2 Engineering Elements

2.1 Introduction

This chapter describes what the TZB needs to achieve or facilitate in the future, as defined in the Project's Purpose and Need Statement. This chapter then describes the requirements of agencies that may either operate the TZB or have a direct interest in it. These agency requirements establish the primary transportation and service components to be included in the TZB. The third part of this chapter is an assessment of the physical condition, vulnerabilities and limitations of the existing TZB. This background information is needed to understand the scale and details of the modifications required of any rehabilitation of the existing TZB. Finally, the options for either the replacement or rehabilitation of the TZB are introduced.

2.2 Purpose & Need

The Purpose and Need Statement of the TZB/I-287 Environmental Review, as contained in the Project's Scoping Update (February 2008), contains the following goals and objectives:

- Improve the mobility of people, goods and services for travel markets served by the TZB/I-287 corridor
  - Reduce traffic congestion levels
  - Improve travel times for local trips
  - Improve travel times for regional trips
  - Provide modal travel alternatives not subject to roadway congestion
  - Increase the share of travel demand accommodated by transit and ridesharing
  - Provide a non-motorized means of travel, such as pedestrian and bicycle, across the Hudson River
- Maximize the flexibility and adaptability of new transportation infrastructure to accommodate changing long-term demand
  - Maximize ability to accommodate increases in travel demand
  - Minimize constraints to serving future travel patterns and markets
- Maintain and preserve vital elements of transportation infrastructure
  - Assure that the corridor's transportation infrastructure meets applicable standards for structural design and integrity
- Improve safety and security of the transportation system
  - Reduce motor vehicle accident severity and rates
  - Improve roadway geometrics to current standards
  - Improve the likelihood that the TZB would withstand a severe natural or manmade event
- Avoid, minimize and/or mitigate any significant adverse environmental impacts caused by corridor improvements
  - Minimize community disruption, displacements and relocations; as well as adverse impacts to public parks, visual resources and aesthetics resulting from mobility improvements in the corridor
  - Implement mitigation measures that are feasible, constructible, innovative, sustainable, cost effective and that address regulatory requirements

All of the above directly affect the TZB and require that significant changes are undertaken as part of the TZB/I287 Environmental Review.

2.3 Operating Criteria and Design Requirements

One of the first steps in developing options for rehabilitating or replacing the TZB was to define the operating requirements for the transportation systems. The following specific requirements were provided by NYSTA and Metro-North. Specific functional design requirements for the crossing approach and bridge were developed from NYSDOT design manuals.

2.3.1 NYSTA

The key operating requirements identified by the New York State Thruway Authority (NYSTA) are:

1. Maintain or improve existing levels of service
2. Locate all highway (vehicular) lanes on one level
3. For safety reasons, locate access roads/ramps to and from the Thruway on the right side
4. Design the TZB to accommodate pedestrians, cyclists, public transportation modes and private road vehicles as well as maintenance and operation vehicles
5. Provide effective separation between pedestrians and CRT
6. Include staging areas on both ends of the TZB for quick and safe stopping of commercial traffic for inspection before entering the TZB
7. Replace, in function, any NYSTA building or facility eliminated or significantly impacted
8. Locate facilities such that State Police and NYSTA emergency vehicles are in close proximity to the TZB, while providing a one-minute access time to the northbound and southbound lanes on the TZB
9. Provide independent and dedicated access (southbound and northbound) from NYSTA maintenance and administrative facilities (including State Police) to the mainline at all times
10. Provide access roads at both ends of the TZB for turn-around of NYSTA maintenance and State Police vehicles carrying out emergency response and maintenance activities
11. Provide unrestricted maintenance access at all times to the TZB structure, including the area over commuter rail tracks
12. Provide four U-turns (with electronic gates) on the main roadway to accommodate emergency response and maintenance vehicles
13. Provide one U-turn on each end of the TZB and two in-between

2.3.2 Metro-North

The key operating requirements identified by Metro-North Railroad, relative to the introduction of CRT to the TZB (meeting the requirements of Alternatives 4A, B & C and Option 4D) are:

1. Ability to operate the railroad system, 24 hours a day, 7 days a week
2. Capacity to support train services at 3 minute frequency
3. Ability to electrify the line using the standard Metro-North third-rail
4. Provide a 10-foot wide vehicular maintenance way adjacent to the railroad tracks, or equivalent access, for scheduled and unscheduled maintenance activities in support of Metro-North's maintenance/inspection procedures that follow the federally mandated code (Code of Federal Regulations (CFR) 49 Part 213- Track Safety Standards) for high speed class V track, ensuring minimum impact on operations
5. Comply with criteria for fire/life safety in National Fire Prevention Association (NFPA) 130, *Standard for Fixed Guideway Transit and Passenger Rail Systems* (2003 Edition) and NFPA 502, *Standard for Road Tunnels, Bridges and Other Limited Access Highways* (2004 Edition). Coordination with local authorities is deferred to the DEIS Stage and final design stages
6. Accommodate both diesel and electrically powered (third-rail underside) operation
7. Any shoulder tunnels shall:
   - Have access points for emergency service personnel and maintenance activities at not more than 0.5-mile centers
   - Access points to be combined with ventilation buildings where possible
   - Have ventilation systems and facilities to exhaust diesel within five minutes and to provide acceptable air quality in underground stations at all times
8. Railroad shall accommodate freight vehicles.
9. Provide crossovers at each end of the river crossing and at each end of the shoulder tunnels to maximize operational flexibility and to ensure that any section of the system can be made available for single-track operation

10. The service plan includes scheduled operation of the following existing and new routes with their associated electrification systems:
    - Port Jervis to Suffern/Hillburn to TZB to Grand Central Terminal (new)
    - Port Jervis to Suffern/Hillburn to Secaucus to Hoboken (existing)
    - Port Jervis to Suffern/Hillburn to Secaucus to Penn Station (new, with the Trans Hudson Express project)
    - Suffern/Hillburn to TZB to Port Chester or Stamford (new)

2.3.3 US Coast Guard

In the main navigation channel, the existing bridge provides a vertical clearance for shipping of 139 feet over a width of 600 feet. This would need to be maintained as a minimum for any replacement or rehabilitated bridge. There is a desire to increase the vertical clearance to 155 feet if a replacement crossing is taken forward.

2.3.4 NYSDOT

The general design criteria enumerated in Table 2-1 are adopted from the *NYSDOT Highway Design Manual*, as amended by the NYSTA, and the *NYSDOT Bridge Design Manual*. These design criteria may be applied to the TZB and its approach roadways along with other criteria to be developed in the DEIS.

Component:	Design Criteria for Tappan Zee Bridge		
PIN:	8TZ1.04.101	NHS (Y/N):	Yes
Route No. & Name:	I-287, NYS Thruway	Functional Class:	Urban Principal Arterial Interstate
Project Type:	Rehabilitation or Replacement	Design Class:	Interstate
% Trucks:	6	Terrain:	Rolling
ADT:	140,000 (2004)	Truck Access/Qualifying Hw.	Qualifying

	Element	Standard Criteria	Existing Conditions on TZB	Proposed Conditions on TZB
1	Design Speed	70 mph	60 mph	70 mph
2	Lane Width	12 ft	11.4 ft (min.)	12 ft
3	Shoulder Width	• Right: 10 ft minimum, 12 ft desirable • Climbing: 4 ft minimum, 12 ft desirable • Left: 10 ft minimum, 12 ft desirable	0.0 ft	12 ft on both sides of travel way
4	Bridge Roadway Width	Full approach roadway width	reduced by one lane from approach	8 travel lanes, the approach roadway width
5	Grade	Mainline – 4%	2.0% max on Main Spans 3.0 % max on approaches	Road - 3% CRT - 2%
6	Horizontal Curvature	2040 ft at maximum 6.0% super-elevation	2600 ft	2500 ft or greater-
7	Super-elevation Rate	6% max	1.56%	6% max
8	Stopping Sight Dist.	730 ft	927 ft	>910 ft
9	Vertical Clearance	16 ft minimum (road) 16'-6" desirable (road) 23' 6" (CRT)	20'-6" (At Main Spans)	16' 6" over Thruway 15 ft under Thruway 17' 9"" over CRT (TOFC) min
	Vertical Clearance at River Road (Urban Local Street)	15 ft	14'-9"	15 ft
	Vertical Clearance at Hudson Line	22'-0" minimum (Mainline) 23'-0" recommended (AREMA)	in excess of 50 ft	in excess of 50 ft
10	Pavement Cross Slope	1.5% to 2%	1.56%	2% max
11	Rollover	4% between lanes; 8% at EOT; (If super-elevation > 6%, and shoulder drainage is a concern, may use 10% for outer 4 ft of shoulder.)	3.125%	4% between lanes; 8% at EOT
12	Structural Capacity	Road – HL-93 Rail – Cooper E-80	HS-20 equivalent	Road – HL-93 Rail-65,000 lb axle load
13	Control of Access	Full	Full	Full
14	Pedestrian & Bicycle Path	10 ft width	None	north and south bridge paths, each 15 ft wide (total width including rails)
15	Median Width	10 ft minimum (6+ lanes) 26 ft desirable	4 ft typical	No Median (only safety barrier)
16	Navigation Clearance	—	139 ft	139 ft minimum 155 ft desirable

Table 2-1

Design Criteria

2.4 Condition & Assessment of Existing TZB

The TZB is comprised of 5 segments – Causeway, West Deck Truss, Main Spans, East Deck Truss and East Trestles (Figure 2-1).

2.4.1 Source Data

The following documents identify activities that were completed by the Project Team to establish the condition, limitations and vulnerability of the existing TZB:

Existing Conditions Report (September 2008)

- 2002 Biennial Inspection
- In-depth bridge inspection completed March 2003
- Biennial bridge inspection completed in December 2004
- Fathometric survey
- Underwater inspection of foundations
- Ground Penetrating Radar (GPR) survey of the TZB deck
- Ultrasonic testing of primary pins on the main truss
- Miscellaneous concrete testing
- Miscellaneous steel testing
- Assessment of historical rates of deterioration

Geotechnical Data Report (June 2007)

- Geotechnical Investigation including seven new boreholes

Structural Assessment Report (September 2008)

- Load rating at inventory and operating levels
- Wind analysis

Risk Assessment (See Appendix B)

- Vulnerability assessment in accordance with the NYSDOT manuals
- Threat and Risk Assessment (TARA)

Seismic Assessment Report (September 2008)

- Multi-modal seismic analysis
- Time-history seismic analysis
- Probabilistic Site Hazard Assessment (PSHA)

The overall assessment of the source data indicates that the TZB is safe for current traffic but with notable vulnerabilities and long term durability concerns. The TZB does not comply with current seismic performance standards. Specific assessment results are presented in the following sub-chapters and the required rehabilitation elements summarized in Table 2-3 (page 6).

2.4.2 Condition

The overall assessment of the TZB indicates that it is safe for continued traffic use with all primary and secondary structural components in good working condition. Tertiary components (such as fascia), particularly on the edge of the deck, were in poor condition with extensive deterioration.

NYSDOT rates its bridges on a scale from 1 to 7, with 7 being the rating of a bridge in new condition. Inspection of the TZB (carried out by NYSTA in 2006) resulted in an overall condition rating of 2.96 indicating substantial ongoing deterioration.

The rate of deterioration of the TZB is unusually high and is a consequence of the de-icing salts used on the concrete deck falling onto components below. Of the approximate 2,600 conditions requiring attention, found in the inspections conducted, 93% were associated with water and de-icing salts penetrating below the concrete deck.

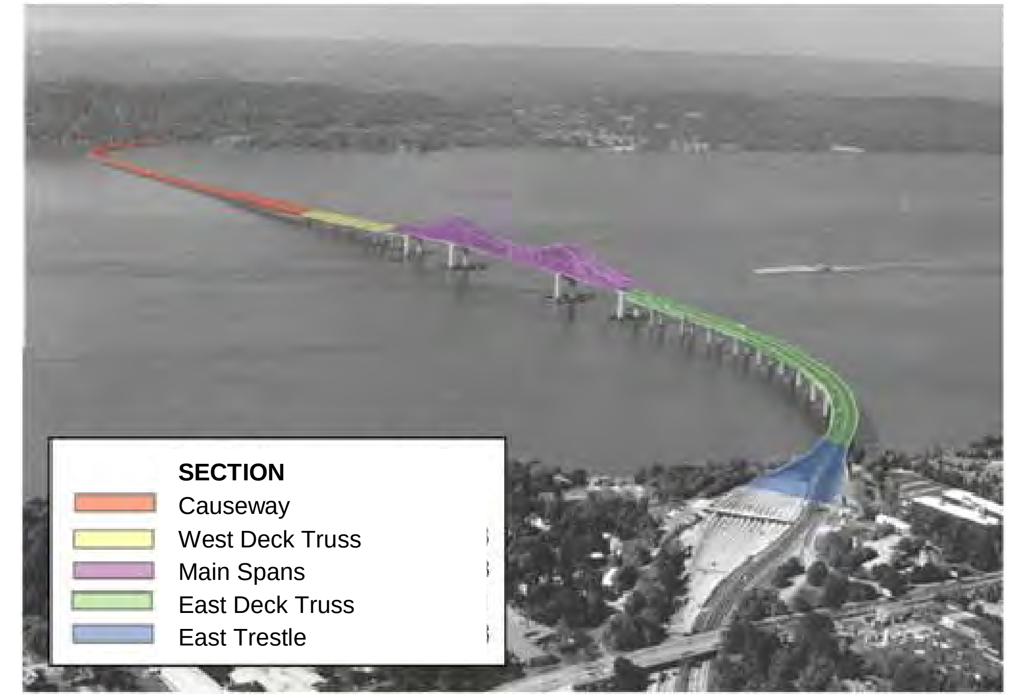

Figure 2-1

TZB Segments

Investigation and inspection of the deck concrete indicates widespread severe deterioration and overall poor condition. It is estimated that 59% of the original deck area will need to be replaced in the next 10-15 years and that the current high occurrence of deck failures is likely to continue. Subsequent to this assessment, the NYSTA has started a maintenance program including deck and stringer replacement and other reconstruction on the outside lanes of the TZB.

The volume of truck traffic on the TZB is detrimental to the bridge deck. A total of 45 punch through deck failures were recorded on the bridge deck during the 18 months preceding this assessment. Of the 45 deck failures, 44 were in the outside two lanes, which carry almost all of the truck traffic on the TZB. The locations of these deck failures were shown to match the areas of severe deterioration indicated by the GPR survey conducted. The presence of approximately 530 local areas of severe deterioration, noted in the GPR survey, and the continuing increase in truck traffic indicates continued and extensive future deck failures of the bridge deck.

2.4.3 Vulnerability and Risk

Of the six vulnerabilities assessed for the TZB, five have ratings that warrant inclusion on NYSDOT's safety program based on its Bridge Safety Assurance vulnerability manuals. These include: collision (vehicle & vessel), overload, seismic and steel details. Concrete details and hydraulics were not judged significant. This number of ratings indicates that the TZB is considered particularly vulnerable (though still is safe) when compared to other bridges, with further assessment and monitoring required.

In accordance with the "Recommendations for Bridge and Tunnel Safety, September 2003", prepared by "The Blue Ribbon Panel on Bridge and Tunnel Safety" at the request of the AASHTO Transportation Security Task Force and FHWA and considered current "best practice", a TARA was conducted for the TZB. The TARA, included in Appendix B of this report, identified that there are a number of significant risks associated with the

TZB, including overload, vehicle collision, vessel collision, seismic vulnerabilities, steel details, and deliberate actions.

Based upon the analysis completed it was determined that the TZB was at risk from multiple hazards as listed in Table 2-2.

Event group
Accidental barge collision
Accidental vehicle collision
Accidental vessel collision
Deliberate actions
Deterioration
Overload
Seismic 500-year
Seismic 2500-year
Wind

Table 2-2

Event Groups

Fatigue failure of weld details on the lower flange of stringers (floor beams that support deck segments) in the Causeway has been identified as a high risk. Calculations indicate that the service life of the edge stringers has been reached, though no signs of related deformation or defect were found during the inspection of the TZB.

Subsequent to this assessment, the NYSTA has initiated a further program of stringer replacement on the Causeway, which is currently in progress.

2.4.4 Seismic

As a ‘critical’ piece of infrastructure, the TZB is required by the NYSTA and the NYSDOT (*Blue Pages*, July 2003, Division 1A Section 6A or *Blue Pages*, September 2007, clause 3.10) to meet the following seismic performance standards:

- **Functional Level Event**: After a moderate seismic event, the TZB should suffer no damage to primary members and be open for traffic within hours. A moderate event is defined as an earthquake with an approximate 500-year return period.
- **Safety Level Event**: After a major seismic event, the TZB should have repairable damage and be open to emergency services within 48 hours and to general traffic within months. A major seismic event is defined as an earthquake with an approximate 2500-year return period.

The existing TZB does not meet the current performance standards for a critical bridge. Should the Safety Level Event occur, the extent of repair work required on the TZB would likely require closure of the TZB for a substantial period. Major damage to various segments of the TZB is possible.

Soil conditions at the TZB, and particularly under the Causeway, amplify the magnitude of a seismic event by factors ranging from 4 to 6. This results in horizontal forces on the various segments equivalent to up to 50% of gravity. These are significantly above the standard horizontal design forces of 10-15% typically used for bridges not designed to contemporary seismic requirements, such as the TZB.

For the Causeway structure, assessment indicates that the capacity of the existing horizontal load resisting system would be substantially exceeded in the Safety Level Event and that the raked end piles at each pier would be significantly overstressed. This overstress of the end piles does not imply failure of the whole structure, as alternative horizontal load capacity exists in the multitude of vertical piles present in the foundations. Analysis that assumes continued functioning of these vertical piles indicates possible adequate capacity to resist the seismic forces, though with substantial roadway displacements along with damage to connections and details.

Despite the alternative horizontal capacity, following a Safety Level Event, it is considered that the structure is likely to be out of position and unusable by general traffic. Further, the potential for major damage cannot be discounted as existing connections and details are inherently non-ductile.

The simplified analysis for the Deck Trusses indicates major overstress of bearings, some steel members and the supporting piers and foundations. The magnitude of the overstresses and the inability of these members to behave in a ductile manner may result in major damage during a Safety Level Event.

Simplified analysis for the Main Spans indicates extensive overstress, with the greatest overstresses at the bearings, pier anchor bolts, steelwork in piers and main trusses and piled foundations. The configuration of the tower legs, connections and piles do not indicate adequate ductile behavior, potentially resulting in major damage from the governing upper limit event with possible collapse.

Should the TZB be retained, retrofit of the Deck Trusses and Main Spans would be recommended with the exact extent determined by further analysis. A preliminary retrofit design has been developed for comparative purposes based on the replacement of bearings, strengthening of steel members, pier modifications and foundation replacement. The proposed seismic retrofit efforts are discussed in Chapter 5.3 of this report.

2.4.5 Live Load Capacity

Though the TZB can adequately support the originally intended design live load, which is equivalent to the modern HS-20 truck, strengthening to support HL-93 highway load and the NYS Design Permit Truck is warranted given the status of I-287/87 as a major trucking route and the national trend towards heavier trucks. Initial analysis indicates that 35% of stringers and all the floor beams in the Deck Trusses and cap beams in the Causeway would require strengthening to accommodate the increased live loading.

Note: Subsequent to this assessment, the NYSTA has initiated a program of deck and stringer replacement that will increase the capacity of these components to support HS-25 loadings.

2.4.6 Traffic Capacity and Condition

On a weekday, peak period traffic demand on the Thruway exceeds the 7,600 vehicle per hour free flow capacity of the TZB. Capacity limitations on the TZB and its approaches cause congestion, which causes motorists to divert onto parallel routes in Westchester and Rockland to avoid the resulting queues.

During the weekend peak hours, Toll Plaza processing rates for the large share of non-E-ZPass vehicles, along with inadequate vehicle storage space, results in traffic backing up and blocking access to the higher speed E-ZPass lanes.

The significant traffic demand during peak hours limits the time available for maintenance of the TZB.

The TZB has a high accident rate. In the three year period from October 1999 to September 2002, 1,424 traffic collisions occurred in the 3.7 mile distance between Interchange 9 (Tarrytown) and Interchange 10 (Nyack). This corresponded to an average collision rate of 1.3 collisions per day and was four times greater than the average rate (per million miles traveled) when compared to the whole of the Thruway system.

The accident rate is considerably higher than what is considered acceptable for modern major bridges. Factors present on the TZB that are likely to induce driver errors include:

- Heavy traffic volumes
- Narrow lane widths
- Lack of shoulders
- Reverse peak direction lane drop
- Sun glare
- Substandard roadway drainage
- Substandard super-elevation
- Truck volumes
- Driver frustration
- Continuous and changing lane closures

- Daily relocation of the moveable barrier
- Speed differentials, limited space and lane changing movements at the Toll Plaza

2.5 Work Required to Rehabilitate Existing TZB

2.5.1 Main Spans and Deck Truss Segments

Should the existing TZB be retained, substantial work would be required to maintain and preserve the Main Spans and Deck Trusses as well to improve safety and security. The proposed rehabilitation efforts would include modifications associated with condition, capacity, vulnerabilities and risks as well as security. The proposed rehabilitation efforts are discussed in detail in Chapters 5.1-5.4 of this report and are summarized in Table 2-3.

2.5.2 Causeway Replacement

Figure 2-2 (page 8) presents a graphical summary of the extent of the modifications required to the Causeway to bring the structure into compliance with current standards as far as is reasonable. As shown, all components on the Causeway would need modification, expansion or replacement. The extent of the physical reconstruction required is substantial: encompassing the full 91-foot width of the highway, the full 8,379-foot length of the Causeway and the full height from the highway deck down to the founding piles. Specific modifications include:

- Replacement of the highway deck and deck joints
- Replacement of the steel deck stringers below the deck, the outer steel fascia beams and the associated drainage system
- Replacement of the bearings supporting the steel stringers and their hold down bolts
- Expansion and strengthening of the piers below the deck
- Expansion and tensioning of the foundations and pile caps
- Removal and reconstruction of the pier and ship protection systems

The NYSTA has commenced a deck replacement program including the outer two lanes of the Causeway. While addressing short term concerns, these efforts are not sufficient to bring the Causeway into an acceptable long term condition, due to persistent seismic and foundation concerns.

The scale of the work listed requires that 50-60% of the existing Causeway structure be replaced or strengthened with the remainder being substantially modified (see Figure 2-2, page 8). New structure would also be introduced outside the footprint of the existing Causeway. The quantity of construction would be extensive, with all construction occurring while the Causeway's existing traffic lanes are kept fully operational.

Following completion of the reconstruction, the rehabilitated Causeway structure would require continued major future investment to maintain the structure in operation. Significant risks as to the future performance of the structure would remain, including:

Element		Detail of Rehabilitation
Condition	Road Deck	• Replace concrete road deck • Replace edge beams, drainage, electrics, lighting, safety fence, cables/ducts
	Steelwork	• Replace steel members with greater than 15% section loss • Investigate and replace critical elements
	Piers	• Repair program required for piers, bearings and hold down bolts. Likely continuous repairs due to water ingress through joints.
	Foundations	• Reinstate steel shields or other similar protection to Deck Truss foundations
	Miscellaneous	• Repairs to bulkhead at shores
	Maintenance Facilities	• Install inspection walkways and upgrade inspection travelers
Capacity	Highway traffic	• Upgrade to HL-93 highway loading and the NYS Design Permit Truck • Increase the number of permanent general traffic lanes from 7 to 8 to eliminate the need for the moveable barrier • Upgrade to full shoulders throughout (Inner and outer shoulders) • Use standard 12-foot wide travel lanes • Upgrade to allow for permit requiring vehicles
	Transit	• Possible addition of 2 BRT/HOT lanes • Possible addition of 2 CRT tracks
	Bicycle & Pedestrian Facilities	• Add Pedestrian & Bicycle Path to crossing • Provide access for pedestrians/cycles in accordance with the requirements of the Americans with Disabilities Act
Vulnerabilities & Risk	Earthquakes	• Upgrade to meet performance requirements for critical bridges
	Fatigue	• Replace those stringers with welded flange plates
	Ice Protection	• Repair/replace fender piles at all piers
	Marine Borers	• Continuous monitoring required. Risk is eliminated with replacement of the Causeway Spans.
	Rate of deterioration	• Replace joints regularly • Switch to the use of non-corrosive deicing material. • Direct drainage outfall away from structure below
	Structural Details	• Harden key details and maximize redundancy
	Ship Impact	• Enhance ship protection at 'floating piers'
	Wind	• Upgrade to current wind code requirements
Security	Deterrence	• Further restrict access to vulnerable locations • Further improve rapid reaction of security personnel to all points on the crossing • Improve provisions for security personnel on the crossing • Enhance provisions at Rockland shore for response personnel and equipment • Improve accommodation for trucks and other vehicle inspection at each end of the crossing • Enhance warning systems for critical components • Enhance the use of closed circuit TV

Table 2-3

Extent of Changes to the Main Spans and Deck Trusses for a Rehabilitated TZB

- **Continued Deterioration**
  Tests have confirmed the presence of contaminants within the pier concrete that, despite repair work, will continue to cause corrosion of the reinforcing steel and spalling of concrete. While the replaced joints and drainage system will initially arrest the rate of salt ingress from the deck, the life span of deck joints is short (less than 10 years) and leakage of salts through the joints would be expected to continue in the future. Salts from the marine environment would continue to cause deterioration of the pile cap and column concrete.

  While deterioration and repairs are expected on all bridges, the number of components and the number of spans subject to deterioration on the TZB greatly multiplies the maintenance effort required and the associated costs. While the use of short spans (50-foot span lengths) was an efficient solution by the original designers to overcome the soil conditions, the maintenance requirements for the resulting 166 spans are extensive.

- **Timber Pile Replacement**
  Deterioration of the timber piles in the splash zone and destruction by marine borers are future risks that may require extensive replacement of the timber piles.

  As is evident from splash zone deterioration of the timber fender piles in the Causeway and in the Causeway pier protection system, timber piles have a limited life span. While inspections of the visible timber founding piles conducted to date do not indicate extensive deterioration, it is not expected that the existing timber piles will last as long as the other principal components of a rehabilitated TZB.

  While there is no current evidence of extensive contamination by marine borers in the timber piles, the presence of marine borers in other timber piles in New York City suggests that the TZB is at risk.

  The future repair or replacement of timber piles is considered to be practically infeasible. Should extensive repair or replacement be necessary in the future, a new replacement foundation system using steel or concrete piles would be required.

- **Post-Seismic Operability**
  Seismic analysis of the Causeway structure has theoretically confirmed that the retrofitted structure could withstand the effects of the Safety Level Events. However, the performance of the structure relies heavily on the timber piles and in particular on the pile-to-pile cap connection. The performance of these components is unproven. There is the potential for the Causeway to be out of position and, possibly, unserviceable for normal traffic operations, after a Safety Level Event.

  Given the propensity of an earthquake to find the weakest link on a structure, the interaction between the existing and expanded foundations in the soft soils of the Causeway, may result in unpredictable behavior and unacceptable post-event operability.

As preliminary cost estimates indicate similar order of magnitude costs for rehabilitation or replacement, it is recommended that the Causeway are completely replaced in all future options for the TZB. Overall, the extent of the required rehabilitation efforts, traffic disruption during their construction, continuing extensive maintenance requirements, uncertainty of performance and future cost and reliability risks raise substantial questions about the value of any further investment in the Causeway.

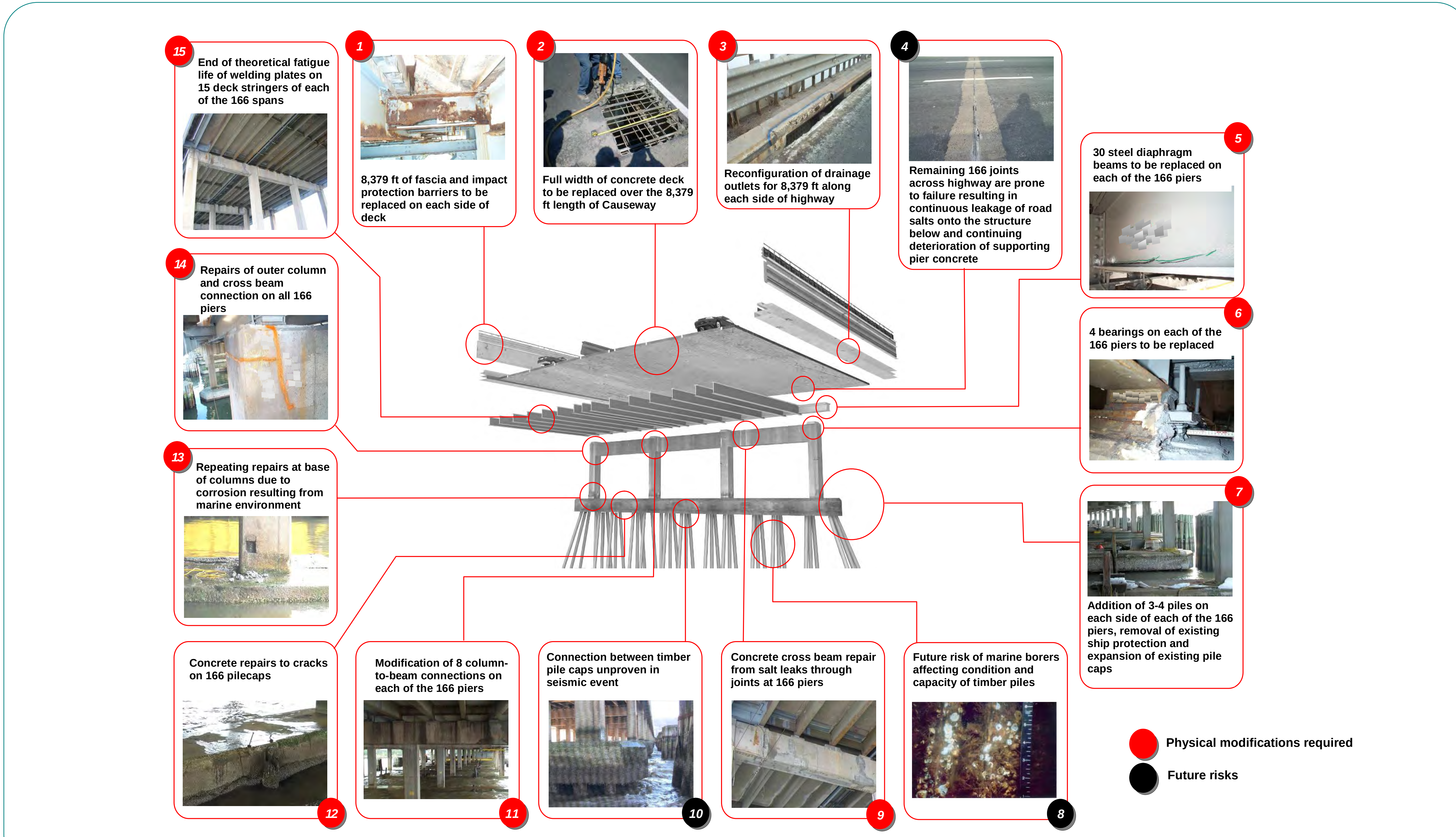

Figure 2-2
Work Required to Rehabilitate Causeway

2.6 Rehabilitation and Replacement Options

To meet the Project's Purpose and Need, changes to the existing TZB are required. These would need to be carried out in accordance with the project's operating and design criteria as well as considering the condition, vulnerabilities and limitations of the existing bridge. The changes to the TZB could be made by either rehabilitating or replacing the TZB.

As shown in Table 2-4 and Figure 2-3 (page 10), four Rehabilitation and three Replacement Options are presented for evaluation. These options are not intended as final bridge alternatives, one or more of which may be progressed into later stages in the environmental process. Rather these seven options are representative of the multitude of potential options possible for the crossing, chosen to ensure evaluation of the full range of potential impacts of either replacement or rehabilitation.

All options include structural and seismic upgrades to current standards, new Pedestrian and Bicycle Path(s) plus Causeway replacement as recommended in Chapter 2.5.2. The seven options differ only in three components – the number of highway lanes and shoulders, provisions for transit and arrangement of the bridge.

Overall, Rehabilitation Option 1 differs from all other options. This option is historic and was first included as part of Alternative 2 in the Alternatives Analysis Report. The option limits the overall changes to the existing TZB, maintaining the original seven lanes without shoulders or provision for transit. All other options include eight lanes and full shoulders plus special provision for transit. Full shoulders means 12-foot wide shoulders on both sides of each travel way.

Corresponding to the transportation options currently included in the environmental process, all options with the exception of Rehabilitation Option 1, include BRT/HOT lanes and either BRT or CRT transit modes.

The most variation among the options results from the bridge arrangement. For Rehabilitation Options 2-4, to accommodate the additional structural width needed to support the additional shoulders, BRT/HOT lanes and transit, the arrangement variations include single level widening, a single level supplemental structure and a dual level supplemental structure. These variations result in different span lengths, structure depth, bridge elevation, foundation sizes and construction methodologies that are the substance of the differences among the options. Similar variations are included in the Replacement Options.

Figure 2-2 (page 8) shows the Rehabilitation and Replacement Options. Further details of the Rehabilitation Options are presented in Chapter 3 of this report and details of the Replacement Options are presented in Chapter 4.

Options		Transportation Components			Structure Components	
		Highway	Transit	Pedestrian and Bicycle Path	Causeway Replacement	TZB Arrangement
Rehabilitation	1	7 lanes	None	✓	✓	As existing
Rehabilitation	2	8 lanes + shoulders	2 BRT/HOT lanes	✓	✓	Existing TZB widened both sides
Rehabilitation	3	8 lanes + shoulders	2 BRT/HOT lanes	✓	✓	Single level supplemental structure
Rehabilitation	4	8 lanes + shoulders	2 BRT/HOT lanes 2 CRT tracks	✓	✓	Dual level supplemental structure
Replacement	1	8 lanes + shoulders	2 BRT/HOT lanes	✓	✓	Single level structure
Replacement	2	8 lanes + shoulders	2 BRT/HOT lanes 2 CRT tracks	✓	✓	Single level structure
Replacement	3	8 lanes + shoulders	2 BRT/HOT lanes 2 CRT tracks	✓	✓	Dual level structure

Table 2-4

Components of TZB Rehabilitation and Replacement Options

Rehabilitation Option 1
Same as existing but with replaced causeway

7 General purpose lanes
1 reversible lane as existing
1 Ped & Cycle path

Rehabilitation Option 2
Existing structure strengthened & widened both sides to fit Alternative 3 components and causeway replaced
8 General purpose lanes
2 BRT/HOT lanes
2 Ped & Cycle paths

Rehabilitation Option 3
Parallel structure added to fit Alternative 3 components and causeway replaced
8 General purpose lanes
2 BRT/HOT lanes
2 Ped & Cycle paths

Rehabilitation Option 4
Parallel structure added to fit Alternative 4(a,b,c,d) components and causeway replaced)
8 General purpose lanes
2 BRT/HOT lanes
2 CRT tracks
2 Ped & Cycle paths

Replacement Option 1
Two new parallel structures added to fit Alternative 3 components on a single level

8 General purpose lanes
2 BRT/HOT lanes
2 Ped & Cycle paths

Replacement Option 2
Three new parallel structures added to fit Alternative 4(a,b,c,d) components on a single level

8 General purpose lanes
2 BRT/HOT lanes
2 CRT tracks
2 Ped & Cycle paths

Replacement Option 3
Two new dual-level parallel structures added to fit Alternative 4(a,b,c,d) components on two levels

8 General purpose lanes
2 BRT/HOT lanes
2 CRT tracks
2 Ped & Cycle paths

Figure 2-3
Rehabilitation &Replacement Options for the Tappan Zee Bridge