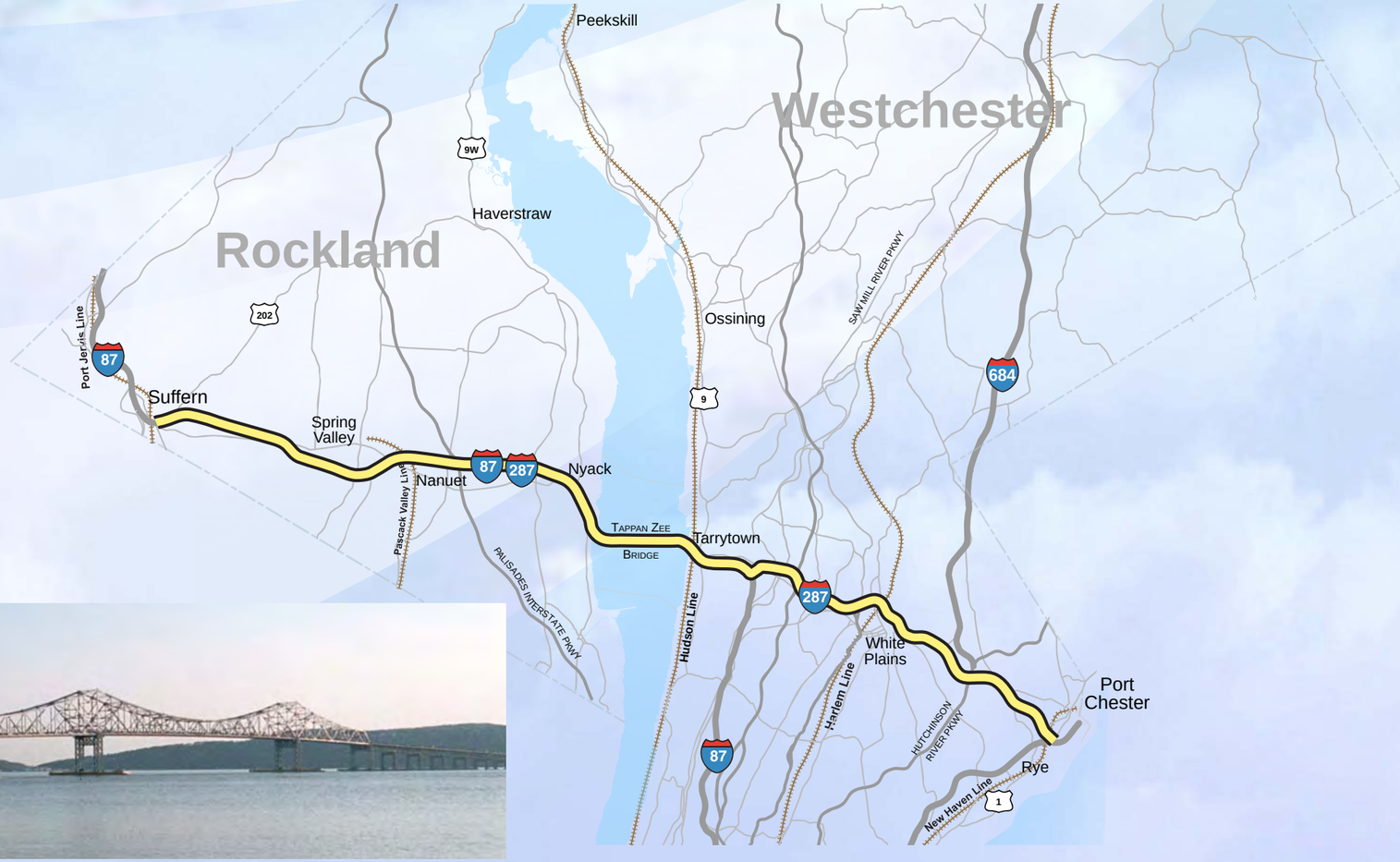
Draft

Alternatives Analysis for Rehabilitation or Replacement of the Tappan Zee Bridge

September 2008

New York State Department of Transportation
New York State Thruway Authority
Metropolitan Transportation Authority/Metro-North Railroad

Tappan Zee Bridge/I-287
Environmental Review



Thruway Authority

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Executive Summary

This report is one in a series that documents the extensive engineering and environmental analyses conducted during the scoping stage of the Tappan Zee Bridge/I-287 Environmental Review. The need for this study, and the overall Tappan Zee Bridge/I-287 study, has been to address the continuing deterioration of the Tappan Zee Bridge (TZB) and the ongoing rehabilitation efforts and expenditures required by the New York State Thruway Authority (NYSTA) to keep the bridge safe for traffic operations. The purpose of this report is to determine which Rehabilitation or Replacement TZB options are reasonable alternatives to be further evaluated in the Draft Environmental Impact Statement (DEIS).

The report concludes that Rehabilitation Options are not reasonable or prudent and should be eliminated from further consideration in the DEIS. While analysis has shown that the existing TZB can be rehabilitated to generally comply with standards, the extent of the necessary alterations is extraordinary. These alterations would result in a structure that is 80% the same as a Replacement Option, with similar environmental impacts, traffic and transit operations, and cost. To retain the remaining 20% in a rehabilitated TZB with its complex, risk-inherent retrofits, inferior engineering performance, and greater life-cycle costs compared to a replacement bridge, is unreasonable.

Evaluation Process

Evaluation criteria (Table S-1) and options to be considered were established and presented to the Stakeholders Advisory Working Group (SAWG) at a regular meeting in November 2007, and to the public at the Scoping Update Meetings held during February 2008. The criteria and options were also included in the Scoping Update Packet transmitted to all participating and cooperating agencies as well as all other stakeholders. No objections to the proposed criteria were received.

Outline designs for both the Rehabilitated and Replacement Options were developed for analysis. The analysis methods and preliminary results for the foundation design for both Rehabilitation and Replacement Options were presented for comment at the Tappan Zee Bridge Foundation Workshop held in March 2008. No technical flaws were discovered and comments received were incorporated into the analysis.

Engineering	Environmental	Transportation	Cost
Structural Integrity	Land Use	Travel Time	Capital Cost
Vulnerability	Displacements & Acquisitions	Roadway Congestion	Operating & Maintenance Cost
Seismic	Historic & Archaeological Resources	Alternative Modes in Mixed Traffic	Life Cycle Cost
Redundancy	Parklands & Section 4(f)/6(f)	Mode Split	
Emergency Response	Ecosystems & Water Resources	Transit Ridership	
Navigation	Visual Resources & Aesthetics	Non-Vehicular Travel	
Construction Impacts		Reserve Capacity	
Life Span		Rail Freight	
		Transportation System Integration	

Table S-1
Evaluation Criteria

Recognizing the TZB's eligibility for listing in the National Register of Historic Places (National Register), a Preliminary assessment was prepared in accordance with Section 106 of the National Historic Preservation Act of 1966 (NHPA), as amended (implementing regulations at 36 CFR Part 800), and Section 4(f) of the Department of Transportation Act of 1966, as amended (implementing regulations at 23 CFR Part 774). The assessment is included in Appendix D of this report.

The draft results in this report will be presented to agencies and stakeholders at individual meetings and to the public at a further Public Information Meeting and will be open to comment for a period of 30 days. Comments received will be reported in the Scope Summary Report prepared at the end of Scoping or this report may be revised based on the comments received.

Tappan Zee Bridge Status

Opened in 1955, it was not until the mid 1980s that notable deterioration of the TZB was recorded, prompting the beginning of an extensive repair program by the NYSTA. Subsequently, targeted repairs were made to all segments and components of the TZB including the concrete deck, primary, secondary and tertiary steelwork, stringers, bearings, pier bents, columns, pile caps, and piles for ice breakers and ship protection. These staged repairs are still underway today and include the current Causeway partial deck replacement program – a $150 million two-year repair contract with activities conducted primarily at night to minimize traffic disruption.

Through the mid 1990s, these continuous repairs by the NYSTA were sufficient to improve the overall condition of the TZB. However, in more recent years the overall condition of the TZB is again in decline, with extensive repairs required to keep the bridge safe for the near future. Within the current maintenance cycle, the need to repair deterioration of the original structure and the additional need to repair the previous repairs that are now deteriorating in places exists. The extent of the required repairs, the high rate of deterioration and the repetitive cycles of repair make a major rehabilitation of the TZB the minimum action required to maintain safe conditions for traffic operation into the foreseeable future.

The effects of age, truck volumes and highway and marine salts are causing the deterioration of the TZB. However, the resulting scale and rate of deterioration is amplified when compared to other bridges of similar size because of the form and details of the TZB including:

- The bridge was designed light. The intention of the original bridge designers was to make the deck and the bridge as light as possible to reduce weight and thus avoid the need for deep foundations in the poor soil conditions of the river. Consequently, the decks were designed to be thin (approximately 30% thinner than modern standard decks) and light resulting in initial cost savings, but with long term durability disadvantages.
- The TZB was designed to be flexible. The original designers introduced deck joints between each of the almost 200 spans. Particularly in the Causeway Spans, these joints allowed for potential movements of the bridge resulting from differential settlements of the shallow foundations in the soft soils beneath the river. These original 200 joints (now 114) provided a direct route for de-icing salts on the highway to leak onto the substructure components below the deck and have proven to be a major source of deterioration.
- The bridge was designed with open drains. Open edge and central drains in the original design provided a route for the deposition of de-icing salts onto all the components of the substructure below the highway. Over time, road salts have reached the primary, secondary and tertiary steelwork members resulting in extensive corrosion and accelerated deterioration.
- Open steelwork sections were used in the trusses. While not uncommon at the time of construction, the truss members consisted of sections with holes to reduce weight and save steel costs. These holes allowed salts to penetrate inside members and into the many adjoining complex connections. The result has been

extensive corrosion and major maintenance challenges because of the inherent difficulty in accessing all parts of the structure.

- The number of individual pieces on the bridge exceeds 100,000. While initially the maintenance requirements for this number of members was readily handled, as widespread deterioration occurred maintenance and repair expenditures accelerated. When compounded by deterioration of members en masse (because of the thin, flexible and open characteristics of the TZB), an exponential increase in maintenance and repair requirements results.

Overall, the TZB was cleverly designed and built to an available budget using bridge components and details in common use in the 1950s. Although long term maintenance was undoubtedly considered during the original design, components and details were not conducive to long term durability and have greatly contributed to the current extensive maintenance and repair requirements. Where possible, these design features are being modified by the NYSTA as part of the ongoing repair contracts. However, some elements cannot be modified to meet current standards.

Beyond deterioration of the TZB, recent studies completed for this report and others have identified other characteristics of the TZB that are notable and warrant inclusion in the evaluation of Rehabilitation and Replacement Options. These include:

- The TZB does not comply with current bridge code requirements for strength and extreme events including wind and seismicity. The TZB is particularly vulnerable to earthquakes because of its foundations, structural configuration and the seismic amplification that can occur through the deep soft soils under the Hudson River
- The lack of redundancy (duplication of critical components of a structure) in parts of the TZB renders risks associated with deliberate actions unacceptable. The nature of the TZB design leaves it vulnerable and difficult to protect from deliberate actions
- The TZB is a critical crossing. While other crossings are present at some distance to the north and south, loss or disruption of the crossing would have major consequences to the economic vitality of the region
- The TZB has a higher rate of highway accidents than the rest of the Thruway system due to its geometry and configuration. The number and severity of accidents on the TZB is compounded by the lack of shoulders and narrow lanes. There is little room for driver error
- In the morning and evening peak hours, the TZB operates at or near its maximum vehicle capacity, with the duration of the peak hours increasing to accommodate traffic demands. While all repairs are scheduled outside of peak hours, the windows of time available for maintenance and repair are constantly being reduced. Major repairs now occur overnight to minimize traffic disruption, with associated increased costs and extended repair periods. Unscheduled repairs impact traffic and result in increased costs

Since the 1980s, investment in the TZB by the NYSTA has more than doubled in each succeeding decade. In the current decade (2000-2010) investment in excess of $1.0 billion (2012 dollars) is being expended, with further expenditures planned for the next decade. While the investment made by the NYSTA is crucial to the immediate safe operation of the TZB, it is not reasonable to make a continued and increasing investment in an aging asset with structural and functional deficiencies. The alternative to rehabilitation of the TZB is replacement, either in part or in whole.

Rehabilitation and Replacement Options

While the issues presented outline the difficulties associated with rehabilitation of the existing TZB, replacement could also bring difficulties; for example, potential environmental impacts to the Hudson River. To address the range of issues in the evaluation of rehabilitation and replacement of the TZB, seven representative options were identified for evaluation – four Rehabilitation Options and three Replacement Options (Table S-2 and Figure 2-3, page 10). These were evaluated using a comprehensive set of criteria (Table S-1, page S1).

With the exception of Rehabilitation Option 1, all options were arranged in an attempt to comply with the Project's Purpose and Need, which included compliance with applicable codes and standards, dedicated transit and safety improvements. These options differed only in the form of dedicated transit and bridge arrangement. Rehabilitation Option 1 may best be described as the minimum Rehabilitation Option. This Option did not fully comply with the Project's Purpose and Need as it would retain the existing TZB transport capacity (seven lanes) and conditions (no shoulders) but would bring the bridge into compliance with current structural standards as much as possible. No provision for dedicated transit was included, and safety improvements such as shoulders would not be provided.

All Rehabilitation Options include the replacement of the 166 Causeway Spans representing approximately half of the overall length of the TZB. Replacement of the Causeway is the only reasonable option in light of the ongoing maintenance requirements, rate of deterioration, repeating deterioration cycles, extent of seismic modifications, structural unreliability and future maintenance risks associated with the existing timber piles.

Option		Highway			Dedicated Transit	Bicycle & Pedestrian Facilities	Bridge Arrangement
		General Lanes	Shoulders	BRT/HOT Lanes			
Rehab	1	7	-	-	-	✓	As existing
	2	8	4	2	BRT	✓	Single level supplemental
	3	8	4	2	BRT	✓	Two single level supplemental
	4	8	4	2	CRT	✓	Dual level supplemental
Replace	1	8	4	2	BRT	✓	Single level
	2	8	4	2	CRT	✓	Single level
	3	8	4	2	CRT	✓	Dual level

Table S-2

Rehabilitation and Replacement Options

Evaluation Results

Evaluation of the criteria did not result in any substantive difference between the Rehabilitation and Replacement Options that would lead to a preference. Instead, the results of the evaluation indicated substantive similarities among the options particularly regarding environmental impacts and capital cost. While initially unexpected, this outcome was a consequence of the extensive modifications necessary to the existing TZB in the Rehabilitation Options to satisfy the Structural Integrity and Seismic Criteria. As a result, the scale and extent of construction required in the Rehabilitation Options was on a par with and of similar type to that in the Replacement Options, leading to similar environmental impacts and cost (Table S-3, page S3).

Similarly, with the exception of Rehabilitation Option 1, evaluation of the Transportation Criteria again resulted in similar performance across all Rehabilitation and Replacement Options with the same transit mode – Bus Rapid Transit (BRT) or Commuter Rail Transit (CRT). In Rehabilitation Option 1, the absence of shoulders and dedicated transit resulted in inferior performance and continuing traffic safety concerns compared to all other options.

Notable differences between the Rehabilitation and Replacement Options did result from the Engineering and Cost Criteria as identified in the following specific criteria: Redundancy, Construction Impacts, Life Span,

Operating and Maintenance Cost, and Life Cycle Cost. Overall, evaluation of these criteria identified inferior performance in the Rehabilitation Options compared to the Replacement Options.

Notable evaluation results that were applicable to specific options included:

1. In all four Rehabilitation Options, replacement of the existing Buoyant Foundations was necessary to comply with the requirements of the Seismic Criteria. Replacement of these foundations involves a unique and highly complex load transfer with associated construction risk and insurance implications. In Rehabilitation Options 1 and 2, these transfer operations would take place while maintaining traffic operations
2. For Rehabilitation Option 2, the need to separate traffic lanes around the retained trusses of the Main Spans was identified in the Traffic Safety Criteria as a potentially unsafe traffic condition
3. For Rehabilitation Option 2, risks associated with construction and traffic safety identified in the Construction Impact Criteria were considered of sufficient concern as to warrant elimination of Rehabilitation Option 2 when compared to Rehabilitation Options 3 and 4. As a result, to accommodate the space required for traffic shoulders and dedicated transit in the Rehabilitations Options, a new Supplemental Bridge is necessary
4. For Rehabilitation Options 3 and 4, 80% of the final TZB is new and is exactly the same as the comparable modal (BRT or CRT) Replacement Options. This leads to similar capital construction costs between the Rehabilitation and Replacement Options for a given BRT or CRT transit mode
5. When the higher maintenance costs of the Rehabilitated Options are included, the Replacement Options are significantly less expensive over the long run

	Cost Estimates (Millions)						
	Rehabilitation Options				Replacement Options		
	1	2	3	4	1	2	3
Dedicated transit provisions	None	BRT	BRT	CRT	BRT	CRT	CRT
Capital Cost	$3,400	$6,400	$5,100	$6,300	$5,200	$6,400	$6,600
Present Value (150-year) Maintenance Cost	$1,100	$1,500	$1,200	$1,400	$700	$700	$900
Life Cycle Cost	$4,500	$7,900	$6,300	$7,700	$5,900	$7,100	$7,500

Table S-3

Cost Estimates

The preliminary Section 106 effects analysis concluded that Rehabilitation Options 1-4 would adversely affect the vast majority of the contributing structural elements of the TZB. These options could not be undertaken in accordance with the *Secretary of the Interior's Standards for Rehabilitation*.

The preliminary Section 4(f) effects analysis concluded that there are no reasonable and prudent avoidance alternatives to use of the TZB. The four Rehabilitation Options require use of the TZB and cannot be implemented in accordance with the *Secretary of the Interior's Standard for Rehabilitation*

Conclusions and Recommendations

Based on specific option results from the evaluation criteria and overall compliance with the Project's Purpose and Need, it is recommended that both Rehabilitation Options 1 and 2 be eliminated from further consideration and not progressed into the DEIS.

- Elimination of Rehabilitation Option 1 is recommended because of its non-compliance with the Project's Purpose and Need. As identified in the engineering and transportation criteria, this option neither improves mobility, nor maximizes flexibility or adaptability for the long term, nor improves safety or security
- Elimination of Rehabilitation Option 2 is recommended as the risks associated with construction and maintaining traffic safety, particularly at the Main Spans, render this option infeasible. Further, the option is not considered reasonable as a result of the potentially unsafe driving conditions where traffic is separated around the existing Main Spans' truss. It also bears greater capital costs, greater construction risks and substantially longer construction duration when compared to Rehabilitation Options 3 and 4

Based on the assessment of the remaining Rehabilitation Options 3 & 4, using all the evaluation criteria, rehabilitation of the Tappan Zee Bridge is not reasonable for the reasons outlined below. Only TZB Replacement Options are recommended to be progressed into the DEIS, the next stage in the process to complete the TZB/I-287 Environmental Review.

1. **Rehabilitation Options 3 and 4 require substantial modifications to the existing TZB to comply with the Structural Integrity and Seismic Criteria**
   - Replacement of the existing Causeway (8,379 feet)
   - Addition of a supplemental span (16,195 feet)
   - Replacement of the Buoyant Foundations in the Main Spans and the West Deck Truss Spans
   - Reconfiguration and enlargement of foundations of the East Deck Truss Spans
   - Strengthening of existing concrete piers throughout
   - Replacement and reconfiguration of bearings
   - Modification of superstructure steelwork throughout
   - Replacement of deck and reconfiguration of edge arrangements
   - Reconfiguration of drainage and utilities
2. **80% of the TZB in Rehabilitations Options 3 and 4 is new and is exactly the same as that of the Replacement Options**

   Rehabilitation Options 3 and 4 comply with the project's Purpose and Need, with both options utilizing a Supplemental Bridge to provide the additional width required for safety improvements (highway shoulders), dedicated transit (either BRT or CRT) and Pedestrian and Bicycle Paths. These supplemental structures are exactly the same structures that make up half the comparable Replacement Options. Overall, when the Causeway replacement and foundation replacement are also included, over 80% of the final TZB in Rehabilitation Options 3 and 4 is new and is exactly the same as that of the Replacement Options.
3. **Rehabilitation and Replacement Options have similar environmental impacts**

   The extent of the similarities between the Rehabilitation and Replacement Options also resulted in similar environmental impacts in the Hudson River and at both the Nyack and Tarrytown landings. Notably, the absolute numbers of cofferdams and piles required was least for Replacement Option 3 because of the long spans possible with the deep superstructure. The minimum number of piles and area of impact in the river required for comparable modal options (Table S-4, Page S4) were similar.

4. Rehabilitation and Replacement Options have the same transportation performance

This result was common for those options with the same transit mode, either BRT or CRT (Table S-4)

5. Rehabilitation and Replacement Options have similar capital costs

- For those options with BRT, the capital cost differed by less than 2% – $5.1 and $5.2 billion for Rehabilitation Option 3 and Replacement Option 1 respectively
- For those options with CRT, the lowest capital costs also differed by less than 2% – $6.3 and $6.4 billion for Rehabilitation Option 4 and Replacement Option 2 respectively
- The differences in the cost estimates for all Rehabilitation and Replacement Options are substantially less than the 30% contingency incorporated

Transit Mode	Rehabilitation Options	Replacement Options
BRT	Option 3	Option 1
CRT	Option 4	Options 2 & 3

Table S-4

Modal Comparable Options

6. The Replacement Options have better engineering performance

For Rehabilitation Options 3 and 4, it is only in the retained segments of the existing TZB, representing only 20% of the final bridge surface area, that rehabilitation and replacement options differ substantially. The majority of the differences in this residual 20% are associated with the poorer engineering performance of the retained structure in the Rehabilitation Options.

- The **Life Span** of the bridge components retained in the Rehabilitation Options would be shorter than those of the Replacement Options. This is a consequence of the historical contamination that is now ingrained in many components from 50 years of aging and exposure to marine and de-icing salts
- A lack of **Redundancy** would remain a characteristic of the TZB in the Rehabilitation Options with the TZB remaining susceptible to some extreme events. In the Replacement Options adequate redundancy would be provided to limit these risks
- While modifications in the Rehabilitation Options have been included to ensure compliance with the **seismic criteria**, compliance is based on strength rather than ductility. As such, the Rehabilitation Options are unlikely to survive an event larger than the Safety Level Event. In the Replacement Options, which are designed to behave in a ductile manner, the ability to survive a seismic event larger than the Safety Level Event is greatly improved
- While the scale of work is similar in all options it is in the sequencing of construction, and in particular access to the existing TZB superstructure in the Rehabilitation Options that results in a difference in **construction duration**. Construction duration for the Replacement Options is approximately one year shorter than that of the Rehabilitation Options

7. The Replacement Options have substantially lower maintenance costs

For the comparable modal options, the present value maintenance costs of the Replacement Options are only 60% of those of the Rehabilitation Options. The higher costs associated with the Rehabilitation Options are associated with the retained segments of the existing TZB.

8. The Rehabilitation Options have greater construction risks and unknowns

- As demonstrated in the last 20 years in the inspection records of the NYSTA, new defects and deterioration are regularly identified on the existing TZB. While allowances for unknowns have been included in the evaluation criteria used in this report, the future rate of deterioration, rehabilitated condition and extent of repair of the retained bridge components may be significantly greater than estimated due to compound effects. The potential for future unpredicted deterioration remains
- In particular, as demonstrated on many other bridges, repairs conducted during rehabilitation can uncover conditions unidentifiable beforehand resulting in increased costs and extended construction duration
- Rehabilitation Options 3 and 4 include replacement of the existing Buoyant Foundations and transfer of the weight of the bridge from existing to replacement foundations. This construction operation is extremely complex and would require substantial analysis to show that the load transfer is possible and buildable. Further, the complexity involved is likely to limit the number of contractors qualified to complete the construction resulting in potential cost escalation

With environmental impacts, transportation performance and capital costs similar to those of the Rehabilitation Options, the Replacement Options have improved engineering performance, lower maintenance costs, reduced construction risk, lesser unknowns and shorter construction duration. In conclusion, it is not reasonable to further evaluate the Rehabilitation Options. It is recommended that only Replacement Options be further developed as alternatives in the DEIS.