HEAVY MOVABLE STRUCTURES, INC.
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The New North Hero Bascule Bridge

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MARRIOTT'S RENAISSANCE HOTEL AT SEAWORLD
ORLANDO, FLORIDA

Introduction

Bridge History:

The North Hero Bridge is the sole highway drawbridge in the state of Vermont. This double leaf bascule bridge links North Hero and Grand Isle (South Hero Island). When the bridge is close to roadway traffic the detour route is over 50 miles. It is also the only passage for east-west marine traffic along Lake Champlain with unrestricted vertical clearance. The Bascule Bridge was originally built in 1953, and rehabilitated in 1996. As the bridge had become more unreliable and requiring increased maintenance to remain operational, the bridge was chosen to be replaced. The Vermont Agency for Transportation (VTrans) began investigating alternatives to replace the bridge.

Scoping Report/ Purpose and Need:

A Scoping Report was prepared for the VTrans by Vanesse Hangen Brustlin, Inc "VHB" in September 2002.

Elevation View of the Existing North Hero Bridge

In the Scoping Report the purpose of the project was given as "The purpose of the project was to enhance the mobility and safety of vehicle, bicycle, pedestrian and boat traveling across and under the bridge structure along US Route 2 between the towns of Grand Isle (South Hero Island) and North Hero"

In the Scoping Report the need was given as: "The causeway and movable bridge of this project provide the only vehicular connection between North Hero and Grand Isle along US Route 2 that provides local connectivity within the island and regional connectivity between New York and Vermont. The water channel provides one of the most important east-west crossing points for Lake Champlain boat traffic. Due to increased vehicular traffic along US Route 2 and boat traffic through the channel, the mobility of both modes of transportation is inhibited by the inefficiency of the movable bridge.

Preliminary Alternative Analysis

Inspection:

HDR performed a scoping inspection on June 3, 2014 through June 5, 2014. The Scoping Report stated that "Numerous concerns and deficiencies regarding the bridge support the purpose. These concerns include:

Traffic

Increases in the amount of marine traffic result in more frequent and longer open drawbridge time periods, thus increasing the delay for vehicular traffic traveling along US Route 2.

The average annual daily traffic (AADT) for the current year is estimated at 3000 vehicles per day. The traffic (marine and vehicular) volumes increase substantially during summer months. The AADT is projected to increase to approximately 3050 vehicles per day during the design year (2026). Average daily truck traffic is predicted to be 495 trucks per day in the design year versus 485 trucks per day currently.

Structural Deficiencies

Deck

The open steel grid deck has developed numerous holes and pits through the main and secondary grating bars. The open deck has exacerbated the accumulation of debris on the structural elements accelerating corrosion.

Superstructure

All of the bascule girders have areas of deep pitting and pack and surface rust. The floor beams in the lift spans are in poor condition with significant section loss at the connections to the bascule girders. These beams were previously patched to correct heavy section loss while some have small rust holes through the beams. The paint system, applied in 1996, is failing in all locations of the bascule span.

Mechanical

The machinery supports and their anchors to the pier are exhibiting significant section loss in numerous locations. The span operating machinery gears sets have excessive backlash and plastic flow of gear teeth. The span lock machinery has excessive clearance resulting in live load being carried throughout the span drive machinery. The front live load shoes are not in full contact and allow vehicles to apply excess impact to the span and may be restricting full closure of the bridge.

Electrical

Motor and machinery brakes are approaching the end of their useful life. Span drive motors have low insulation readings indicating that they are at the end of their useful life. Other electrical conditions include exposed and improperly terminated conductors within each submarine cable cabinet, and throughout the bridge which are a reliability concern. The layout of the electrical equipment is not in compliance with National electrical Code requirements for access and arc-flash protection. The control system safety interlocks are not redundant as required by code and current design practices which poses a significant safety risk to both VTrans staff and the Public.

Maintenance Concerns

The drawbridge, originally constructed in 1953 and rehabilitated in 2008, requires enhanced and increasingly costly maintenance to prolong reliable operation.

Pedestrian and Bicycle Access

This crossing is utilized by increasing numbers of pedestrians and bicycles and provisions should be considered for the safety and mobility of these modes of transportation. The existing open grid deck has been identified as the primary cause of bicycle accidents on the bridge.

Interim Repairs

Alternatives Analysis

General

The following describes the alternatives developed by the Team to address the Purpose and Need Statement. The alternatives developed take into consideration the background conditions, resource information and local concerns feedback, permitting realities and cost. The project alternatives were developed in accordance with the design standards listed previously.

The Team developed and investigated multiple alternatives for the rehabilitation or replacement of the bridge. Based upon both internal and external review of the various alternatives, Three (3) options were identified. VTrans had eliminated a high level fixed bridge option due to community concerns. The selected options meet the requirements identified by the local concerns, vehicular impacts, marine impacts, maintenance, operation, and minimizes detour.

Through this development process, four feasible alternatives were chosen for presentation with three options each for Alternatives II & III:

- No-Build
- Alternative I – Rehabilitation of the existing structure
- Alternative II – New Movable Structure on Existing Alignment
    - Option A – Twin Leaf Bascule
    - Option B – Single Leaf Bascule
    - Option C – Vertical Lift
- Alternative III – New Movable Structure on New Alignment
    - Option A – Twin Leaf Bascule
    - Option B – Single Leaf Bascule
    - Option C – Vertical Lift

No Build – Existing Condition

The no-build alternative leaves the bridge and the alignment in their current condition, and assumes normal roadway maintenance and bridge maintenance will continue.

Advantages:

Low initial cost and no new direct environmental or social impacts result from the no-build option.

Disadvantages:

The no-build alternative does not meet the goals of the project's purpose and need statement. Several key objectives would be left unaddressed under this alternative including, no reduction of delays on US Route 2 and through the channel, no reduction in maintenance costs of the drawbridge, and no improvements of pedestrian and bicycle safety within the project area.

Alternative I – Rehabilitation

The team investigated rehabilitating the current twin leaf bascule span in place and determined during the inspection that the structural steel needs extensive repairs and it would be more cost effective and beneficial to perform a replacement of the bascule leaves. The team developed this alternative that will incorporate building the replacement twin leaf bascule spans remotely and then shipping the units to the project site. In an effort to reduce the impacts of construction on the traveling public, the replacement of the twin leaf bascule span would take place during the winter months over planned weekend outages. The team estimated that the rehabilitation alternative would be completed over two construction seasons. In the first season the approach spans would be rehabilitated while the new bascule spans are being fabricated. The bascule spans will be replaced during the winter months and then the next construction season the bridge structure rehabilitation would be completed.

Advantages:

This alternative allows VTrans to address the deterioration of the twin leaf bascule spans structural steel, mechanical, and electrical components. This alternative increases the remaining life of the bascule bridge structure. This rehabilitation alternative would eliminate the need for a detour or temporary bridge. The rehabilitation would likely satisfy the potential historic rehabilitation conditions. The operator's house and control tower would remain.

Disadvantages:

The rehabilitation option does not fully meet the purpose and need statement. This alternative will not raise the bascule bridge structure to eliminate the counterweights from entering the water during opening. The existing mechanical and electrical system will be repaired and not replaced which does not address the safety and long term reliability concerns. This alternative provides the ability to address the bascule span for service life but does not allow us to address the service life of the mechanical and electrical systems.

The life cycle cost analysis shows that the cost of constructing, operating, and maintaining the existing bridge over the design service life for the rehabilitation option is the most expensive .

The low voltage submarine cable would remain and as noted in the inspection report, the low ohms reading for the submarine cables shows signs of degradation and need for replacement.

Alternative II – New Movable Structure on Existing Alignment

This alternative constructs a new movable bridge in place of the existing drawbridge. This alternative consists of removing and replacing the existing drawbridge in stages to allow for one-way vehicular and marine traffic to be maintained throughout the construction operations. There may be times when vehicular and boat traffic will need to be delayed for short periods of times for life safety issues that may arise while lifting bridge components. The approach spans, from the abutments to bascule pier, can be supported on corbels off the back of the bascule pier. The profile of the bridge surface will be raised approximately 4 ½ feet to prevent the end of the draw span from entering the water when open, thus reducing potential maintenance problems and improving navigational clearance. Raising the grade at the bridge center requires the roadway approaches to be reconstructed for approximately 300 feet to the east and west of the bridge. The team investigated three movable bridge options within this alternative::

- **Twin Leaf Bascule**
- **Single Leaf Bascule**
- **Vertical Lift Bridge**

With all these options listed above the concept is to build without disturbing vehicle and marine traffic during construction. Both options a) and b) will need to be completed in stages roughly half the bridge at a time to allow one lane of vehicular traffic and normal marine traffic to pass through the open bridge structure during construction. Option c) would be built above the traffic on a platform and then lowered down into place once it was completed.

The traffic Team used SimTraffic to evaluate the impact of the alternating one-way traffic operations during construction on queuing and LOS. These analyses were used to analyze the operations for two scenarios: [1] alternating traffic operations without lift bridge operations, and [2] alternating traffic operations with the lift bridge operation. The basis of the analysis was the Existing Design Hour Volume of 485 vehicles with a 60/40 directional distribution. The assumed design speed for the work zone was 30 mph.

The analysis of the typical alternating one-way traffic operations (without the lift bridge operation) indicates that the levels of service in the design hour will be LOS C for both directions, with average delays of 21.5 seconds delay per vehicle in the peak direction and 24.1 seconds in the non-peak direction. The 95th percentile design queue is 200 feet in the peak direction and 155 feet in the non-peak direction.

The analysis of alternating one-way traffic operations with the lift bridge operations considered the following typical lift operations as documented in the Design Report:

- The lift bridge operates on a regular 30-minute schedule (on the hour and half-hour), subject to actual marine traffic, which is variable.
- The average amount of time to accommodate each bridge lift is 4 minutes.

The SimTraffic simulations of this scenario indicate average vehicle delays of 56.2 seconds in the peak direction and 56.0 seconds in the non-peak direction, with 95th percentile queues of 531 feet in the peak direction and 288 feet in the non-peak direction. Other relevant metrics for the traffic operations with the lift bridge are the following:

- The max queue formed during the lift operations
- The time period needed to dissipate these queues and restore operations to typical alternating traffic.

Based on the SimTraffic models, the max queue during the design hour is 666 feet (approximately 27 vehicles) in the peak direction and 368 feet (approximately 15 vehicles) in the non-peak direction during periods when the lift bridge is raised. The simulations show that the average time taken for these max queues to dissipate after the end of each lift bridge cycle will be approximately 5 minutes.

Based on these analyses, it is concluded that the alternating one way traffic management plan will accommodate the existing design hour traffic during construction with or without the lift bridge in operation.

All three options under this alternative meet the purpose and need statement and do not require any long term detours or closures.

Advantages:

A new and more efficient movable bridge structure would be designed to open/close the drawspan within the open/close time prescribed by AASHTO. This alternative meets the purpose and need statement for the project. Additionally, a new movable bridge structure requires less maintenance than the existing structure, effectively reducing the overall operating costs. The new drawbridge superstructure will be deeper and provide a walkway between the bascule girders to allow access from the pier to the span locks from the underside of the deck as well as keeping the counterweights from entering the water. This feature provides a safe area for the VTrans District personnel to access the span locks at the middle of the bridge.

The first two options maintain a similar configuration to the existing bridge and will maintain the character of the area. The third option is a vertical lift bridge option that has two towers with a span in the middle that rises up and down to allow vessel traffic to pass. During the public presentation and the public outreach process, the public voiced their opinions for support of the twin leaf bascule over the single leaf bascule. The public sentiment for the existing twin leaf bascule bridge was to design the new bridge to duplicate the appearance and functionality of the existing bridge.

All three options can be built without requiring a detour or temporary bridge structure.

The first two options can accomplish opening and closing of the drawbridge spans by either hydraulics or mechanical systems. During the design phase, the Consultant will work with VTrans to determine which lifting system will be used. The steel grid deck system will be replaced with a concrete filled steel grid deck system, thus reducing the rate of structural steel deterioration.

The low voltage submarine cable will be replaced under all options of this alternative. The first option will replace the low voltage submarine cable with another submarine cable, the second option would remove the submarine cable and be placed on the approach span substructure, and the third option will replace the existing submarine cable with an aerial system on the vertical lift bridge.

Disadvantages:

This alternative will prolong the construction duration of this project. The Team estimated that the construction would be completed over three seasons. In the first season the Contractor would demo and rebuild one half of the bridge, the second season the Contractor would demo and rebuild the remaining half, and then in the third construction season they would complete construction. The third construction season will consist of combining the two separate bridges together. This combination will be accomplished with temporary lane closures on the bridge. The bridge will be open to two way traffic in the third construction season. The new bascule options will need to be constructed as two separate bridges and then connected together. This new raised structure does not allow for an increase in height of boats allowed under without opening due to the increase in superstructure depth. An underwater archeological evaluation will need to be completed for this alternative based on the areas of impacts in Lake Champlain.

The control tower will need to be relocated and raised to provide the required visibility for the operator.

The vertical lift bridge option will require additional permitting time over the other two options within this alternative, due to the altering of the visual impact from a bascule bridge to a vertical lift bridge and receiving approval from SHPO.

Alternative III – New Movable Structure Off-Alignment

This alternative consists of building a new movable bridge adjacent to the existing and maintaining vehicular and marine traffic throughout the construction operations on the existing alignment and structure. There may be times when vehicular and marine traffic will need to be delayed for short period of times for life safety issues that may arise while lifting bridge components. The Team has investigated three movable bridge options within this alternative:

- Twin Leaf Bascule
- Single Leaf Bascule
- Vertical Lift Bridge

With all these options listed above the general construction concept is to build a new structure off alignment and then modify the approach roadway alignments to incorporate the new movable bridge location.

All three options under this alternative meet the purpose and need statement and do not require any long term detours or closures.

Advantages:

A new and more efficient movable bridge structure would be designed to open/close the drawspan within the open/close time prescribed by AASHTO. This alternative meets the purpose and need statement for this project. Additionally, a new movable bridge structure would require less maintenance than the existing structure, effectively reducing the overall operating costs. The new drawbridge superstructure will be deeper and provide a walkway between the bascule girders to allow access from the pier to the span locks from the underside of the deck. This feature will provide a safe area for the VTrans District personnel to access the span locks at the middle of the bridge.

The first two options maintain a similar configuration to the existing bridge and will maintain the character of the area. The third option is a movable bridge option that has two towers with a span in the middle that lifts up and down to open.

All three options can be built without requiring a detour or temporary bridge structure.

The first two options can accomplish opening and closing of the drawbridge spans by either hydraulics or mechanical systems. During the design phase, the Consultant will work with VTrans to determine which lifting system will be used. The steel grid deck system would be replaced with a concrete half filled grid deck system, thus reducing the rate of structural steel deterioration.

The off alignment option allows the new structure to be built next to the existing and will not affect the traveling public. VTrans will have a new operations house structure.

The approach roadway improvements will extend for a length of 3,300 feet, not including the structure length. In addition, the profile of the bridge surface will be raised approximately 4 ½ feet, similar to alternative II, in order to prevent the same existing issues explained for alternative II in the section above.

The low voltage submarine cable will be replaced under all options of this alternative. The first option will replace the low voltage submarine cable with another submarine cable, the second option would remove the submarine cable and be placed on the approach span substructure, and the third option will replace the existing submarine cable with an aerial system on the vertical lift bridge.

Disadvantages:

This alternative would be more costly and require extensive design and permitting time. The construction of a new movable bridge off alignment will require the taking of lake shore and expanding the causeway. This alternative will mostly likely require an EA or EIS versus a CE and have greater impacts to historic and archeologically sensitive areas that would need approval prior to construction. This alternative will require ROW acquisitions that would require additional time and money. This alternative will be the most expensive and take the longest time to receive permit approvals prior to construction and this would require that VTrans spend significant funds repairing the existing movable structure to remain operational until the replacement is constructed.

The control tower will need to be relocated and raised to provide the required visibility for the operator.

In order for the new alignment to remain within the causeway the new off alignment structure would need to be located to the east of the existing structure. The operation house is located on the east side of the bridge and this will need to be moved. This structure is considered historic and any relocation will need to be reviewed and approved by SHPO. An underwater archeological evaluation will need to be completed for this alternative based on the areas of impacts in Lake Champlain.

The bridge replacement will require three construction seasons to complete. The first two construction seasons the new roadway and bridge would be constructed adjacent to the existing and then in the third construction season the traffic would be shifted onto the new roadway and bridge and then demolition of the existing would be completed.

Life Cycle Cost Analysis

The life-cycle analysis of the proposed alternatives/options showed that the single leaf bascule span was the lowest cost alternative/option by a very small margin over the twin leaf bascule span. Other significant factors including historic integrity and public opinion led to the selection of the twin leaf bascule span as the preferred alternative. The rehabilitation option has the highest life cycle cost.

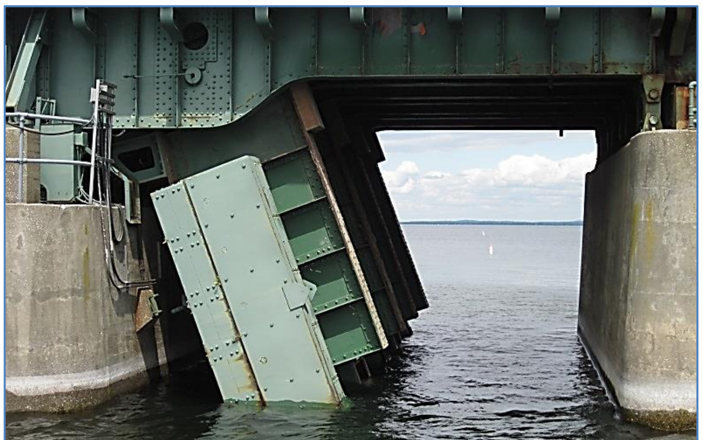
Preliminary Design

Alternative III-A was selected as the alternative of choice and the team proceeded with the preliminary design.

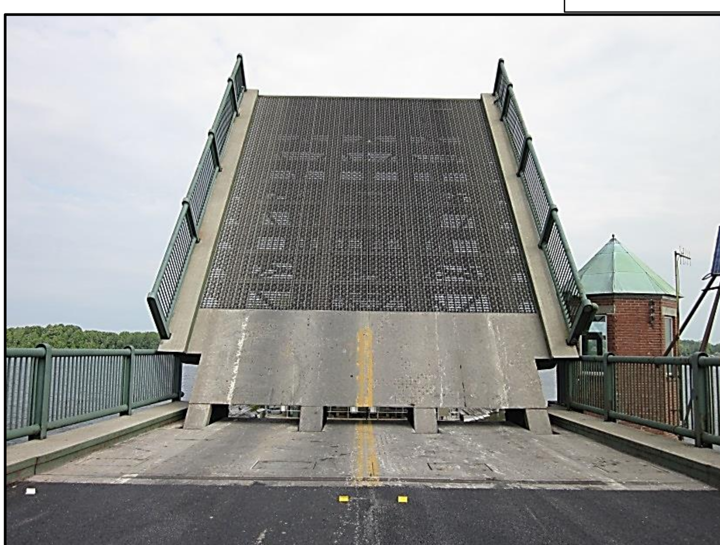
Goals:

The following goals were established for the project:

- **Improved Machinery Access:** Maintenance of movable bridges is only as good as the access provided to perform maintenance. Improved maintenance extends the useful life of bridge and machinery. Therefore we have provided walkways to access the underside of the deck across the entire bridge with maintenance platforms for span locks navigation lights trunnions, electrical equipment, live load shoes, Counterweight pockets, etc. In order to provide headroom at the catwalk across the entire bridge the structure depth was increased and the bridge profile was raised.

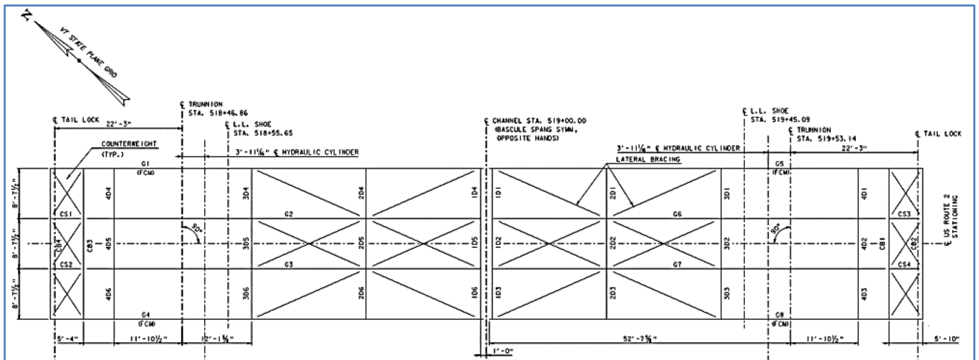


View of the existing span in the open position. Note counterweight partially submerged in the water.



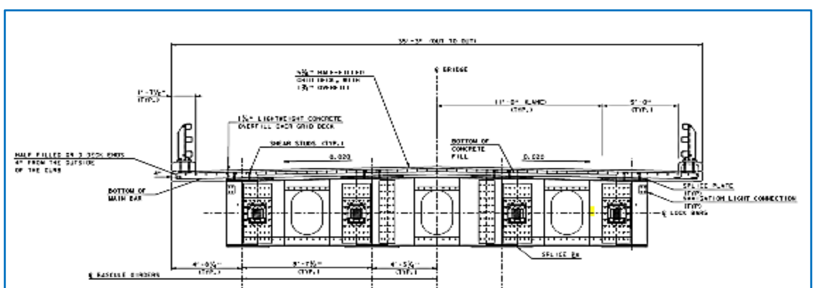
View of leaf in the open position. Note: four flower box joints at each bascule girder.

- **Provide Better Protection for Machinery from the Elements and Road Salts:** This started with an enclosed counterweight pit. The new dry pit area will prevent the counterweight from being dunked in Lake Champlain during bridge operation. By providing a closed deck system road salts would not fall on the bridge faming. This will reduce corrosion and extend the useful life of the bridge. In addition the closed deck system will provide an improved riding surface. By eliminating the flower box joint arrangements around the bridge girders debris and road salt would be prevented from falling onto the trunnions. A joint would be provided that wraps around the entire back of the bascule span. The jointed would be detailed with overlapping joint plates with compression seals. This was done to minimize water from falling on to concrete walkways below deck and creating a slipping hazard in the Vermont winter. Lastly we have attempted to close up gaps between the movable span and the bascule pier to reduce pigeon intrusion into the pier.



Proposed Framing Plan

- **Redundant Framing System:**
  The Bridge Framing consists of four parallel girders on each leaf. Each girder is provided with lock bars. There is driving machinery for two lock bars on each leaf, and there are two receivers on each leaf. This provides balanced loading for the two leaves. Each girder has live load shoes at each leaf and hydraulic cylinders. There are rigid diaphragms that connect the parallel girders.



Typical Bridge Cross Section. Note Three Walkway Openings and Four Span Locks in the End Floor Beam

- **Redundant Routes of Egress:**
  We have attempted to provide a minimum of two egress paths from any location below deck in case of fire or other emergency. Primary route of egress will always be enclosed stairs with fire rated doors. Secondary routes may include ladders and access hatches. There is an enclosed stairway underneath the control house that extends from the bottom of the pit to the roadway

level. There are enclosed stairways at the other three corners of the bridge that extend from the bottom of the pit to just below the roadway level. There are ladders with access hatches to reach the roadway level at these locations. In addition there is an under deck walkway from pier to pier and stairs that access the fenders.

- **Improved Corrosion Protection:**
  All structural steel will be metalized to improve the corrosion resistance of steel bridge elements.

- **Improved Operator Facilities:**
  The existing operator's house doesn't provide enough room for multiple persons to be inside if someone needs to access the lower level. Access to the lower level is through a hatch and down an access ladder on to an open pier. The Vermont Transportation Agencies safety protocol requires a safety boat in the water any time the lower level of the pier is accessed. Also there are no facilities in the operator's house. This means that operators would be in the house only during operation and then leave the bridge. The new operator's house will have room to sit with kitchen facilities. There will be easy access to the lower level via fire protected stairways. There will be lavatory facilities on the lower level. The electrical and mechanical rooms would be down one level, and there will be storage in the lower level. Again the lower level would be easily accessed by stairways.

Section through Pier and Control House of Proposed New North Hero Bridge

Staged Construction

Plan showing staged construction

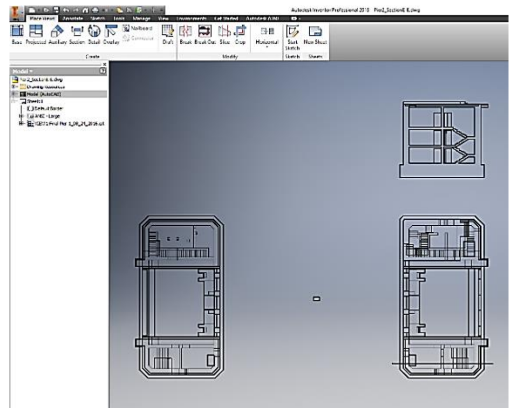
During the preliminary design phase we anticipated that the bridge could be built using staged construction. The existing bascule spans had 4 parallel bascule girders. Therefore, it would be possible to cut the bridge in half and use one half while the other side is demolished. To accomplish this we would povride a temporary barrier along what was the middle of the bridge leaving one lane open to traffic, and provide a temporary signalized system to alternate traffic during construction.

Hydraulic Cylinders

It was originally decided to use hydraulic cylinders as the bridge mover. There were several factors that were considered in this decision. First, hydraulic cylinders are a little more forgiving with regards to alignment. Second, the Vermont Transportation Agency is very comfortable maintaining a hydraulic system. Third, since the bridge is not operated during the cold Vermont winters it is not necessary to heat the Hydraulic fluid during the winter months. Since we were planning to stage the bridge construction hydraulic cylinders are preferred since they provided better flexibility. For redundancy, we designed the cylinders assuming that one of the four cylinders could be out of service and the three other cylinders could operate the bridge in the final condition. During the staged construction we were to design two cylinders to operate the bridge with an increased bridge imbalance. The increased imbalance would be the result of losing the center section of counterweight during the staged demolition since one of the supporting girders would be removed at that time.

3-D Design Development Tools

The bridge was fully modeled in Inventor Pro 2014. The purpose of using 3D software was to have a better view of the bridge, find interferences with bridge geometry, and cut section views to place into the drafting platform required by the client. The model also provided the client with graphics to help them better understand the design concepts that were being developed as well as the issues that could arise with staged construction. In the model we were able to rotate the bascule span and make changes to the platforms required to meet clearances necessary. Having the model also made it easier to coordinate between disciplines as to where we could place machinery and electrical equipment. Inventor allowed us to obtain more accurate volumes when it came to estimating quantities. Working drawings were created by cutting sections from the 3_D model.

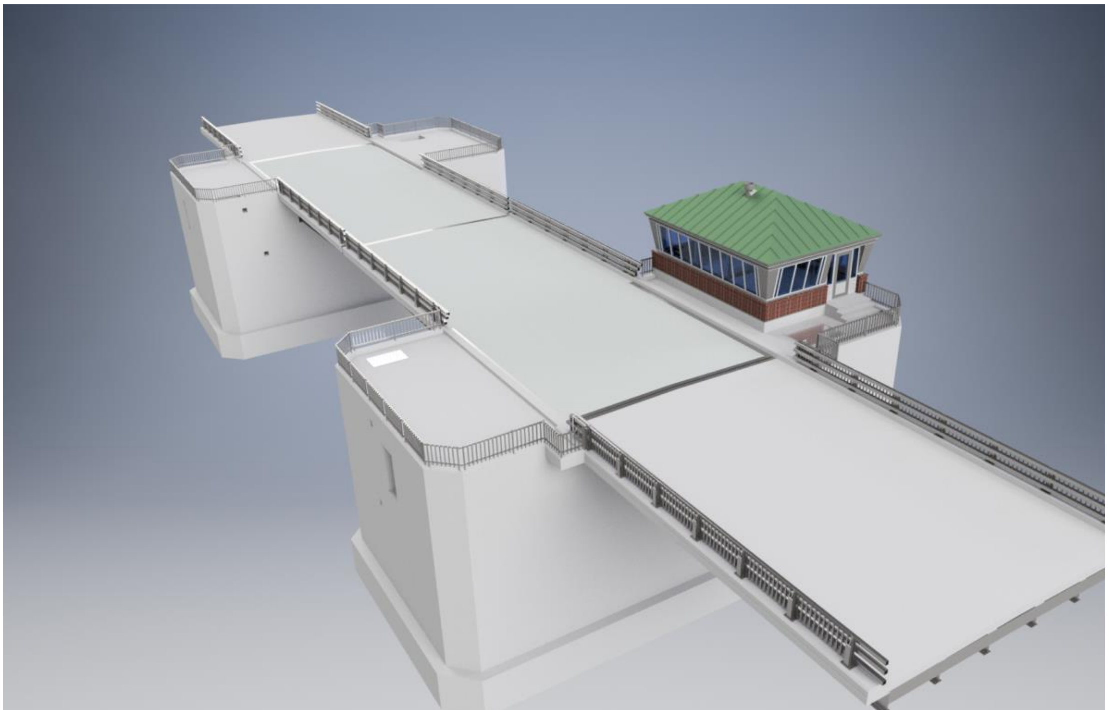


Historic Involvement:

The State Historic Preservation Office reviewed the proposed design and provided Comments and Issues with which they were concerned. The number one concern was that the North Hero Bridge is the only Movable Highway Bridge in the State of Vermont. Therefore the replacement should also be a movable bridge of the same type (Double Leaf Bascule). There second concern is that the bridge tenders house located on the NE corner should remain. We had anticipated that SHPO would want to keep a similar control house on the new bridge. It would have to be scaled up to be more useful as the existing house did not provide enough room. However, it turned out that SHPO was not tied to the existing octagonal shape and a rectangular house was selected with standing seam roof. SHPO had instead wanted that the existing control house be removed from the existing bridge and be placed in a local park. This idea was abandoned due to cost and inherent risks. The last issue of concern was the bridge railing. SHPO wanted a railing that looked similar to the existing bridge railing. However the existing railing was not crash rated. Eventually it was decided that a standard MassDOT crash tested railing would be acceptable.

Tail Locks:

Our design used a rear road break in an effort to reduce water into the pier and particularly to keep runoff from landing on mechanical components. As the result of this design live load on the roadway behind the trunnion would cause tension in the cylinders. Since the bridge would be closed during the winder there would be no operator on duty. The issue is that live load on the cylinders could lead to hydraulic pressure loss and there would be no one present to restore pressure in the system. Therefore two tail lock were included to remove the live load from the cylinders.



Partial Rendering of the New North Hero Bridge

CMGC Procurement/ Final Design

The project was advanced from the concept design stage utilizing the Construction Management General Contractor (CMGC) procurement methodology. The selected contractor was Cianbro Corporation of Pittsfield Maine, HDR as the engineer of record and Keville Associates as the independent cost estimator. Over a 24 month period the design was advanced taking into account contractor preferred means and methods based upon a risk mitigation approach. Early in the collaboration process a detailed risk register was jointly created between VTrans, Cianbro and HDR. As the design advanced, the register was modified to include new risks, and removal of mitigated risks. This risk mitigation approach not only included design impacts as well as MPT, Environmental permit issues and contract terms and conditions. Collaboration meetings were held where all parties provided comments and insights into the root cause for cost and schedule impacts. The process was successful due to the high level of cooperation and honest discussion between all parties.

Temporary Movable Bridge

The original design concept included staged construction where the bridge would remain operational for single lane highway traffic and fully operational for marine traffic. During the early evaluation process a temporary movable bridge was considered, but was deemed too expensive. In order to assure reliability of the existing bridge until the new bridge was completed, interim mechanical and electrical repairs were required. During the summer of 2016 these repairs were implemented. The impact to roadway traffic during construction became a concern to both local residents and VTrans. Vtrans requested that the design team revisit alternate means to maintain highway traffic. Utilizing the measured delay times for queued traffic during construction, user delay costs were calculated.

	2017	2018	2019	Total
Traffic				
Daily Vehicles	3,005	3,010	3,015	
Annual Vehicles	1,096,811	1,098,626	1,100,443	
Annual Vehicles Not Impacted by Opening	902,240	903,733	905,228	
Annual Vehicles Impacted by Opening	194,571	194,893	195,216	
Average Hours of Delay Per Vehicle - Single Lane				
No Bridge Opening	0.025	0.025	0.025	
Bridge Opening	0.125	0.125	0.125	
Travel Time Cost				
Bridge Crossing Cost				
Existing Conditions	$434,361	$439,430	$444,559	
Temporary Bridge	$1,447,869	$1,464,767	$1,481,862	
Single Lane	$1,447,869	$1,464,767	$1,481,862	
Single Lane Delay	$1,040,556	$1,052,700	$1,064,986	
Total Additional Costs				
Temporary Bridge - Travel Time	$1,013,508	$1,025,337	$1,037,304	**$3,076,149**
Single Lane Bridge - Travel Time	$2,054,064	$2,078,037	$2,102,289	**$6,234,390**
Single Lane Bridge Emissions	$1,575	$1,578	$1,581	**$4,734**

Based upon this analysis, VTrans decided that a temporary bridge would be a preferred approach to the staged construction.

BIM Model for Future Maintenance

During the design team's partnership with VTrans, it became apparent that in order to maximize the useful life of the new bridge maintenance guidance would be highly beneficial. Based upon discussions with VTrans something more than typical operations and maintenance manuals would be required. The design team in partnership with VTrans asset management team agreed to develop a geospatial tool which includes all key bridge structural, mechanical and electrical components. The tool is cloud based and includes data input capability as well as work order generation for both maintenance and inspection requirements.