge (Wheelock Avenue) and downstream of the Friends of Dartmouth Rowing Boathouse (Figure 1). The seasonal dock consists of a series of connected aluminum rafts with foam cores that run parallel and are anchored to the shore by steel rails connected to concrete posts in the riverbank (Figure 2). The width of the dock is 12 feet, and the combined length of the dock is 80 feet.



Engineering, Landscape Architecture and Environmental Science MILONE & MACBROOM® 1233 Shelburne Road Suite 150 South Burlington, Vermont 05403 (802) 864-1600 Fax: (802) 864-1601 www.miloneandmacbroom.com	Dartmouth College Swim Dock Alternatives Analysis		LOCATION: Hanover, NH
	MMI#: 4459-01-11 MXD: H:\Alternatives.mxd SOURCE: NH GRANIT, VGIS	Project Site Map and Summary of Alternatives	Map By: SMG Date: Jan. 2011 Scale: See Scale Bar SHEET: Figure 1


12" PVC
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RIPRAP
GSE
GRAVEL
STEEL RAIL SHORE CONNECTOR, TYP.
15" PVC
INV=394.88
RIPRAP
SLOPING 20' LONG GANGWAY
CLCB
TG=402.17
GATE
GRAVEL TRAIL WITH 4X4 PT WOOD RETAINING BLOCKS
EXISTING SWIMMING AREA DESIGNATED BY ANCHORED ROPES
WOODEN STORAGE
EXISTING ALUMINUM SWIM DOCK WITH CARPETED SURFACE AND FOAM CORE, TYP.
RIPRAP
CONC ANCHOR DOCK
ELECTRICAL OUTLET
360
370
380
390
400
CONC POST (TYP)
GENERATOR ON CONC PAD
CONNECTICUT RIVER
WATER EDGE
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MILONE & MACBROOM
DARTMOUTH COLLEGE SEASONAL SWIM DOCK ALTERNATIVES ANALYSIS
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HANOVER, NH
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2

The docks are accessed in a single location by a steep gravel trail with four-inch x four-inch wood retaining blocks that bring swimmers from the edge of the existing parking lot to a concrete block (Figure 3A). A three-foot wide aluminum gangway with railings connects the concrete block on shore to the dock surface. The slope on the gangway is steep (approximately one foot drop every two feet) and varies with the water surface elevation in the impounded river. A gate exists at the entrance to the gangway that has a facility and safety sign mounted on it (Figure 3B).

(A)

(B)

Figure 3: (A) Trail and wood retaining blocks leading to the existing concrete swim dock anchor. (B) Signage on the gated entrance to the gangway leading to the existing dock that is currently in storage on the riverbank.

The entire swim dock was removed after each swimming season for storage along the riverbank during the winter months. It was last removed at the end of summer 2009 and has remained out of service ever since. A brief inspection of the docks in storage shows some normal wear and tear on the docks. Dented aluminum and small holes in the foam interior are visible. The docks appear to be suitable for reuse at this time.

A rectangular roped-off area projected out from the docks approximately 30 feet to designate the swimming area. The ropes floated by buoys and were anchored on the riverbed by cinder blocks or marine anchors. The ropes were regularly swept downstream during periods of high flow. Lifeguards monitored student swimmers at the dock when it was open, typically between 11:00 a.m. and 7:00 p.m.

Hydrology

The hydrology of the Connecticut River is important to understanding flows at Dartmouth's riverfront and the implications to swimming safety. The Connecticut River drains approximately 3,330 square miles upstream of the project site. A ballpark estimate of peak flows is 35,000 cfs for the two-year flood and 78,000 for the 100-year flood (Olson, 2009). However, these estimates do not completely apply to the area given that the flow is locally regulated by an upstream dam. The effective Federal Emergency Management Agency (FEMA) 100-year peak flow rate upstream of the White River (watershed area ~ 3,380 square miles) is 108,000 cfs. Again, that flow rate does not explicitly consider the backwatering from nearby dams.

An active U.S. Geological Survey (USGS) stream gauge is located on the Connecticut River approximately 50 miles upstream from the project site in Wells River, Vermont (#01138500). The watershed area at the gauge is 2,644 square miles. The gauge has been operating since 1950. Records reflect a two-year flood of approximately 30,000 cfs and a 10-year flood near 50,000 cfs. The seven-day duration low flow that occurs once in 10 years (7Q10) is 700 cfs. An active gauge is also located on the Wells River at Wells River, Vermont (#0113900). The next downstream USGS stream gauge on the Connecticut River is in West Lebanon (#01144500). The gauge record reflects the flow release patterns of Wilder Dam after the input from the White River.

The White River remains one of the few large unregulated rivers in the Connecticut River watershed. Flood flows travel through the White River at varying rates, depending on the nature of the precipitation and ground conditions. For example, a regional storm in the northeast (nor'easter) and an intense thunderstorm would lead to different magnitudes and durations of flows in the White and Connecticut Rivers downstream of the project site. Ground conditions will influence runoff amount. Frozen, snow-covered, or saturated ground will lead to more rapid runoff and higher peak flows than precipitation on dry ground where more infiltration occurs. Although downstream of the project site, the USGS stream gauge on the White River (#01144000) may provide useful information on unregulated tributary inputs to the Connecticut River.

The Ompompanoosuc River is a tributary of the Connecticut River located approximately seven miles upstream of the project site. The Union Village Dam on the Ompompanoosuc River, located six miles upstream of the confluence with the Connecticut River, reduces flood flows at the project site by an estimated 5% (FEMA, 2008). The USGS stream gauge located downstream of the dam (#01141500) illustrates retention of floodwaters and monthly releases. This gauge may be useful as an indicator of upstream tributary flows influencing the project site.

The upper Connecticut River is regulated and synchronized for hydroelectric power generation. Three main stem water storage dams in the headwaters store and release water to operate downstream hydroelectric dams. Power stations from upstream to downstream include Moore Reservoir (largest), Comerford, McIndoes, Wilder (project site), Bellows Falls, and Vernon (Figure 4). The power generation capacity of the combined Connecticut River Station is 480 megawatts.

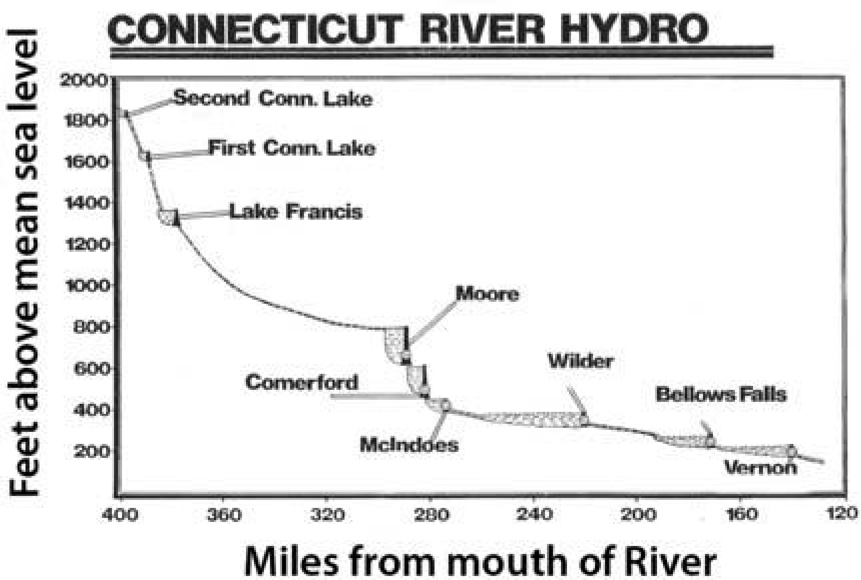

Figure 4: Water storage and hydroelectric dams on the upper Connecticut River.
Source: (CRJC, 2009 and New England Power Co. [now TransCanada])

Wilder Dam

The Connecticut River near the existing swim dock location is impounded by the Wilder Dam, located approximately 2.5 miles downstream of Dartmouth's riverfront. The dam influences 45 miles of river upstream of the 40-foot tall spillway (personal communication, Ken Alton, Vice President of Public Relations, TransCanada). The operation of the dam for hydropower production has the potential to cause significant fluctuations in water levels along the entire college riverfront and is a safety consideration for future swimming and boating activities.

The Wilder Dam was constructed in 1950 and operates under a license from the Federal Energy Regulatory Commission. The dam was designed to pass the flood of record in 1927 of 160,000 cfs. The peak flow measured at the dam to date is approximately 50,000 cfs, and the lowest flow is 500 cfs. It operates as a modified run-of-river hydroelectric facility with daily peaking. Run-of-river is when gate operations are not used to retain or release water beyond what occurs from the dam alone. A modified run-of-river indicates that a water surface operating range has been provided to the facility for electrical generation by control over pool level and downstream flow rates. Peaking hydroelectric facilities store and release large amounts of water when electricity is needed and most expensive, and have the greatest impact on upstream water surface elevations. Wilder Dam has a five-foot operating range between 380 and 385 feet NGVD29 that it adjusts daily and, thus, operates as a daily peaking facility (Figure 5).

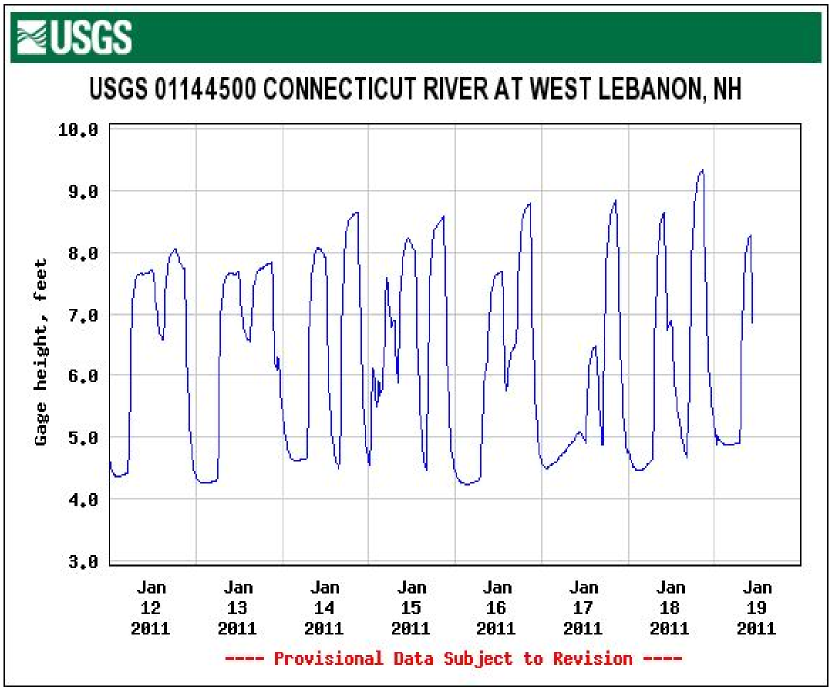

Figure 5: Changing water surface elevation downstream of Wilder Dam.

Approximate flow and planned flow data for below Wilder Dam are available on the WaterLine website (http://www.h2oline.com/505121.asp). Although flows may vary from predictions, the estimates give an understanding of the expected fluctuations in flow conditions downstream of the dam that influence the level and rate of change of the upstream pool level. The data show frequent changes in flow with low flows during off-peak times such as midday and high flows during peak demand times such as morning and evening (Table 1). This common dam operation pattern attempts to maximize power generation when electricity is most needed and most expensive to increase profits.

Table 1: Flow Predictions at Wilder Dam Illustrating Planned Fluctuations in Daily Flow

Date	Start Time	End Time	Target Flow (cfs)	Actual Flow (cfs)
12/31/2010	10:14 a.m.	11:00 a.m.	8,700	9,933
	11:00 a.m.	4:00 p.m.	700	
	4:00 p.m.	9:00 p.m.	8,700	
	9:00 p.m.	12:00 a.m.	700	
1/3/2011	12:22 p.m.			11,121
1/4/2011		12:01 a.m.	11,000	
	12:01 a.m.	6:00 a.m.	700	
	6:00 a.m.	12:00 a.m.	11,000	
1/5/2011	8:41 p.m.	12:01 a.m.	8,700	9,997
	12:01 a.m.	7:00 a.m.	700	
	7:00 a.m.	12:00 a.m.	8,700	
1/9/2011	9:08 p.m.			943
1/10/2011		4:00 p.m.	700	
	4:00 p.m.	9:00 p.m.	6,800	
	9:00 p.m.	12:00 a.m.	700	
1/11/2011	11:35 a.m.	12:00 p.m.	6,800	7,680
	12:00 p.m.	3:00 p.m.	700	
	3:00 p.m.	9:00 p.m.	6,800	
	9:00 p.m.	12:00 a.m.	700	
1/19/2011	11:43 a.m.	4:00 p.m.	700	700
	4:00 p.m.	5:00 p.m.	4,100	
	5:00 p.m.	8:00 p.m.	6,800	
	8:00 p.m.			
1/20/2011		7:00 a.m.	700	
	7:00 a.m.	10:00 a.m.	6,800	
	10:00 a.m.	4:00 p.m.	700	
	4:00 p.m.	5:00 p.m.	6,800	
	5:00 p.m.	8:00 p.m.	8,700	
	8:00 p.m.	9:00 p.m.	4,100	
	9:00 p.m.	12:00 a.m.	700	

The possibility exists for abrupt changes to water levels in the Connecticut River that do not match predictions should a sudden regional demand for power occur such as when a base power plant goes off line. Monitoring for and responding to such fluctuations are important swimming safety considerations in the Wilder Dam impoundment.

The Connecticut River has a gentle slope in the region. The mean channel slope at the existing swim dock location is 0.08% based on the effective river flood profile (FEMA, 2008). In other words, the river bottom drops approximately four feet in one mile. Variations do tend to occur in the local slope of the riverbed due to both natural and man-made features in the river corridor.

The channel is very wide and deep, having a typical width at the project site of 300 feet and a maximum depth of 28 feet. The cross section is said to have a compound shape with a 10- to 20-foot wide sloping bench on the New Hampshire side and 75-foot bench on the Vermont side and then an abrupt drop to the main channel that is 24 to 28 feet deep. FEMA cross sections S and T span the Dartmouth riverfront site (FEMA, 2008), yet geometry data for these locations did not exist in the input code of the hydraulic model used to generate the flood profile and insurance rate maps. A cross section located approximately 0.7 miles downstream of the project site near the confluence of Mink Brook was surveyed in the past for the FEMA study and confirms the Connecticut River main channel is wide and deep, with some compound features in the overbank (Figure 6).

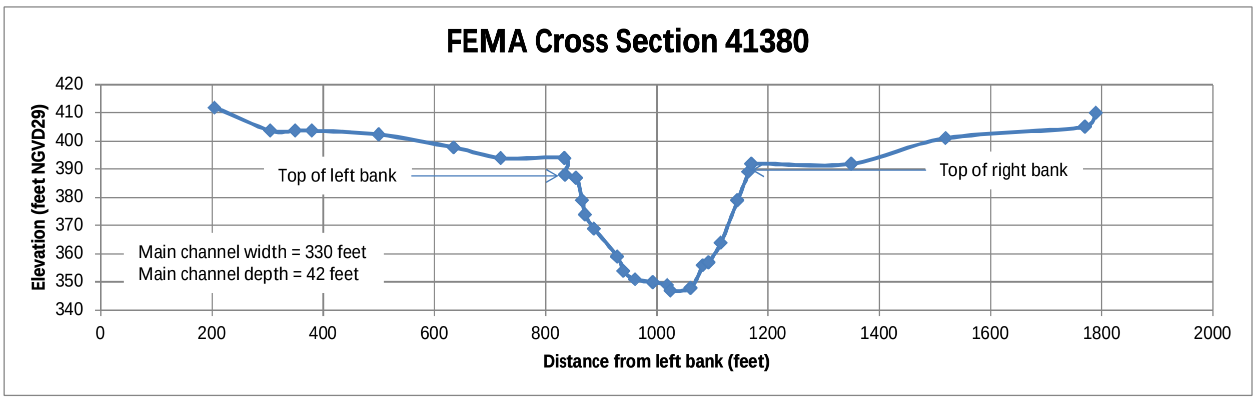

Figure 6: Surveyed FEMA cross section near project site.

The five-foot operating range at Wilder Dam contains the predicted peak flood water surface elevations for the 50-, 100-, and 500-year floods (FEMA, 2008). Following these flood profiles upstream leads to an estimated water surface fluctuation at the project site of 388 to 393 feet NGVD29. Water surface elevations will likely be lower at times during periods of low flow.

The low channel slope, deep and wide channel, and impounded conditions suggest that low water velocities at the project site are the most common condition. However, there are scenarios when velocity could increase and be coupled with strong currents at the surface or subsurface such as during an increase in hydropower generation or following a storm event. Wilder Dam releases water through the lower portion of the dam for power generation, so bottom currents may be strong at times. When floods occur and the impoundment fills, water is passed over the top of the dam to maintain or lower the water level in the impoundment. The impoundment may mask turbulent currents. Strong currents have been observed along the Dartmouth riverfront during floods and when Wilder Dam is generating power (personal communication, Sergeant Lauren Cummings, Investigation and Marine Safety, Dartmouth College Safety and Security Administration).

Swimming in the Connecticut River

The Connecticut River supports active and passive recreation. Rowing, canoeing, kayaking, power boating, camping, fishing, swimming, hiking, and bird watching are common.

The Connecticut River Joint Commissions has sponsored water quality assessment projects and gathered information from past studies to determine if water quality is good enough on the Connecticut River for safe swimming. The primary threat is pathogens in the water such as *E. Coli* bacteria. The river was determined to be safe for swimming in the Upper Valley Region that extends from Bradford/Piermont to Hartford/Lebanon and includes the existing Dartmouth College swim dock site. Low levels of some pesticides were identified in river bottom sediments at the vicinity of the existing swim dock location (CRJC, 2009).

A 1,000-foot long no-wake zone exists upstream of Ledyard Bridge, and all boaters are instructed to watch out for swimmers.

The Connecticut River Joint Commissions gives the following recommendations for swimming in the river:

1. Look before you leap to avoid hitting debris, especially after rains
2. Watch for boats
3. Utilize best management practices near the river to protect water quality

Other recommendations on river swimming beyond basic swimming safety such as do not swim alone, no head-first diving in unknown waters, and do not mix alcohol and swimming include the following:

- Do not swim following rain events when floods can increase bacteria concentrations due to polluted runoff (Walk et al., 1998).
- Check exits first before entering locations with steep banks (Fryer, 2010).
- Use comprehensive signage to describe hazards, including pictures of varying water levels that are safe and unsafe.
- Debris loads in rivers increase following spring runoff and other floods, so avoid swimming following flooding. Keep an eye out for debris when entering water.
- Know currents and do not swim when they are strong.

The New Hampshire Department of Environmental Services OneStop Database was accessed to search all existing wetland permits on the Connecticut River. Many of the permits are for private seasonal swim docks with access walkways. The docks tend to be small and thus are mostly permitted under the Expedited Application Process. The docks are typically six feet wide, and length varies from 10 to 30 feet. Docks are accessed via gangways in a similar configuration as the existing Dartmouth swim dock.

The Massachusetts Department of Environmental Protection indicates that many docks exist on the Connecticut River for boating. There are no known swim rafts in the river most likely due to the difficulty keeping these floating structures in place on such a large river without attachments to shore. Docks exist at marinas, private residences, and schools. Swimming is known to occur at designated beaches, informal shallows such as oxbows and sand bars, and at marina docks. Although large debris in the river is not removed as it serves important functions for the aquatic ecosystem, debris at or near the water surface that has hung up on the riverbed or banks is flagged to increase visibility for boaters.

Discussions with regulators in Connecticut indicate that poor water quality, excessive boat traffic, and strong currents in the Connecticut River limit the desire to swim and, thus, few permits for seasonal swim docks exist. The Connecticut River is very wide and deep approaching Long Island Sound and is known to have deceptively strong currents even with the appearance of a smooth water surface.

Open-Water Swimming Safety

The Safe Swim Defense Program of the Boy Scouts of America (accessed at the web site: http://www.scouting.org/scoutsource/HealthandSafety/GSS/gss02.aspx) provides guidelines for safe swimming in natural waters. The target swimming depth is 12 feet in clear water and eight feet in turbid water since turbidity reduces the ability for lifeguard rescue. Turbid waters are operationally defined by the lack of a swimmer treading water to see his or her feet. Swimming under water and diving are prohibited in turbid waters. The Swim Defense Program also recommends measures to ensure that the bottom is clear of debris. Abrupt changes in depth are not permitted in designated nonswimming (i.e., wading) areas.

Swimmers must be able to overcome the water velocity while in the river so that they can safely return to the dock or shore when finished swimming. To overcome the current, swimmers must be able to swim faster than the water is moving. This is complicated by the fact that currents can be turbulent rather than smooth such that it would take more energy to move faster than the water is flowing. An average person can likely move freely long enough to reach safety in a water velocity of one to two feet per second. For reference, a competitive swimmer moves at a rate of six feet per second for a 100-yard freestyle.

Permitting

Permitting a seasonal swim dock on the Connecticut River requires a Wetlands Permit from the Wetlands Bureau of the New Hampshire Department of Environmental Services. New Hampshire does not require permitting for swim rafts (structures that are not connected to shore), yet any proposed swim dock would need to be permitted as a docking structure since it would likely be connected to the east bank of the Connecticut River. Docks must be placed at least 20 feet from abutting property lines. Under the current regulations, the maximum allowable dock projection into the river perpendicular to the bank from the high water line is 40 feet, and the maximum allowable width of a dock is six feet.

The type of wetlands permit application is dependent on the size of the dock relative to the dimensions of two boat slips (width = six feet and length = 40 feet). Docks that have maximum dimensions less than or equal to two boat slips may apply for a permit using the *Minimum Impact Expedited Application* while docks that are larger than two slips require a *Standard Dredge and Fill Application.* These two applications mostly contain the same information requirements, including plans showing location, dock modifications or new components, anchors, and access areas. The primary difference between the two application processes is the required review time. The minimum impact application has a 30-day review period following sign-off by the local Conservation Commission while the standard application has a 75-day review period. A $200 base fee is required when applying for a wetlands permit. An additional fee of $1 per square foot of dock is required for a *Standard Dredge and Fill Application* while no additional fee exists for the *Minimum Impact Expedited Application*.

Access trails and stairs may be improved or constructed under the wetlands permit as long as the width does not exceed six feet and heavy machinery is not used for construction. Wider structures or use of heavy equipment would require a *Shoreline Permit*.

The Connecticut River is a "designated river" in New Hampshire for its outstanding natural and cultural resources (RSA 483). The local advisory subcommittees under the supervision of the Connecticut River Joint Commissions would review and comment on the wetlands permit application.

An *Application for Swim Line Permit* will need to be filed with the New Hampshire Marine Patrol Bureau in the Department of Safety to change or move the rope designating the existing student swimming area. Current regulations require a variance for any swim line placed in a water depth greater than six feet or a distance from shore of 50 feet, whichever occurs first moving away from shore.

If a change is made to a dock, local permitting would likely be required by the Hanover Zoning Board of Adjustment (Zoning Ordinance compliance), Planning Board (Site Plan Review), and Planning and Zoning Department (Building Permit).

Alternative 1 – Restore Swimming at the Existing Swimming Location With the Same Dock Configuration

Background

This alternative evaluates the concerns raised with the existing swim dock location and explores potential improvements that would enable a reopening of the swim area (see Figure 1 for the location of each of the alternatives). Swimming safety concerns such as excessively deep water, an abrupt drop moving away from the riverbank, high turbidity levels, varying and unknown water currents, and the potential for submerged debris have led to the closing of the existing swimming student swimming area for the 2010 summer.

Slope Considerations

Field survey was performed by Milone & MacBroom, Inc. the week of December 6, 2010 as part of the *Dartmouth College Riverfront Master Planning Project*. Survey included the near-shore area of the Connecticut River up to a depth of approximately 25 feet. The survey data were used to create two-foot contours (draft survey plan attached). At the time of survey on December 8, 2010, the water surface elevation was 384 feet NAVD88. Moving away from shore at the existing swim dock location, the river bottom drops at a rate of one foot vertical per every two feet horizontal (slope ~50%). The steep slope of the river bottom moving away from shore in the existing swimming dock location means that the water depth will increase to 25 feet at a distance of 50 feet from the shore. With the historic dock formation, swimming was most typically taking place in water depths around 20 feet.

The riverbank above the water surface drops at one foot per every 1.5 feet (slope ~ 65%). A slope with a drop of one foot every three feet is the accepted engineering convention for maximum slope for operation and maintenance. A gentler slope is often recommended for areas heavily used by pedestrians. The Americans with Disabilities Act of 1990 (ADA) standards include a maximum running slope (i.e., the slope in the direction of travel) for walking surfaces of one foot vertical every 20 feet horizontal (slope = 5%) (DOJ, 2010). The recommended running slope for ramps is one foot every 12 feet (slope = 8%). Steeper slopes are permitted for smaller vertical rises. The existing steep slope of the bank, trail, and gangway complicates access to and egress from the water for all swimmers.

Water Clarity

The Connecticut River drains a large watershed at the project site and carries high loads of sediment. Fine particles such as silts and clays carried by the river stay suspended in the water column and increase turbidity, reducing visibility in the water. The turbidity is expected in larger rivers such as the Connecticut River at the project site. Coarse particulate organic matter is broken down into fine particulate organic matter as material travels down the channel, increasing turbidity. Turbidity is increased in impounded areas where water velocities are lower than free-flowing rivers.

Turbidity has not been measured at the project site, yet field observations indicate that moderate levels of turbidity exist. Turbidity levels increase during floods when stormwater runoff mobilizes large loads of sediment and debris.

River Hydraulics

During river survey by Milone & MacBroom, Inc. on December 8, 2010, a noticeable decrease in the water surface elevation had taken place. Ice along the riverbank was suspended above the water several inches and then collapsed onto the lower water surface. The change in water surface elevation illustrated the influence of Wilder Dam operations. The dam has a five-foot operating range for the pool water surface elevation, and FEMA hydraulic modeling suggests that this could translate to a five-foot change in water surface at the existing swim dock location.

The typical operating range at the dam is reported to be 382.0 to 384.5 feet NGVD29 (CRJC, 2009). The 2.5-foot water surface elevation change agrees with informal accounts of what is typically seen at the existing Dartmouth College swim dock.

The velocity was slow and flow was tranquil on the water surface during the near-shore survey performed from a row boat along the eastern edge of the channel. The current seemed to be swifter in the center of the channel. The existing swim dock location lies on the inside of a gradual meander bend. Flow velocity is lower on the inside of a meander bend than on the outside (FISRWG, 1998).

A slight jog in the river channel exists approaching the Ledyard Canoe Club from upstream that bends the channel toward the right (western) bank. The large-scale flow pattern seems to bring the main current near the dock at the Ledyard Canoe Club before the water begins to cross over the channel toward the western bank. A strong current has been previously observed in front of the canoe club (personal communication, Brian Kunz, Deputy Director, Department of Outdoor Programs, Dartmouth College).

Traveling downstream along the Dartmouth riverfront, the primary current begins to move across the channel from the east to the west bank. The channel then bends back to the east as it approaches the Ledyard Bridge. The existing swim dock location is approximately 200 feet upstream of the apex of the large meander and, thus, it likely experiences lower water velocities than in the center of the channel.

During the December 8, 2010 survey, a small surface current was evident that appeared to be partially generated from winds out of the north. Downstream of the apex of the meander bend, the trees on the riverbank shelter the water, and surface currents are calmer.

Floating and Submerged Debris

In addition to the fine sediment, the Connecticut River carries large woody debris. This material can be floating, just under the water surface, or suspended in the water column. The bulk of the debris load tends to travel in the main current, with local areas of deposition in quiescent areas such as along the riverbanks. The debris poses hazards for swimming, especially when swimmers enter the water by diving or jumping.

Permitting Considerations

The existing seasonal swim dock has been previously permitted with state and local regulators and, thus, additional permitting would not be needed if the existing swim dock were to be reopened with the same dock configuration. Permits would only be needed to change the existing dock configuration or move it to another location.

Operational Improvements

The physical site conditions at the existing swim dock location such as deep water, a rapid drop-off of the channel bottom, turbid waters, and varying currents suggest that improved monitoring and dock operations are the only ways to increase swimming safety at this location. Monitoring, improved signage, and increased swimming safety operations are recommended if the existing swim dock is to be reopened. The findings below should be combined with the recommendations of the College Swim Dock working group such as moving the student swimming requirement deadline from graduation to the end of freshman year.

Closures due to increased surface currents, debris, and turbidity occasionally took place at the existing student swimming area. A more formal method should be established for directly monitoring and identifying periods of increased currents and turbidity so the swim docks can be temporarily closed until favorable swim conditions return. The most informative and desirable option is to install a monitoring station along the Dartmouth College riverfront in the vicinity of the swim docks to track water velocity, temperature, turbidity, *E. Coli*, and other variables of interest. The Dartmouth Environmental Studies Program and the Thayer School of Engineering could install and maintain the monitoring station to provide an important tool to increase safety for all waterfront recreation users. The monitoring station and resulting data would provide an opportunity to expand learning about the Connecticut River.

Improved signage is recommended to display dock closures, monitoring results, and the primary risks that exist with swimming at the Dartmouth riverfront. For example, signage could signify that there is no safe location for gradual entry into the water for wading. Signage could include a monitor to display monitoring data so that swimmers understand why the dock is either opened or closed. Such a display would improve understanding of swimming risks in large impounded rivers.

Another option for monitoring the existing swimming dock site for increased swimming safety is to establish a set of field indicators that can rapidly be observed by a lifeguard to make an informed decision to close or open the docks. For example, lifeguards can read a staff gauge to track water surface elevation and determine if Wilder Dam is beginning to generate power, observe a buoy at the edge of the swim dock area to estimate the strength of the local currents, take Secchi depth readings to determine visibility, and periodically check the density of visible debris to allow for a more educated decision to close the docks if risks increase. The bottom of the swim area could be combed for large debris weekly or after large storms.

The combination of websites available for monitoring provisional flows at Wilder Dam and area tributaries could be used to try and create an algorithm for closing the swim docks when currents or turbidity levels may be high. This approach to monitoring using readily available public information is less costly than establishing a monitoring station but only approximates site conditions.

The access trail should be reconfigured to formalize the trail and reduce the running slope approaching the gangway and docks. The gangway slope also needs to be decreased to improve access safety.

In summary, safety improvements recommended with Alternative 1 include:

- Implement the swimming safety recommendations of the College Swim Dock working group
- Install a monitoring station to measure velocity, turbidity, and other variables
- Improve signage to signify dock closures and display the risks of the existing swim site
- Reconfigure the access trail
- Reduce the slope of the gangway

Alternative 2 – Restore Swimming at the Existing Swimming Location With a New Dock Configuration

Background

This alternative explores adjusting the dock configuration to try to reduce swimming risks by creating a partially or fully enclosed swimming area. The site conditions are unchanged in that deep water and a steep near-shore slope will remain. Dock layout can be optimized to attempt to shield swimmers from surface currents generated by flow and wind and protect swimmers from some surface debris. Lifeguard access to swimmers can be improved by new configurations. Three new dock configurations were evaluated (sketch plan attached):

A. A rectangular dock with an enclosed inner swim area
B. A U-shaped dock with a partially enclosed swim area
C. A linear dock along shore with retractable ends perpendicular to shore

Structural Considerations

The further a dock projects out into the river, the more robust the anchoring system will be needed to keep the dock in place. Shore connections or bottom anchors must overcome the forces due to the flowing water. Anchors that rest on the riverbed are not presently used to install any of the docks on the Dartmouth waterfront. Small anchors are used to install the rope designating the swimming area that projects off of the existing swimming dock.

The frictional drag force is highest along the bed and banks and, thus, flow velocity would tend to be lowest in these locations. The force to overcome in order to keep a dock in place is thus typically lowest near the shore. The further a dock projects toward the center of the river channel the more flowing water will work to push the dock downstream and the larger the shore attachments or bottom anchors needed to keep the structure in place. The more surface area that flow encounters the more force on the dock.

Alternative 2A – A Rectangular Dock With an Enclosed Inner Swim Area

The rectangular dock layout (Figure 7) recommended in the *Student Swim Dock Report* is similar to that commonly used on lakes with shallow slopes on the shore where swimmers can easily walk into and out of the water. On the Connecticut River along the Dartmouth riverfront, entry into the inner swim area would typically only be possible by jumping or diving into the water, and exit would be via ladder on the dock.

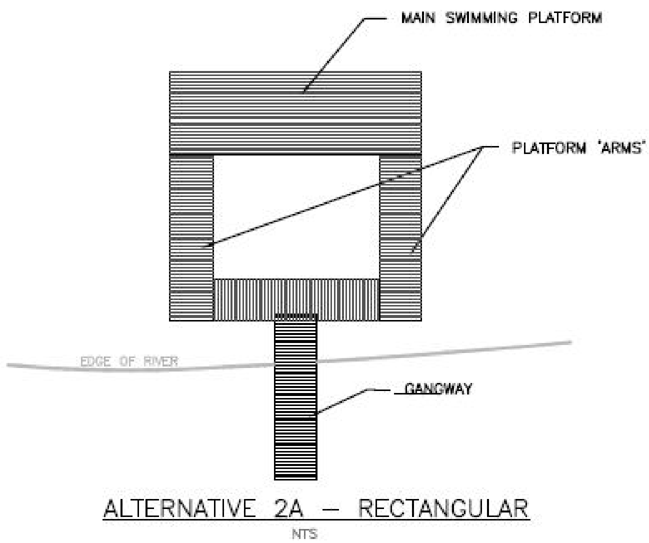

Figure 7: Concept sketch of the rectangular dock layout.

With dock surfaces running perpendicular to the direction of flow, bottom anchors are likely needed to keep the rectangular dock in place. The anchors would be used with connector bars on the side of the dock that is closest to shore.

A rectangular dock layout may reduce mild surface currents in the swim area yet is likely limited in its ability to eliminate moving water during changes in pool elevation resulting from hydropower generation and small floods. Swimmers would not be sheltered from subsurface currents by a rectangular dock.

An inner swim area would likely reduce the risks posed by floating large woody debris as most of this material tends to come down the river at or just under the water surface so the dock can shield swimmers. The potential remains for some debris to travel under the dock into the swim area. Pieces of wood that get into the swimming area or lodged on the upstream side of the proposed rectangular dock would need to be moved toward the center of the channel so they could continue to travel downstream. Daily checks for debris would be needed.

The inner swim area will increase lifeguard access beyond the linear layout of the existing swim dock. The enclosure may lead to new swimming risks as the potential exists for struggling swimmers to be pushed into and under the docks.

The *Student Swim Dock Report* suggests that below-water fencing be considered to limit the potential for submerged debris to find its way into the inner swimming area. This is not recommended as the fence will be prone to frequent clogging due to the high sediment and debris load in the Connecticut River. The fence would need to be cleared regularly to limit the hydraulic force on the dock structure. The anchoring system would need to be overdesigned to stabilize the rectangular dock because should the fence clog the flowing water would increase the force on the dock. Keeping the fence clear of debris would be a substantial maintenance task. The fence would also be prone to damage and could inadvertently create snags that could create swimming risks near the dock on the upstream side of the rectangular dock.

Alternative 2A Permitting Considerations

According to state regulations, a dock cannot extend more than 40 feet out toward the center of the river perpendicular to the shore. Assuming a standard six-foot wide dock and eight feet along the shore to reach ample depth for the dock to float, the maximum dimension of the inner swim area perpendicular to the bank is 20 feet. A rectangular dock will likely require a *Standard Dredge and Fill Application* for a Wetlands Permit due to change in shape, increased dock size, and an anchoring system.

Alternative 2B – A U-Shaped Dock With a Partially Enclosed Swim Area

The U-shaped dock layout (Figure 8) is similar to the rectangular dock except that there is no enclosure on the side furthest from shore. The U-shaped layout will provide the similar benefits of sheltering swimmers from mild surface currents, increasing lifeguard access to swimmers, and providing some protection from woody debris that are achieved with the rectangular dock. In addition, this layout will allow for debris lodged upstream or in the swimming area to readily be moved into the channel and away from the dock. Less dock will be needed to construct this layout and, thus, the cost would be lower.

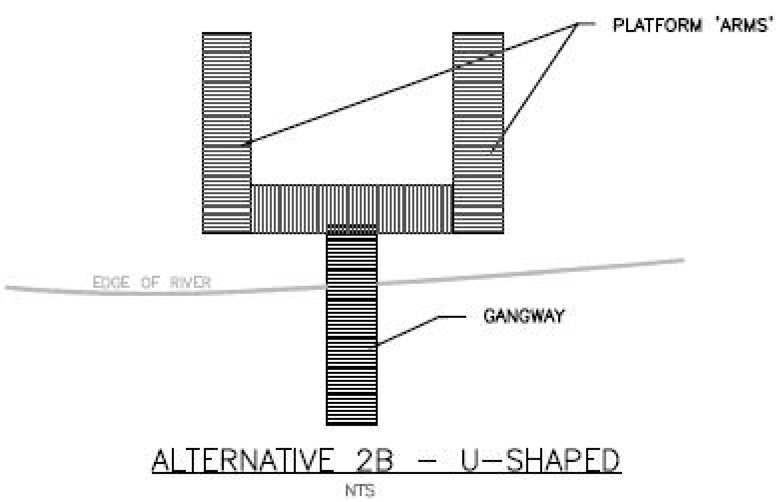

Figure 8: Concept sketch of the U-shaped dock layout.

The partial enclosure may still lead to new swimming risks as the potential exists for struggling swimmers to be pushed into and under the docks, yet the open side may allow for easier movement away from the dock if needed. The U-shaped dock layout would provide access for life-saving boats such as sea kayaks and canoes that are often used during open-water swimming events should a decision be made to monitor the swim area from the water. With the current tending to move out toward the center of the channel in the existing swim dock location, it is not likely that the open side of the dock would catch more water and lead to increased force on the dock.

Alternative 2B Permitting Considerations

Permitting requirements for the U-shaped dock would be similar to the rectangular dock as expanded anchoring would be needed.

Alternative 2C – A Linear Dock Along Shore With Retractable Ends Perpendicular to Shore

The retractable end dock layout (Figure 9) builds on the existing swim dock layout parallel to shore by including one or two retractable arms that would create an L- or U-shaped dock. The arm(s) would be extended when the swim dock is open and would be retracted to a compact position when the dock is closed. The arms of the dock would generally provide similar benefits and disadvantages of the rectangular and U-shaped docks.

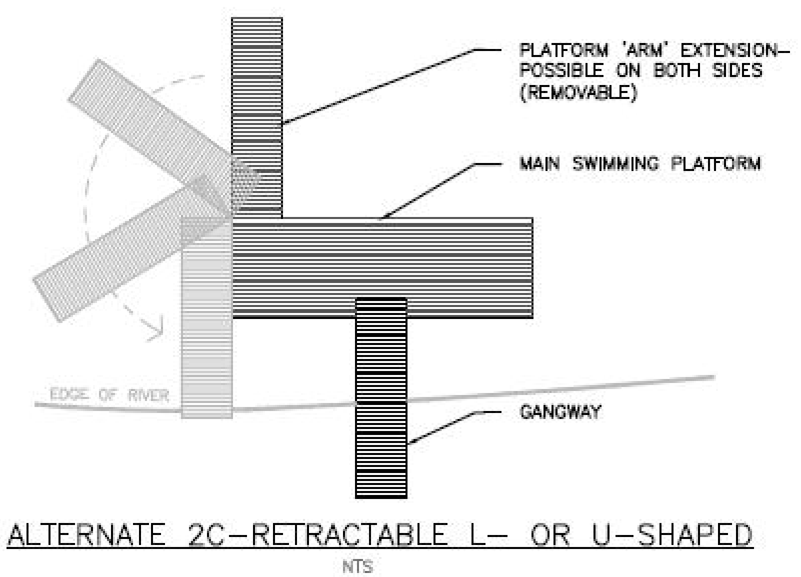

Figure 9: Concept sketch of the retractable end(s) dock layout.

Retractable arms would reduce the exposure and force on the dock during nonswimming times when velocities are high. This would likely reduce the required anchoring since the arms would only be out when flow velocities are low. The compacted dock would hug the shore in a manner similar to the existing swim docks. A retractable structure would likely increase the lifetime of a dock that permanently projects into the river perpendicular to the flow. Retracting the arm(s) would simplify debris management as the dock would not be prone to catching debris during nonswimming periods. The retractable arms would also provide an obvious indication of the docks being open or closed.

The initial concept of the retractable arms is that they would pivot on hinges on the ends of the dock along shore. Prior to the docks opening, the arms would be rotated out toward the river center to create an L- or U-shaped dock and locked into place. The arms would be pivoted back to shore and locked to the main dock after the dock closes.

Alternative 2C Permitting Considerations

Permitting requirements for the dock with retractable arms may qualify for the *Minimum Impact Expedited Application*, reducing the state permitting effort.

Alternative 3 – Restore Swimming at Other Locations on the Connecticut River Frontage

Background

The 1,700-foot long Dartmouth riverfront was investigated for a new swimming location that would reduce risks (see Figure 1). Possible new swimming areas include:

A. Near the Ledyard Canoe Club
B. Between the canoe club and the Friends of the Dartmouth Rowing Boathouse
C. Downstream of the existing swim dock location
D. Upstream of Ledyard Bridge

Survey indicates that the water is deep and the slope of the river bottom extending from the bank is steep (42 to 58%) for the entire riverfront. At these slopes, the water reaches a 25-foot depth within 43 to 63 feet of shore.

Alternative 3A – Near Ledyard Canoe Club

Water is deep and the near-bank slope is steep (55%) in the vicinity of Ledyard Canoe Club. The strongest river currents are reported to hug the outside of the meander bend along the eastern shore (personal communication, Brian Kunz, Deputy Director, Department of Outdoor Programs, Dartmouth College). Swimming in the vicinity of the Ledyard Canoe Club has the same risks as the existing swim dock location and is not considered further.

Alternative 3B – Between the Canoe Club and the Friends of the Dartmouth Rowing Boathouse

A local shallow exists off the upstream corner of the Friends of Dartmouth Rowing Crew Dock. The river bottom drops less steeply in this location and has a slope of 25%. Water depth ranges from 10 feet at the corner of the dock to 22 feet at a distance of 40 feet from the dock. Crew boat traffic eliminates this possible swimming location from further consideration.

<u>Alternative 3C – Downstream of the Existing Swim Dock Location</u>

Approximately 200 feet downstream of the existing swim dock location, just downstream of the apex of the meander bend, the river bottom drops off more slowly away from shore as compared to other locations along the riverfront. The bottom slopes away from the bank at a net slope of 42% and, thus, the water depth is approximately 21 feet at a distance of 50 feet from shore while the depth is typically five feet deeper at other riverfront locations. The local bottom slope as the depth increases from 14 feet to 24 feet is 30%, the shallowest observed at the project site.

This area appears to be locally sheltered from flows and winds as the main current pulls off of the east bank toward the center of the channel (Figure 10). The minor difference in slope of the channel bottom does not substantially change the swimming scenario yet suggests that less erosion of bottom sediments is taking place due to the sheltered setting. This sheltered setting is likely to have less large woody debris than closer to the main current.

Figure 10: Upstream view of a possible new swimming location that is approximately 200 feet downstream of the existing swim dock location. This area is more sheltered from the main current as it is downstream of the meander apex, and the main current is in the center of the channel (to the left side of the photograph).

Although the existing riverbank is steep at this location (slope perpendicular to shore ~ 66%), there is ample space to create an angled approach trail with a gentler grade to improve access. A tiered approach could be established to integrate the trail, river, and other recreation facilities. The gangway could be established at a lower slope. This location generally provides more space and access opportunities than the existing swim dock location that is located immediately off the end of the existing parking lot.

Moving the swimming dock 200 feet downstream improves the ability to observe the dock from both the parking lot at the top of the riverbank and from Ledyard Bridge. This would allow Dartmouth College patrol officers more opportunity to observe the proposed swimming area when the dock is open and during the night when the dock is closed.

Alternative 3D – Upstream of Ledyard Bridge

A shallow area near shore is located at the discharge location of the stormwater detention basin on the east bank approximately 100 feet upstream of Ledyard Bridge. The basin largely consists of riprap and contains three outfall pipes that convey stormwater runoff from Tuck Drive and Wheelock Street. Although swimming depths near shore are shallower, this site is not desirable for swimming due to the periodic runoff discharge, accumulated sediment that is likely not clean, nearby stormwater infrastructure, proximity to the bridge, and proximity to the reported upstream extent of the bridge debris field (personal communication, Sergeant Lauren Cummings, Investigation and Marine Safety, Dartmouth College Safety and Security Administration).

Summary

Survey and field observations suggest that moving the existing swim dock approximately 200 feet downstream, around the apex of the meander bend in the river channel, is the best location along the Dartmouth riverfront to reduce swimming risks and improve access. All other locations along the riverfront generally share the same risks as the existing dock location. The analysis suggests that the location of the existing student swimming area is the second best location for the docks as some sheltering from the current occurs.

The potential swim dock location site is approximately 300 feet upstream of Ledyard Bridge and 200 feet upstream of the reported extent of the debris field (personal communication, Sergeant Lauren Cummings, Investigation and Marine Safety, Dartmouth College Safety and Security Administration). The operation and management recommendations discussed for Alternative 1 apply to this alternative as well. Monitoring remains an essential need for safer swimming.

Alternative 4 – Move Swimming to Another Location(s) Near the Campus

Alternative 4A – Storrs Pond

Since the temporary closing of the existing swim dock on the Connecticut River, a free shuttle has been provided for students to access the Storrs Pond Recreational Area. The 13-acre, man-made pond is 2.5 miles from campus. A roped-off designated swimming area exists at the pond with a gently sloping sandy beach, safe wading area, and lifeguards.

Student sentiment suggests that traveling away from campus for swimming is not a suitable alternative. "The convenience of the Connecticut [River] is why students swim there, and offering us free access to an inconvenient and inaccessible pond is not a viable alternative" (Niparko, 2010).

Alternative 4B – The Western Side of the Connecticut River

The Connecticut River may be shallower on the western side of the channel, yet currents are likely to be stronger at the outside of the meander bend. This possible swimming location appears to be more exposed to the main upstream flow path and wind and is thus not likely a safer alternative than the existing student swim area.

Moving the swim dock to the western side of the river is also less desirable from a use and operations perspective. Access would be limited by the small amount of land off the riverbank due to the presence of River Road that hugs the Vermont side of the river. Students do not want to have to walk further than the college riverfront area to swim. The further the docks are from the center of campus the less the docks will get used.

Preferred Alternative

Upon review of the findings of the alternatives analysis (Table 2), the project team has identified the preferred alternative to be moving the student swimming area 200 feet downstream (Alternative 3C). Swimming risks are improved slightly over the existing location primarily due to increased shelter from the main river current downstream of the apex of the meander bend. The new location allows more space for creating a safer access. Safety monitoring is improved from the bridge as vantage points to the dock from the high spot in the parking area exist as well as a clear sightline from the Ledyard Bridge.

The alternatives analysis identified important operation and management needs required to increase the safety at the proposed swim dock location as well as all recreation activities along the riverfront. The following list highlights the recommendations for the Dartmouth College student swim dock and area.

- Move the existing swimming dock 200 feet downstream into the more sheltered location.
- Establish a monitoring station along the riverfront area in the vicinity of the swim docks to track water velocity, temperature, turbidity, and *E. Coli*. Data should be readily accessible by the college safety personnel and the public via the internet. Thresholds for dock closure should be initially set and refined once the monitoring station is functioning.
- Install improved signage to display dock closures, monitoring results, and the primary risks that exist with swimming at the Dartmouth riverfront.
- Reconfigure the dock access to reduce the slope of the trail and gangway and create a safer approach to the swimming area.
- Establish a protocol for regular monitoring for and removal of debris in the swimming area.
- Improve the anchoring mechanism for the rope designating the swimming area so it is not swept downstream during high flows.

Table 2: Summary of Alternatives Analysis.

ID	ALTERNATIVES↓	SWIMMNIG SAFETY OBJECTIVES→ Shallower water	Gentler channel bottom side slope	Less turbidity	Weaker currents	Less debris	Improved swimmer access	Improved lifeguard access	Ease of maintenance	Relative implementation cost	Relative permitting complexity	Notes
1	*Restore Swimming at the Former Swimming Location with the Same Dock Configuration*								√√	*Low*	*Low*	*Only way to improve swimming safety here is to improve monitoring and operations. Real-time monitoring for flow, temperature, turbidity, and E. Coli recommended for all alternatives.*
2A	*Restore Swimming at the Former Swimming Location with a Rectangular Dock with an Enclosed Inner Swim Area*				√	√√		√√√	√	*Moderate*	*Moderate*	*Bottom anchors likely needed with shore attachment bars. Fencing to block debris not recommended as it will be prone to clogging.*
2B	*Restore Swimming at the Former Swimming Location with a U-Shaped Dock with a Partially Enclosed Swim Area*				√	√√		√√	√√	*Low to Moderate*	*Moderate*	*Opening on river side will ease maintenance, allow lifeguard boat/board access, and reduce cost.*
2C	*Restore Swimming at the Former Swimming Location with a Linear Dock Along Shore with Retractable Ends Perpendicular to Shore*				√	√√		√√	√√	*Low*	*Low to Moderate*	*Retractable arms would be extended when dock open and swimming safer. Retracting arms when dock closed and current higher could reduce anchoring needs.*
3A	*Restore Swimming on the Connecticut River Frontage Near Ledyard Canoe Club*									*n/a*	*n/a*	*Not considered as currents reported to be stronger in this location than at former swim dock. Similar if not more risk with less access.*
3B	*Restore Swimming on the Connecticut River Frontage Between the Canoe Club and the Friends of the Dartmouth Rowing Boathouse*	√								*n/a*	*n/a*	*Not considered as located in an area with high crew boat traffic. Swimming risk is higher in this location.*
3C	*Restore Swimming on the Connecticut River Frontage Downstream of the Former Swim Dock Location*	√			√	√	√√√	√√	√√√	*Moderate*	*Moderate*	*Minor benefits with this more sheltered swimming location exist. Additional space is available to create a safer access with ADA access. Monitoring and improved signage are recommended.*
3D	*Restore Swimming on the Connecticut River Frontage Immediately Upstream of Ledyard Bridge*	√	√		√	√	√√	√	√√	*Moderate*	*Moderate*	*Not desired given proximity to stormwater outfall, Ledyard Bridge, and debris field upstream of bridge.*
4	*Move swimming to non-Connecticut River location(s) near the campus*	√√√	√√√	√√√	√√√	√√√	√√√	√√√	*n/a*	*Low*	*n/a*	*Although this alternative virtually eliminates swimming risks , it is socially not desired due to the need to travel and required planning and time.*

Key

	Objective not met at all.
√	*Alternative anticipated to have little benefit towards meeting objective.*
√√	*Alternative anticipated to create improvements that substantially meet objective.*
√√√	*Alternative anticipated to have major benefits and fully meet objective.*

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