

**INITIAL ASSESSMENT OF THE
CENTRAL ARTERY/TUNNEL PROJECT
STEM TO STERN SAFETY REVIEW**

Federal Highway Administration

Report Number: MH-2007-063

Date Issued: August 16, 2007




Memorandum

U.S. Department of
Transportation

Office of the Secretary
of Transportation
Office of Inspector General

Subject: **ACTION:** Initial Assessment of
the Central Artery/Tunnel Project
Stem to Stern Safety Review
Report Number: MH-2007-063

Date: August 16, 2007

From: Rebecca Anne Batts 
Acting Assistant Inspector General
for Surface and Maritime Programs

Reply to
Attn. of: JA-40

To: James Ray
Acting Deputy Administrator
and Chief Counsel

This report presents the results of our initial assessment of the Commonwealth of Massachusetts's ongoing Stem to Stern Safety Review. The Commonwealth initiated the safety review last year as an independent and comprehensive look at the overall soundness of the Boston Metropolitan Highway System, including the Central Artery/Tunnel Project. This project-wide review was prompted by the July 10, 2006, collapse of ceiling panels in a Central Artery Project tunnel, which killed a motorist. The safety review is divided into several phases, with Phase I being a purposely limited and expeditious review to identify immediate risks to public safety. In November 2006, the Commonwealth published the findings of Phase I in a report released to the public and made recommendations for further analysis and remediation.¹

The Office of Inspector General (OIG) is overseeing the Stem to Stern Safety Review—and other Central Artery Project safety reviews and remediation work—as directed by the National Transportation Safety Board Reauthorization Act of 2006.² In addition to the Stem to Stern Safety Review, we provided independent oversight to the reopenings of sections of the Central Artery Project that were closed to traffic following the July 2006 collapse. This involved overseeing an 8-stage series of safety reviews and remediation work to correct deficiencies. All sections of the Central Artery Project have since been reopened. Our broad

¹ Issued November 15, 2006, <http://www.eot.state.ma.us/stemtostern/>.

² Public Law No. 109-443, § 11 (2006).

objective is to provide assurance to the Congress, the Secretary of Transportation, and the traveling public that Central Artery Project safety reviews and remediation work are comprehensive and being performed in a rigorous and complete manner.

For this report, we evaluated whether the findings and recommendations in the Stem to Stern Safety Review's Phase I report adequately analyzed immediate risks and whether necessary remedial measures were identified. We monitored the Commonwealth's activities after issuing the Phase I report, including activities initiated to address our observations on the classification of certain safety risks and on the Commonwealth's follow-up activities (referred to as Phase IA). Further, we also assessed the methodology and work plans for the remaining phases of the safety review to determine whether they are clear and comprehensive.

We contracted with the U.S. Army Corps of Engineers (Corps) in August 2006 to obtain its assistance and expertise in large infrastructure projects. Corps engineers worked directly with the Commonwealth's engineers performing the safety review, monitored safety review activities, and provided updated information to our engineers on a regular basis. We conducted this performance audit in accordance with Generally Accepted Government Auditing Standards as prescribed by the Comptroller General of the United States. Exhibit A presents our scope and methodology.

BACKGROUND

Construction of the Central Artery Project began in late 1991 and was originally scheduled to be substantially completed by December 1998. Work on the project continues to this day. In response to rising project costs, which had increased to \$14.625 billion by 2006, Congress in October 2000 limited Federal contributions to \$8.549 billion.³ Congress also directed the Secretary of Transportation to withhold obligations of Federal funds and all project approvals until OIG determines that the annual finance plan update is consistent with Federal Highway Administration (FHWA) guidance.⁴ Exhibit B is a map of the Central Artery Project.

Following the collapse of tunnel ceiling panels in July 2006, the overall safety of the entire Central Artery Project was called into question. In response, the Stem to Stern Safety Review was initiated by the former Governor of Massachusetts to provide an independent assessment of both near- and long-term safety. The review was authorized by the Massachusetts legislature, which appropriated \$20 million specifically for a comprehensive audit of the safety of the

³ Department of Transportation Appropriations Act of 2001, Public Law No. 106-346, § 340(b) (2000).

⁴ On June 27, 2007, we initiated an audit of the Massachusetts Turnpike Authority's 2007 Finance Plan Update for the Central Artery/Tunnel Project.

Metropolitan Highway System. The Governor issued an executive order to initiate the safety review in the summer of 2006. The previous Governor's term ended in January 2007 and a transition to a new administration ensued. The current Governor decided to continue the safety review.

In August 2006, the then-Governor of Massachusetts appointed his Secretary of Environmental Affairs as safety review director to provide overall leadership to the Stem to Stern Safety Review. Wiss, Janney, Elstner Associates, Inc. (WJE), a forensic engineering firm with significant experience in high-profile accident investigations, was retained to actually conduct the review. The scope of the review was divided into 10 separate areas, 9 of which covered major components of the Central Artery Project. The tenth area covered the ceiling systems of the Central Artery North Area (CANA) Tunnel, the Sumner Tunnel, and the Callahan Tunnel, which are distinct from the Central Artery Project. During Phase I, the Commonwealth evaluated all major components of the Central Artery Project and other components of the Metropolitan Highway System to identify immediate risks to public safety. A more comprehensive review of all safety risks is expected to be completed in Phase II. Of the \$20 million appropriated by the Massachusetts legislature to conduct the safety review, \$5.7 million has been budgeted for safety review activities leading up to Phase II.

In addition to the Commonwealth's safety review team, a five-member independent Advisory Panel was created by the then-Governor to help ensure the comprehensiveness, objectivity, and effectiveness of the review. The panel includes the chief engineer of the Port Authority of New York and New Jersey and the executive director of the Transportation Research Board of the National Academies of Sciences and Engineering. The chair formerly served in the U.S. Department of Transportation as an Assistant Secretary.

RESULTS IN BRIEF

The Phase I report of the Stem to Stern Safety Review identified numerous high priority safety risks across the major components of the Central Artery Project. Overall, we found that the Phase I process was conducted in a professional manner and was generally comprehensive for the short time period in which it was conducted. However, due to the limited 90-day duration of Phase I, certain key safety studies were purposely deferred to the later Phase II, which is intended to be a longer-term effort. For example, we noted, as did the Commonwealth's Advisory Panel, that the 90-day duration of Phase I limited the depth of the review of the Central Artery Project's complex life-safety systems, such as fire detection, ventilation, communications, and traffic monitoring. The Phase I review did not include detailed field inspections on foundations and underwater structures, such as bridge piers. The work of the Stem to Stern Safety Review will not be

complete until more thorough studies of these systems and structures are conducted during the safety review's other phases.

During the Phase I review, WJE identified and recorded safety risks as *reportable conditions*. According to the Phase I report, examples of reportable conditions include members exhibiting distress or deterioration, apparent safety-related construction deficiencies, and other safety-related conditions that required detailed investigation. Reportable conditions were included in the Phase I report and rated on a scale prioritizing when the Commonwealth should conduct follow-up activities. The most serious conditions were classified as "immediate or dangerous conditions" that warrant immediate follow-up activities to fully assess the safety risks and conduct remediation as necessary.⁵

Specifically, based on our assessment of the Phase I report and plans for future safety review activities, we concluded the following.

- **Phase I of the Stem to Stern Safety Review generally analyzed the correct project components, but certain items should have been classified as higher priority safety risks in the Phase I report, or necessary follow-up activities were not sufficiently clear. Thus, timely and thorough follow-up activities are necessary to complete the full assessment of immediate safety risks and conduct remedial work.** For example, we noted that the risk assessment of warped anchor plates on the Central Artery Project's Zakim Bridge, which connect the bridge's cables to its steel girders, was incomplete in the Commonwealth's Phase I report. The safety review team gave this reportable condition a priority rating that classified it as needing further analysis during Phase II. In contrast, based on the analysis conducted by the Corps, we concluded that the warped anchor plates posed a higher safety risk. The OIG recommended that the safety review team address this safety risk immediately without waiting for Phase II; this correlated to a rating of an "immediate or dangerous condition" using the Commonwealth's scale. The Zakim Bridge's most recent bridge inspection performed in 2005 did not report the warped anchor plates, which underscored the need to fully assess this safety risk in a timely manner. In addition to the Zakim Bridge deformations, we concluded that expeditious follow-up analysis is required in several other key areas, such as the possible effects of large fires in the tunnels.

In response to our observations about some of the findings and recommendations in the Phase I report, the Commonwealth agreed in December 2006 to create "Phase IA"—a new short-term phase of the safety review to occur between Phases I and II. Phase IA is intended to expeditiously

⁵ See Exhibit C for an explanation of the system used by the safety review team to classify and prioritize safety risks.

conduct follow-up work to fully assess the conditions that we highlighted in our review of the Commonwealth's Phase I report. On August 14, 2007, the Commonwealth released reports addressing many of the issues included in Phase IA. We have initiated our review of these reports. Among the key areas that the Commonwealth agreed to expeditiously address in Phase IA are:

- *performing additional analysis on the adhesive anchors supporting the ceiling in the Ted Williams Tunnel.* In the Phase I report, the safety review team expressed concern about the long-term reliability of the adhesive anchors used to secure the ceiling panels to the tunnel roof in the Ted Williams Tunnel. The July 2006 collapse of ceiling panels in the Central Artery Project is attributed to the failure of the adhesive anchors in a section of the Interstate 90 connector tunnels. The adhesive anchors in the Ted Williams Tunnel are distinct from the anchors that failed because they are produced by a different manufacturer, have different design specifications, were installed by a different contractor, and are supporting a ceiling system that is much lighter than the ceiling systems used in the other tunnels. Nevertheless, there have been occurrences in the Ted Williams Tunnel of adhesive anchor bolts being embedded into concrete at a less than optimal depth and of anchor bolts partially slipping out of the concrete. We concluded that additional analysis of the adhesive anchors in the Ted Williams Tunnel should not be put off to Phase II. The Commonwealth agreed to raise the priority of follow-up analysis and initiate efforts in Phase IA.
- *performing additional fire modeling in the tunnels.* In Phase I, the safety review conducted fire modeling on the effects of a single bus or truck fire in the Central Artery Project's tunnels, which meets the current design standard for tunnels established in 2004. However, our fire experts recommended modeling for a two-truck fire as an extra precaution, which could create as much as three times the amount of heat that a single bus or truck fire produces. Specifically, we expressed concern that a high-temperature fire could seriously damage adhesive anchors supporting ceiling panels in the Ted Williams Tunnel. The safety review team agreed to reevaluate its fire modeling and discuss modeling the effects of a more intense fire in Phase IA.
- **The leadership, scope, and methodology for Phase II of the Stem to Stern Safety Review need to be specified and aggressive action must be taken going forward.** The Stem to Stern Safety Review is not complete and the Commonwealth must still produce a detailed scope and methodology for Phase II activities. On June 25, 2007, the Commonwealth's Secretary of Transportation announced the appointment of a new Deputy Secretary for Public Works who would also fill the Stem to Stern director position, which

had been vacant since January 2007. However, unlike the previous director, the new Deputy Secretary will not be exclusively dedicated to driving the Stem to Stern Safety Review's completion, nor will he report directly to the Governor. The Commonwealth should reconsider where to place the leadership of the safety review. A dedicated director position will help ensure that attention and resources are not diverted from this critical safety review and the remediation of identified safety risks. Completion of the Stem to Stern Safety Review in a timely, thorough, and independent manner is necessary because many key safety-related analyses were deferred.

When the Stem to Stern Safety Review was initiated last year, officials of FHWA informed us that their role would be advisory during the initial phase because the Commonwealth initiated the effort with no Federal funding. At that time, they also informed us that they intended to exercise greater oversight over the remediation of identified safety risks. Now that safety risks have been identified and remediation has begun, FHWA will need to exercise greater oversight to ensure that the Commonwealth completes the remaining phases of the safety review and remedial work in a timely, thorough, and independent manner.

FHWA has already recognized the need to provide more oversight. For example, in March 2007, FHWA formally issued a letter to the Commonwealth expressing concern about the lack of substantive progress on the Stem to Stern Safety Review since the former Governor's term ended in January 2007. This was a positive first step from FHWA, although it needs to increase its oversight going forward because safety risks have been identified and considering the massive Federal investment in the project to date. Moreover, FHWA should ensure that the Commonwealth expeditiously determines the responsible parties and pursues cost recovery from consultants or contractors for those conditions identified during the safety review that appear to be caused by design errors or inadequate construction practices.⁶

Accordingly, we are recommending that FHWA (1) designate a lead official to monitor the Commonwealth's progress on the Stem to Stern Safety Review and (2) report regularly to the Department of Transportation Oversight Committee on the Central Artery Project regarding progress being made by the Commonwealth to complete the safety review.⁷ FHWA should provide a copy

⁶ The Massachusetts Attorney General's office has the lead on pursuing cost recovery efforts for the Central Artery Project.

⁷ Acting Secretary of Transportation Maria Cino established the Department of Transportation Oversight Committee on the Central Artery Project to provide independent assurance that FHWA's response to the July 10, 2006, ceiling collapse is sufficiently robust and comprehensive in assessing the cause of the failure and in overseeing the remedial steps taken by the Commonwealth to address safety concerns, such as the Stem to Stern Safety Review. The Committee is comprised of high-level DOT officials from outside FHWA.

of each report to OIG. A list of our complete recommendations is provided beginning on page 16.

FINDINGS

Timely and Thorough Follow-Up of Stem to Stern Phase I Activities Is Necessary To Complete the Full Assessment of Immediate Safety Risks and Conduct Remedial Work

The Commonwealth's Stem to Stern Safety Review Phase I report, issued in November 2006, generally analyzed the correct items across the major components of the Central Artery Project, such as the tunnels and the Zakim Bridge. Our oversight team examined the Phase I report and made recommendations in cases where items were not given high enough priority as safety risks, or in instances when follow-up activities were not sufficiently clear. In response to our observations, the Commonwealth agreed in December 2006 to create "Phase IA"—a new phase of the safety review to occur between Phases I and II—to expeditiously conduct rigorous follow-up analyses to fully assess the conditions that we highlighted in our review of the Phase I report. Progress on completing Phase IA's assessment of immediate risks and remediating these problems has been slower than expected. On August 14, 2007, the Commonwealth released reports addressing many of the issues included in Phase IA. We have initiated our review of these reports.

Certain Conditions Were Not Classified as High Enough Safety Risks in the Commonwealth's Phase I Report, or Necessary Follow-Up Activities Were Not Sufficiently Clear

The Commonwealth's Phase I report identified 34 items in "immediate or dangerous condition" that require immediate assessment and remediation. Examples range from light pole and signage structures at risk of falling to water leaks in main electrical rooms. The report also designated numerous other safety risks that require further investigation during the Stem to Stern Safety Review's future Phase II. Overall, we found that the Phase I process was conducted in a professional manner and was generally comprehensive for the short time period in which it was conducted. Based on our oversight of Phase I activities as they were occurring and review of the Phase I report, we recommended that the Commonwealth's safety review team raise the priority of certain safety risks and quickly clarify follow-up activities in a number of key areas, including: (1) conducting a follow-up investigation of the Zakim Bridge's warped steel anchor plates, (2) investigating missing records that document the strength and quality of the Zakim Bridge's structural steel, (3) performing additional analysis of the adhesive anchors supporting ceiling panels in the Ted Williams Tunnel,

(4) conducting a more rigorous analysis of the impact of potential earthquake conditions on the tunnels' suspended ceiling systems, and (5) performing additional fire modeling to fully assess the effects of high-temperature fires in the tunnels.

The Commonwealth agreed with our recommendations to expeditiously conduct additional analyses in these areas as part of a new short-term Phase IA, which was created in December 2006. The intention was to immediately begin Phase IA; however, progress was slower than expected between January and May 2007. In May 2007, the Commonwealth agreed to kick-start Phase IA activities and complete them as soon as possible. Timely and thorough completion of Phase IA is necessary to fully understand the extent of the general safety risks already identified in Phase I and set the stage for the longer-term Phase II.

Conduct a follow-up investigation of the Zakim Bridge's warped steel anchor plates. The safety review team found a total of six warped steel anchor plates on the Central Artery Project's Zakim Bridge—a condition not disclosed during its most recent bridge inspection performed in 2005. Such warping should have been identified in the project's quality assurance process if it had occurred during construction, but we found no evidence that it was identified. Anchor plates, which connect the bridge's cables to its steel girders, should not exhibit visible warping under normal stress conditions.⁸ Warping of this kind may suggest that the anchor plates are overstressed and warrant special attention to assess any possible safety risks they may present. According to the Corps, in a worse-case scenario, overstressed anchor plates could lead to progressive bridge failure.⁹

The safety review team gave this reportable condition a priority rating that classified it as needing further analysis during Phase II. In contrast, based on the analysis conducted by the Corps, we concluded that the warped anchor plates posed a higher safety risk that needed immediate follow-up. The OIG recommended that the safety review team address this safety risk immediately without waiting for Phase II; this correlates to a higher rating of an “immediate or dangerous condition” using the Commonwealth's scale. The safety review team concurred with us and included an expeditious follow-up analysis in Phase IA instead of deferring it to a future Phase II.

Investigate missing records that document whether the strength and quality of the Zakim Bridge's structural steel meet project specifications. During Phase I, the safety review team was unable to locate records of mill certifications for the

⁸ See Exhibit D for pictures of the Zakim Bridge's steel anchor plates.

⁹ According to the Corps, a progressive failure can occur when a critical tension member (like an anchor plate) fails and all of its tension is abruptly transferred to adjacent members causing their overstress and failure in a progressive “unzipping” mode.

Zakim Bridge's structural steel despite significant efforts to find them. Reviewing the certifications is necessary to document that the Zakim Bridge was not constructed using structural steel of lesser strength or quality than required by the original design plans, which in a worse-case scenario could ultimately lead to bridge collapse. The missing certifications will also assist with the analysis of the bridge's previously mentioned six warped steel anchor plates, which could be deformed because they were made using lower quality steel. On July 13, 2007, the Commonwealth informed us that the mill certifications had been found, although at the time of this report we had not received them.

The Phase I report recommended deferring the search for mill certifications to Phase II. However, considering past instances of poor quality construction, such as defects in concrete wall panels that led to water leaks and the use of inferior concrete mix found as part of an OIG investigation,¹⁰ we recommended that this activity receive higher priority. Leaks in the tunnel wall panels became a public concern in September 2004 when one panel was breached, spilling 300 gallons of water a minute onto the I-93 tunnel roadway. In this case, the examination of construction records was crucial to discovering numerous errors and irregularities in the oversight of the contractors that built the I-93 tunnel walls and in the walls' construction. Separately, six current and former employees holding managerial positions in Aggregate Industries' concrete division were charged in May 2006 with highway project fraud and related offenses for their participation in a scheme to provide concrete to the Central Artery Project that did not meet contract specifications.

The safety review team agreed with our recommendation and decided to further investigate the mill certifications in Phase IA. Thoroughly analyzing these mill certifications is critical to determining the structural integrity of the Zakim Bridge. Meanwhile, to fully address these concerns, the safety review team agreed to conduct tests of the bridge's steel if the mill certifications are not found.

Perform additional analysis of the safety of adhesive anchors supporting ceiling panels in the Ted Williams Tunnel. The July 2006 collapse of ceiling panels in the Central Artery Project tunnel was attributed to the failure of the adhesive anchors in a section of the Interstate 90 connector tunnels. Consequently, all adhesive anchors used to support ceiling panels in the I-90 tunnels have since been removed, excluding those in the Ted Williams Tunnel. The adhesive anchors in the Ted Williams Tunnel are distinct from the anchors that failed because they are

¹⁰ On July 27, 2007, Aggregate Industries agreed to plead guilty and pay \$50 million to resolve its criminal and civil liabilities in connection with a fraudulent scheme to deliver adulterated concrete to the Central Artery Project. The plea was a result of a multiparty investigation that included OIG, the Massachusetts Attorney General's Office, the Federal Bureau of Investigation, the Massachusetts State Police, and the U.S. Attorney's Office, District of Massachusetts.

produced by a different manufacturer, have different design specifications, were installed by a different contractor, and are supporting a ceiling system that is much lighter than the ceiling systems used in the other tunnels. Nevertheless, the safety review team was still concerned about the long-term reliability of the adhesive anchors used in the Ted Williams Tunnel, which secure ceiling panels into the concrete of the tunnel roof. The safety review team came to this conclusion through its analysis of limited data on the long-term performance of adhesive anchors, which includes occurrences of adhesive anchor bolts being embedded into concrete at a less than optimal depth and of anchor bolts partially slipping out of the concrete.

The Phase I report noted that more detailed analysis is needed in Phase II to evaluate possible long-term safety risks posed by these adhesive anchors. However, we concluded that these efforts should not be put off to the longer-term Phase II. The safety review team agreed with our recommendation to raise the priority of these activities and initiate them in Phase IA. These efforts will continue into Phase II when the safety review team will study the long-term safety of continuing to use adhesive anchors in the Ted Williams Tunnel, determine the probability of a ceiling failure, and identify appropriate design requirements for mitigating the likelihood of any ceiling failure.

Conduct a more rigorous analysis of the impact of potential earthquake conditions on the tunnels' ceiling systems. Design codes require that a seismic analysis be performed of structures like a highway tunnel. A seismic analysis involves evaluating the integrity of the structure under potential earthquake conditions. Considering the July 2006 collapse of ceiling panels in one of the Central Artery Project tunnels, we believe the safety review team should ensure the evaluation of the design is complete and includes the appropriate seismic analyses. Specifically, we recommended that the safety review team reexamine how it treated ceiling systems in its seismic analyses and consider using more stringent seismic design requirements for the ceiling systems. For example, the current formulation of the seismic analyses does not treat the tunnels' ceiling systems as integrated components of the structure, as the roof, floor slabs, and walls are treated. Such components are subject to more stringent seismic design requirements. Since Boston is located in a designated earthquake zone, it is essential to provide clarification on the ability of the tunnels' ceiling systems to withstand an earthquake. In response to our concerns, the Commonwealth's safety review team agreed to reevaluate the current formulation of the seismic analyses.

Perform additional fire modeling to fully assess the effects of high-temperature fires on the Central Artery Project's tunnels. The safety review team conducted fire modeling on the effects of a single bus or truck fire in the Central Artery Project's tunnels. This modeling meets the current design standard for tunnels

established in 2004. In addition, according to the Commonwealth, the tunnels were built to design standards that were applicable at the time of construction. However, our fire experts, who include a prominent scientist from the National Institute of Standards and Technology, recommended, based on the current body of knowledge and the possibility of such an event, that the safety review team perform additional fire modeling for a two-truck accident. Such an event is plausible and could create as much as three times the amount of heat that a single bus or truck fire produces.¹¹

Additionally, our experts expressed concern over the impact of high temperatures in the plenum area. The plenum is the space between the roof of the tunnel and the suspended ceiling panels, which is used for ventilation purposes. We believe that high temperatures could have a serious impact on adhesive anchors, which secure ceiling panels to the tunnel roof in the plenum area of the Ted Williams Tunnel. A high-temperature fire could cause the anchors to fail. In the Phase I report, the safety review team recognized the need for further review by noting that “more detailed analysis and testing will be needed in Phase II to establish the performance of the ceiling system epoxy anchors during a large fire.” In response to our observations, the safety review team agreed to reevaluate its fire modeling and discuss modeling a more intense fire to examine the fire’s effects on the ceiling plenum and the adhesive anchors.

The Leadership, Scope, and Methodology for Phase II of the Stem to Stern Safety Review Need to be Specified and Aggressive Action Must Be Taken Going Forward

The leadership, scope, and methodology for Phase II of the Stem to Stern Safety Review need to be specified as soon as possible. The former safety review director resigned in January 2007 and the Commonwealth did not designate a replacement until June 2007. Additionally, the Commonwealth has yet to announce its specific plans for the direction of certain Phase II activities, including the role of the Advisory Panel, and what the *detailed* scope and methodology for Phase II will be. Phase I was purposely limited and intended to set the stage for a more rigorous and comprehensive Phase II. Sustained progress is necessary because many key safety-related analyses have not been completed. Completion of the *entire* safety review in a timely, thorough, and independent manner is critical to ensure that key safety-related analyses are accomplished.

¹¹ Tunnel fires with heat release rates higher than the rate of a single truck fire have occurred throughout the world. The results of the 2003 Runehamar fire tests published by the *Fire Safety Journal* in January 2006 indicate that the heat and temperature released in tunnel fires were considerably higher than the values reflected in the current design standard for truck fires used for the Central Artery Project. Further, a FHWA sponsored study issued in June 2006 on European underground transportation systems also highlights the occurrence of tunnel fires with heat release rates much higher than what is reflected in the current design standard.

Going forward, FHWA will need to exercise greater oversight to ensure that the Commonwealth completes the safety review in this manner, considering the massive Federal investment in the project to date and the identified, significant risks. Moreover, the discovery of items in “immediate or dangerous condition,” as identified in the Phase I report, calls into question the quality of the Central Artery Project’s design and construction. FHWA should ensure that the Commonwealth expeditiously determines the responsible parties and pursues cost recovery from consultants or contractors for those conditions identified during the safety review that appear to be caused by design errors or inadequate construction practices.

The Stem to Stern Safety Review Has Lacked a Designated Leader in Recent Months

In a January 2007 transition report to the incoming Governor, the former safety review director identified the naming of a new director and the appointment of members to the Advisory Panel as immediate priorities, but these key decisions were not finalized for nearly 6 months. In announcing the newly appointed director on June 25, 2007, the Commonwealth’s Secretary of Transportation stated that the position would be organizationally located in the Executive Office of Transportation, hold the title of “Deputy Secretary of Public Works,” and have an array of other duties in addition to the Stem to Stern Safety Review, such as coordinating the inspection and construction of major highway and rail projects as well as pursuing cost saving opportunities at the Massachusetts Highway Department and the Massachusetts Turnpike Authority.

The previous safety review director was exclusively dedicated to driving the safety review’s completion and reported directly to the Governor. Having the safety review director wear many hats creates the risk of diverting the director’s attention away from this critical safety review and possibly delays the review and the remediation of identified safety risks. The Commonwealth should reconsider where to place the leadership of the safety review. A dedicated director position will help ensure that attention and resources are not diverted from this critical safety review and the remediation of identified safety risks. Further, the role of the Advisory Panel, members of which serve at the pleasure of the Governor, remains unclear because the panel’s chair stepped down at the conclusion of Phase I. The Stem to Stern Advisory Panel can supply independent expertise and help provide assurance to the public that the review is being conducted in a rigorous manner.

The Commonwealth Needs to Produce a Detailed Scope and Methodology for Phase II

Phase II of the Stem to Stern Safety Review requires a clear and detailed scope and methodology to complete the full assessment of safety risks identified in

Phase I. The safety review's preliminary implementation plan for Phase II identifies and prioritizes follow-up activities to address Phase I recommendations, but lacks key components, including a realistic schedule with a critical path for sequencing activities, and reasonable cost estimates. On July 13, 2007, the Commonwealth informed us that it had finalized a scope of work with WJE for the Phase II work. Our review showed that the finalized scope of work does not include a detailed plan with specific activities that will be conducted during Phase II and time frames for their completion. This information will be needed. The methodology used in Phase II should also include activities to independently verify the remediation of safety risks. Additionally, the Phase II plan will need to be updated to reflect any new findings that are identified in the coming months during Phase IA. Finally, the Commonwealth's safety review team should also continue to routinely communicate to FHWA and OIG the latest developments on Phase II planning and the status of Phase IA activities.

In particular, we believe that our recommendations regarding fire protection and life safety should be carefully considered in designing a comprehensive scope for Phase II activities. These analyses were not conducted during Phase I of the safety review. Because detailed Phase II plans are not yet complete, it is unclear whether these recommendations will be included. Accordingly, we recommended that the safety review team conduct follow-up activities during Phase II to:

- Perform an analysis of the ventilation system's capability to maintain safe air quality in the tunnel during rush hour or traffic backups. The performance of the ventilation system during such non-fire situations, including its response to higher levels of carbon monoxide, was not evaluated.
- Assess the fire resistance of various utility cables that run along the tunnel ceiling and evaluate the impact of cable failure. These cables need to perform during emergencies, such as fires, to allow centralized electronic systems to be fully operational and function as designed during fire emergencies.
- Initiate an investigation to determine an acceptable time period for the back-up Operational Control Center (OCC) to take over if the primary OCC were to fail and put plans into place to help ensure the preparedness of the back-up OCC. We believe an acceptable time period for the back-up OCC to take over should be established and that the back-up OCC should be tested periodically to make sure it is in working order.

Furthermore, for the Stem to Stern Safety Review to be more comprehensive, it should take into consideration all previously identified problems and those that may be identified in other ongoing investigations. For example, the Commonwealth should incorporate the results of the National Transportation Safety Board's (NTSB) forensic investigation into its comprehensive plan for

Phase II.¹² Further, the Commonwealth should take into account the results of FHWA's independent review. The Commonwealth should not wait for the final NTSB report or the results of FHWA's review, but update its Phase II plan as necessary.

Enhanced FHWA Oversight Is Needed Going Forward

When the safety review was initiated last year, FHWA officials informed us that their role would be advisory in nature because the Commonwealth initiated the effort with no Federal funding. They also stated that they intended to exercise greater oversight over the remediation of identified safety risks. Now that safety risks have been identified and remediation has begun, FHWA will need to exercise greater oversight to ensure that the Commonwealth completes the remaining phases of the safety review and remedial work in a timely, thorough, and independent manner.

As the Operating Administration in charge of overseeing the Federal Government's investment in the Central Artery Project, FHWA recently recognized the need to become more involved in the Stem to Stern Safety Review. For example, in March 2007, the Acting Deputy Federal Highway Administrator issued a letter to the Massachusetts Secretary of Transportation noting FHWA's concern about the lack of substantive progress on the Stem to Stern Safety Review since the former Governor's term ended in January 2007. This was a positive first step. Going forward, FHWA will need to increase its oversight considering the massive Federal investment in the project to date and the significant risks that have already been identified.

Moreover, the discovery of 34 items in "immediate or dangerous condition," as identified in the Phase I report, calls into question the quality of the Central Artery Project's design and construction. Timely and thorough execution of the remaining phases of the Stem to Stern Safety Review will help determine whether these problems emerged from errors, omissions, or other deficient or unsatisfactory performance in designing or constructing the project and what remediation actions will be necessary. The Commonwealth should pursue cost recovery for conditions resulting from design or construction deficiencies. For example, we identified the following key areas that warrant investigation into whether problems resulted from design or construction deficiencies.

- The Zakim Bridge, at a cost of over \$110 million, is a "signature" structure that represents the state of the art in bridge design and construction. However, after only about 4 years in service, the safety review team found that there were

¹² NTSB investigated the circumstances of the July 2006 collapse of ceiling panels in the Central Artery Project. Its investigation has focused on those issues surrounding the failure of the adhesive anchors. On July 10, 2007, NTSB released an executive summary of the results of its investigation, with a final report expected in the coming weeks.

deformations in the steel anchor plates for cables, discrepancies between as-built conditions and the designs, and the lack of material certifications for the bridge's structural steel. These problems warrant immediate attention. Accordingly, the Stem to Stern Safety Review will address them in Phase IA, which will help determine the root causes of the problems and the extent to which cost recovery is possible.

- The Central Artery Project OCC houses the centralized electronic systems that monitor traffic flow, tunnel ventilation, and fire detection and control communications. The Commonwealth has reported that the center contains “the most advanced electronic traffic monitoring and incident response system in the world.”¹³ However, all the systems were not delivered as originally planned upon substantial completion of the project, which was declared in January 2006. Rather, final activation and testing of the fully integrated systems has been delayed until 2008.

The Phase I results revealed that the installed OCC and centralized systems' noncompliance with design specifications is attributable to delays as well as to deficiencies. During Phase I, the safety review team found “the fire detection system is not in full compliance with the modified basis of design” and identified inconsistencies regarding the fire detection time. Separately, we found the systems related to traffic incident detection, highway advisory radio, and variable message signs to be incomplete or not in service. The safety review team made recommendations in its Phase I report, supplemented by recommendations from our review, to identify the causes of these deficiencies and restore full compliance with project design specifications. Because of the substantial Federal investment made in the OCC and centralized systems, we believe that the Phase I recommendations should be implemented immediately to identify the root causes for these deficiencies.

Evidence of design or construction deficiencies identified in the course of the safety review could lay the foundation for cost recovery by the Commonwealth. FHWA should ensure that the Commonwealth pursues cost recovery expeditiously because determining who is responsible to pay for remedial work is complex and requires additional analysis. Problems could be caused by poor construction, design errors, poor oversight, or a combination of those factors. The resulting “finger-pointing” that usually follows such investigations increases the complexity of determining the responsible parties.

FHWA's efforts to ensure an expeditious cost recovery effort are necessary because, historically, the Commonwealth's cost recovery efforts have been time-consuming. We have previously reported that as of March 2003, 8 years of

¹³ “Cost/Schedule Status of the Central Artery/Tunnel Project,” Massachusetts Turnpike Authority, April 1, 2005.

cost recovery efforts led to only \$30,000 in recoveries from a single consultant, even though 76 cost recovery items, involving \$53.7 million in change orders, had been resolved. Over the next 2 years, a new cost recovery team directed by a retired Probate Court judge was more successful, but recovered only \$3.5 million. Since February 2005, when the Massachusetts Turnpike Authority transferred cost recovery efforts to the Massachusetts Attorney General's Office, the Commonwealth has not reached any significant settlements.

Accordingly, we are recommending that FHWA (1) designate a lead official to monitor the Commonwealth's progress on the Stem to Stern Safety Review and (2) report regularly to the Department of Transportation Oversight Committee on the Central Artery Project regarding progress being made by the Commonwealth to complete the safety review. FHWA should provide a copy of each report to OIG.

RECOMMENDATIONS

To ensure prompt action on the Central Artery safety reviews and protect the large Federal investment in the project, we recommend that FHWA:

1. Designate a lead official to ensure that the Commonwealth:
 - a. Completes the analyses of all safety risks—especially those posing immediate safety risks—in a timely, independent, and thorough manner, since many key safety studies were limited or deferred, and carries out prompt remediation for any deficiencies identified.
 - b. Produces a clear and comprehensive methodology for Phase II, including a realistic schedule with a critical path for sequencing activities and reasonable cost estimates. The methodology should reflect the analyses and remedial work to be performed on outstanding findings and recommendations of the Commonwealth's Phase I report. The methodology should also include plans to independently verify that remedial work is completed.
 - c. Expeditiously pursues cost recovery to the extent possible for those conditions that result from design errors or inadequate construction practices.
 - d. Continues to routinely communicate latest developments to key stakeholders, including FHWA and OIG.
2. Report regularly to the Department of Transportation Oversight Committee on the Central Artery Project regarding progress being made by the

Commonwealth to complete the safety reviews and on any concerns the FHWA may have. FHWA should provide a copy of each report to OIG.

AGENCY COMMENTS AND OFFICE OF INSPECTOR GENERAL RESPONSE

We provided FHWA with a draft of this report on July 18, 2007. On August 3, 2007, FHWA provided us with formal comments on our draft report (see Appendix). FHWA stated that on the whole “the findings in the report are valid.”

Recommendation 1. FHWA concurred with the recommendation. FHWA designated the Acting Deputy Administrator and Chief Counsel as the lead official to ensure that the Commonwealth progresses in the noted areas.

OIG Response. FHWA’s planned actions meet the intent of our recommendation.

Recommendation 2. FHWA concurred with the recommendation to report to the Department of Transportation Oversight Committee on the Central Artery Project on progress being made by the Commonwealth to complete the safety reviews. FHWA agreed to provide a copy of each report to the OIG.

OIG Response. FHWA’s planned actions meet the intent of our recommendation. Based on FHWA’s comments, we revised the second recommendation to clarify that FHWA will provide to OIG a copy of each report submitted to the Department of Transportation Oversight Committee on the Central Artery Project.

ACTION REQUIRED

FHWA’s actions taken and planned satisfy the intent of our recommendations, subject to follow-up provisions in DOT Order 8000.1C. We appreciate the cooperation and assistance provided by you and your staff during our review. If you have any questions concerning this report, please call me at (202) 366-5630.

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cc: Secretary of Transportation
Deputy Secretary of Transportation
Members of the Department of Transportation Oversight Committee on the
Central Artery Project

EXHIBIT A. SCOPE AND METHODOLOGY

To accomplish our broad objective of ensuring that Phase I of the Central Artery Project's Stem to Stern Safety Review was comprehensive and conducted in a complete and rigorous manner, we assessed whether the findings and recommendations of the Phase I report adequately identified and analyzed immediate risks and whether necessary remedial measures were identified. We monitored the Commonwealth's activities after issuing the Phase I report, including activities initiated to address our observations on the classification of certain safety risks and on the Commonwealth's follow-up activities (referred to as Phase IA). We also evaluated whether work plans for remaining phases of the safety review were clear and comprehensive.

As a part of this audit, we reviewed the work plan for Phase I to determine whether it included a comprehensive review of safety priorities in the project's physical infrastructure, mechanical and electrical systems, and integrated project control systems. We monitored the progress of Phase I to ensure that the activities adhered to the work plan and complied with established engineering standards and protocols, and to identify risk areas that were not addressed. We also evaluated the Commonwealth of Massachusetts's November 2006 Phase I report to ensure that mitigation plans were developed to address identified risks, and reviewed the implementation plan for subsequent activities in Phase II.

Due to the complexity of this audit and the limited time frame in which to complete it, we engaged the U.S. Army Corps of Engineers (Corps) to provide technical assistance to our engineers during Phase I of the review. The scope of work for our review of Phase I was developed by the Corps under the direction of our engineers. Using these guidelines, the Corps closely and independently monitored the safety review by:

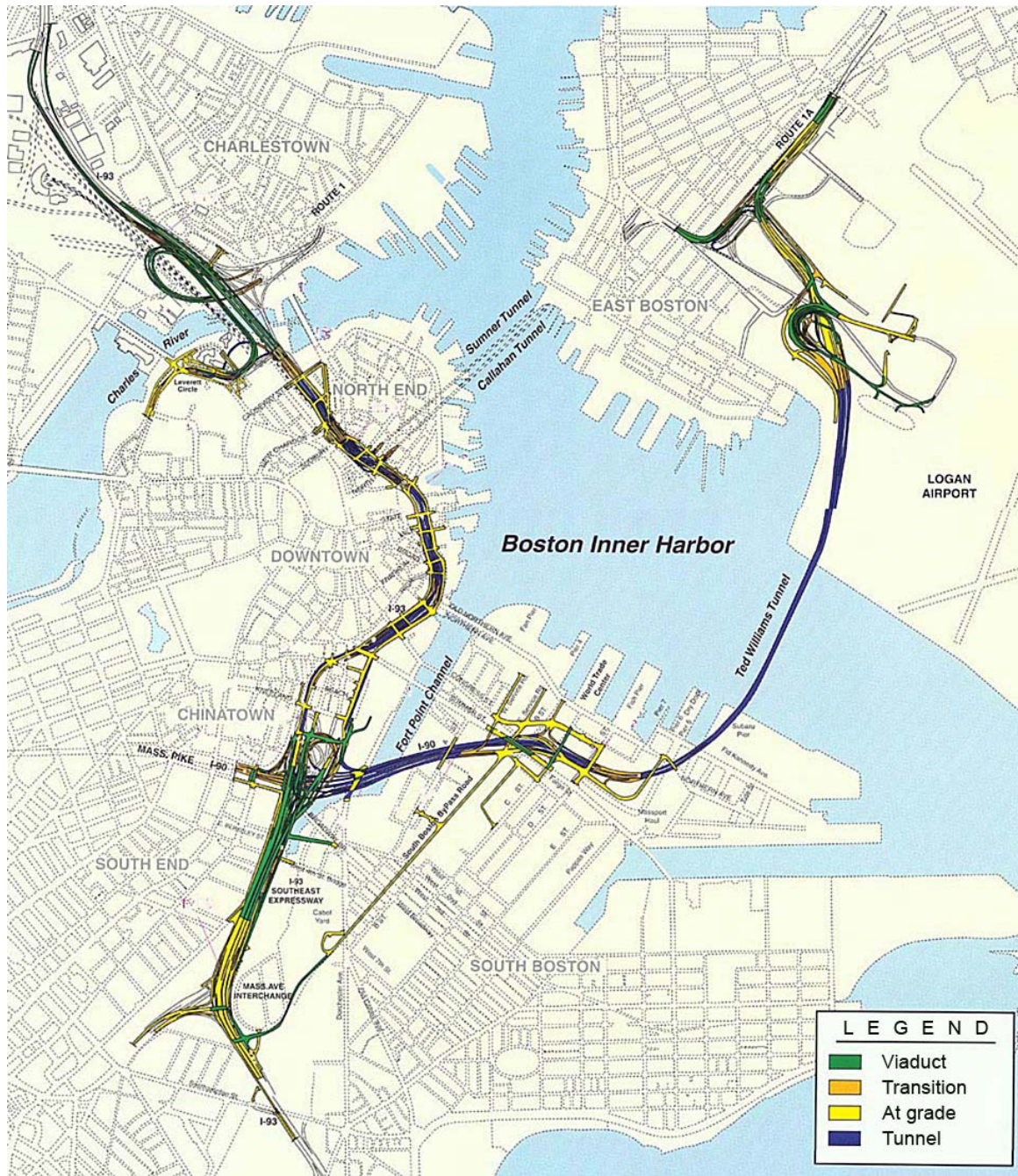
- assembling a technical team of experts and embedding this team with the consultant performing the safety review;
- participating in initial Wiss, Janney, Elstner Associates, Inc. (WJE) field activities;
- reviewing WJE work plans and providing comments;
- reviewing WJE interim submissions and providing comments;
- attending weekly meetings of the Governor's Advisory Panel;
- attending site visits (along with members of the audit team); and
- regularly briefing OIG engineers on the status of Phase I.

The Corps performed its technical reviews using criteria from the American Association of State Highway and Transportation Officials, the FHWA, the National Fire Protection Association, and the American Concrete Institute. Additionally, the Corps used geologic conditions/seismic zoning criteria for the review of the seismic analysis.

We closely monitored the progress of Phase I and will continue to monitor future phases. At the outset, we conducted planning sessions with senior Corps executives to discuss the scope of the work to be performed and established rules of engagement with WJE. The Corps provided updated information to our engineers on a regular basis. After reviewing information that the Corps provided, our engineers shared their concerns with the Commonwealth's safety review team, as necessary, to affect the direction of the safety review. Our engineers also performed some site visits along with the Corps during Phase I.

This performance audit was performed from July 2006 through August 2007 in accordance with Generally Accepted Government Auditing Standards as prescribed by the Comptroller General of the United States.

EXHIBIT B. MAP OF THE CENTRAL ARTERY/TUNNEL PROJECT



Source: Massachusetts Turnpike Authority, <http://www.masspike.com/>

Exhibit B. Map of the Central Artery/Tunnel Project

EXHIBIT C. THE COMMONWEALTH OF MASSACHUSETTS'S CLASSIFICATION OF SAFETY CONCERNS

Safety risks identified by the Commonwealth's Stem to Stern Safety Review during Phase I were classified using the following categories of risk:

- **IC:** Immediate or dangerous conditions that pose the greatest safety risk—such conditions were immediately reported to the Massachusetts Turnpike Authority for remediation
- **R1:** Conditions that require remediation as soon as possible
- **R2:** Conditions requiring remediation that should be coordinated with near-term maintenance and capital improvement programs
- **MR:** Conditions that should be monitored and considered for remediation if the condition worsens
- **PII:** Phase II follow-up work recommended to confirm or resolve identified concerns
- **NA:** No follow-up necessary as part of the Stem to Stern Safety Review

EXHIBIT D. PICTURES OF THE ZAKIM BRIDGE AND ITS ANCHOR PLATES



A. Zakim Bridge



B. Close-up of cables



C. Close-up of anchor plate securing cable to a steel girder. According to the Phase I report, six of the anchor plates are deformed.

Source: U.S. Army Corps of Engineers

Exhibit D. Pictures of the Zakim Bridge and Its Anchor Plates

EXHIBIT E. MAJOR CONTRIBUTORS TO THIS REPORT

THE FOLLOWING INDIVIDUALS CONTRIBUTED TO THIS REPORT.

| <u>Name</u> | <u>Title</u> |
|-------------------|--|
| Kurt Hyde | Former Assistant Inspector General for Surface and Maritime Programs |
| Tom Yatsco | Program Director |
| Eric Mader | Project Manager |
| Donald Lango | Senior Auditor |
| Charles Wilson | Analyst |
| Rodolfo Pérez | Engineer Advisor |
| Anne-Marie Joseph | Engineer |
| Aron Wedekind | Engineer |
| Harriet Lambert | Writer-Editor |

APPENDIX. MANAGEMENT COMMENTS



U.S. Department
of Transportation
**Federal Highway
Administration**

Memorandum

Subject: **INFORMATION:** Federal Highway Administration
Response to Office of Inspector General (OIG) Draft
Report, "Initial Assessment of the Central Artery/Tunnel
Project Stem to Stern Safety Review"

Date: August 3, 2007

From: James D. Ray
Acting Deputy Administrator and
Chief Counsel

In Reply
Refer To: HCC-3

To: Calvin L. Scovel III
Inspector General (JA-40)

Thank you for the opportunity to review and comment on the OIG Draft Report, "Initial Assessment of the Central Artery/Tunnel Project Stem to Stern Safety Review." As noted in the Report, the scope of the Stem to Stern Safety Review (STS) initiated by the Commonwealth is not limited to the Central Artery/Tunnel (CA/T) Project; it covers the entire Boston Metropolitan Highway System, which includes wholly State funded facilities. In light of the Federal investment in the CA/T Project and the need to restore public confidence in the safety of the entire system, FHWA, from the inception of the STS, has recognized its responsibility to ensure that the former and current Administration in the Commonwealth proceed with the appropriate dispatch to correct all safety concerns identified as part of the review. We will continue to provide diligent oversight of the progress made by the Commonwealth in completing the STS and implementing the recommendations. On the whole, we believe the findings in the report are valid. We also believe the Commonwealth has taken steps recently to steadily move the STS forward.

Our comments and planned actions on the specific audit report recommendations follow.

Recommendation 1: “To ensure prompt action on the Central Artery safety reviews and protect the massive Federal investment in the project, we recommend that FHWA:

1. Designate a lead official to ensure that the Commonwealth:
 - a. Completes the analyses of all safety risks—especially those posing immediate safety risks—in a timely, independent, and thorough manner, since many key safety studies were limited or deferred; and carries out prompt remediation for any deficiencies identified.
 - b. Produces a clear and comprehensive methodology for Phase II, including a realistic schedule with a critical path for sequencing activities and reasonable cost estimates. The methodology should reflect the analyses and remedial work to be performed on outstanding findings and recommendations of the Commonwealth’s Phase I report. The methodology should also include plans to independently verify that remedial work is completed.
 - c. Expeditiously pursues cost recovery to the extent possible for those conditions that result from design errors or inadequate construction practices.
 - d. Continues to routinely communicate latest developments to key stakeholders, including FHWA and OIG.”

Response: We concur in the recommendation to designate an official in FHWA to ensure the State progresses in the above noted areas. In carrying out our oversight responsibilities, we will utilize the tools available to us to spur appropriate action by the State, recognizing and respecting our differing roles. In keeping with our response to Recommendation 2 below, we will apprise the Department of Transportation Oversight Committee of any issues of major concern. As Acting Deputy Administrator, I will perform the functions of the designated lead official and serve as the point of contact to coordinate the efforts of relevant units in FHWA involved in overseeing action by the State.

Recommendation 2: “Report monthly to the Department of Transportation Oversight Committee on the Central Artery Project and the OIG regarding progress being made by the Commonwealth to complete the safety reviews and on any concerns the FHWA may have.”

Response: We concur in the intent of the recommendation to report periodically to the Oversight Committee on progress made by the State. We have in the past reported to the Committee as needed on all of the activities FHWA is involved in related to the CA/T Project, and we have provided copies of our reports to the OIG. We would continue to provide the OIG copies of our report to the Committee. However, we do not believe it appropriate to characterize our actions as “reporting” to the OIG. It appears to suggest that the OIG is part of the FHWA’s management chain of command.

We would defer to the Oversight Committee on the frequency of our reports rather than requiring monthly reports regardless of activity levels with respect to the Stem to Stern Review. Moreover, because the makeup of the Committee may change over time, FHWA will continue to report to either the Committee or its functional equivalent until such time as it is determined by the Committee to be no longer necessary.

In closing, we would like to emphasize that the FHWA is committed to being good stewards of the Federal investment in the CA/T and the Federal interest in public safety.

The efforts of the OIG auditors are greatly appreciated. If you have any questions or comments regarding this response, please contact Jo Anne Robinson at (202) 366-0740.